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Assessing the Economic Impact of Alternative Biomass Uses: Biofuels, Wood Pellets, and Energy Production

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Abstract. The green economy, including biofuels and biomass production, has received considerable academic and popular press attention. Yet, documenting and measuring the economic impact of green economy activities remains a challenge, as this ill-defined economic sector's benefits are often overstated. This article makes two unique contributions to the emerging academic literature on the green economy. First, it contributes to the applied academic literature on economic impact assessments of the green economy by documenting approaches to measure the economic impact of three alternative biomass uses: electricity generation, wood pellet manufacturing, and biofuels manufacturing. Second, it examines the regulatory influences and market volatility that challenge the long-term viability of each alternative use.

1. Introduction

The green economy, including biofuels and biomass production, has received considerable academic and popular press attention. Yet, documenting and measuring the economic impact of green economy activities remains a challenge, as this ill-defined economic sector's benefits are often overstated (Swenson, 2006 and 2007; Schlosser, Leatherman, and Peterson, 2008). This article makes two unique contributions to the emerging academic literature on the green economy. First, it contributes to the applied academic literature on economic impact assessments of the green economy by documenting approaches to measure the economic impact of three alternative biomass uses: electricity generation, wood pellet manufacturing, and biofuels manufacturing (both enzymatic and thermochemical processing). Second, it examines the regulatory influences and market volatility that challenge the long-term viability of each alternative use. For each scenario of our model, we used 1,000 tons per day (T/D) of locally sourced hardwood biomass. The hypothetical processing facilities are located in Pitt County, North Carolina, which is in the heart of the state's "wood basket."

2. Literature review

The economic and policy implications of green economy efforts, such as biofuels usage and renewable energy mandates, have received considerable attention in regional science journals. Twenty-nine states have adopted renewable portfolio standards (RPS) and seven others have adopted "renewable portfolio goals" (Dincer, Payne, and Simkins, 2014). RPS mandate that a portion of the state's utility energy needs be generated from renewable sources (Rabe, 2007). Internal factors, such as citizen preferences, appear to be the primary driver of initial state RPS adoption (Matisoff, 2008). Once adopted, state target levels for the percentage of renewable energy generation have ranged from 0% to as high as 40% (Dincer et al., 2014). Multiple factors explain this variation, with a state's RPS target level being positively influenced by neighboring state targets, renewable energy potential, transmission capacity, unemployment rate, and educational attainment (Dincer et al., 2014). States represented by a Democratic governor also have higher RPS target levels (Dincer et al., 2014).

RPS are also promoted as economic development tools (Rabe, 2007). States may engage in import substitution by supplying renewable feedstocks in-state rather than importing fossil fuels (Rabe, 2007). The presence of RPS positively influences renewable energy development within a state (Yin and Powers, 2010). Energy consumption has been closely tied to state economic growth (Payne, 2009), and state-level energy efficiency programs diminish residential energy consumption (Cebula and Herder, 2010; Cebula, 2012). Theoretically, engaging in import substitution by producing energy feedstocks in-state could counteract the economic loss from reduced energy consumption.

The emergence and policy interests in the green economy have stimulated researchers to apply input-output approaches to measure the economic impact of biomass, biofuels, and other green economy activities on local, regional, and state economies. For example, Swenson and Eathington (2006) utilized input-output modeling to capture the economic impact of varying levels of investment in ethanol production in Iowa. Aksoy et al. (2011) modeled the economic feasibility and impact of woody biomass and mill waste usage for biomass or biofuels in Alabama. Daniel, English, and Jensen (2007) examined producing sixty billion gallons of ethanol and biodiesel by 2030. Other studies have examined the externalities around ethanol such as the impact on water resources (Guerrero et al., 2011), residential property values (Hodge, 2011), and land use change and greenhouse gas emissions (Khanna, Crago, and Black, 2011).

3. Methodology and Modeling Assumptions

Three alternative use scenarios were modeled utilizing analysis-by-parts in the IMPLAN 3.0 model. Each modeling scenario and the underlying assumptions will be discussed in detail in this section. Three separate model scenarios were developed. Our modeling reflects many of the recommendations from Swenson (2006) and Swenson and Eathington (2006), including benchmarking against real world industry data from existing facilities, customizing the industry in IMPLAN, and noting the influence of market volatility.

First, the electricity generation scenario involved the construction and operation of a 1,000 ton per day (T/D) biomass-to-energy power generation facility to be located in Pitt County utilizing locally sourced hardwoods (woody biomass). It is assumed that the power generated by this facility is sold to businesses and households within North Carolina at the existing (wholesale) price of power on the statewide market.

Second, the wood pellet export facility involved the construction and operation of a 1,000 T/D biomass-to-wood pellet facility in Pitt County. It is assumed that 100 percent of the outputs from this plant will be exported outside the state and sold at existing price levels. Since all of the wood pellets are assumed to be sold to customers in Europe (where renewable energy standards create strong demand for wood pellets in power generation), the impact of increased economic activity at the Port of Wilmington (New Hanover County) in North Carolina is also estimated.

Third, enzymatic and thermochemical models were developed in the biofuels scenario, which involved construction and operation of a 1000 T/D biomass-to-liquid fuels facility in Pitt County. It is assumed that the output products of this facility will be ethanol fuel additives and will be used 100 percent within the state to fill the demand for ethanol additives in the state's gasoline supply.

3.1. IMPLAN modeling

The estimated direct, indirect, and induced impacts of the construction and full operation for each of the four alternatives of construction and operation was calculated for each of the proposed plants using IMPLAN 3.0 (IMpact Analysis for PLANners) software[1] using 2013 dollars. IMPLAN is an industry standard input-output modeling program that permits researchers to estimate the projected effects of an exogenous ("outside") change in final demand that results from new economic activity within a study region. This analysis assumes that any new spending that results from the new economic activity in the region would not have otherwise occurred. Moreover, no public dollars are assumed to subsidize the activities. Forward linkages between producers and consumers (e.g., new fuel blenders and

[1] IMPLAN models are static models that cannot adjust for future structural changes in a study region's economy. Therefore, it is best to limit study periods to around three to four years. This analysis estimates impacts of construction and full operations in 2013 dollars and is useful for short-term projections.

gasoline retailers resulting from the increased production of biofuels) are not measured.

•Direct impacts are the changes in spending in a given industry that result from the increase in final demand for the products of that industry. The direct impact includes individuals that work at the proposed plants (i.e., biomass power plant, wood pellet factory, or biofuels facility).

•Indirect impacts include the impacts created by inter-industry spending. For example, Figure 1 shows the economic relationship between the biofuels plants and one of its suppliers, waste remediation services.

•Induced impacts are the increases in spending by household consumers resulting from increases in income and population due to the new direct and indirect economic activity.

•The total economic impact of each plant is found by summing the direct, indirect, and induced effects.

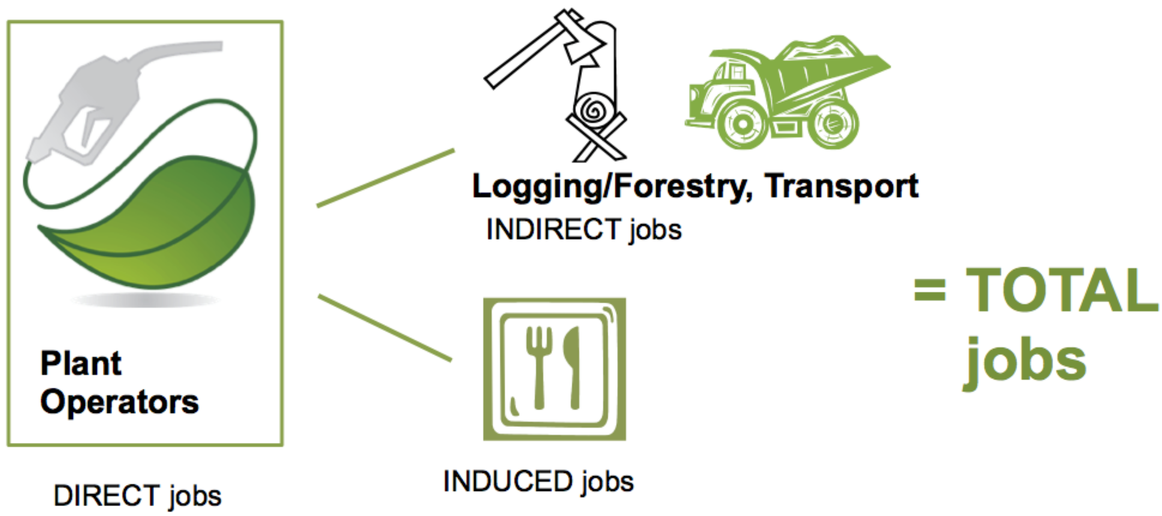

Figure 1. Illustration of direct, indirect, and induced impacts.

Our results show the estimated change in demand (i.e., spending) that could result from the purchasing associated with a plant's construction and operation. The investment in the new plants stimulates activity that is captured in a regional multiplier, which predicts how many additional jobs or dollars will be added to the economy as a result of the jobs or dollars created by the initial event (Swenson, 2006). The multiplier, calculated from the average amount of local spending, represents the ratio of total impacts to direct impacts. The modeling results include employment figures, labor income (annual wages), and output (the value of increased production in one year).

The technologies considered in all three of these alternative scenarios are relatively new manufacturing activities that remain undefined by the National Inventory of Product Accounts (NIPA). As such, a customized impact analysis using a technique called "analysis-by-parts" is required. Analysis-by-parts differs from a typical IMPLAN analysis in that the analyst separates the calculation of direct impacts from indirect and induced impacts. The direct effects are specified by the analyst from original data on employment levels, wages, and output (total sales). The second "part" of this technique is the specification of a unique production function for each alternative (i.e., the industry-to-commodity purchasing relationships that are the basis of the multiplier process).

The biomass alternative plant models are characterized based on the facility type, which varies primarily by final output market (i.e., electricity grid, pellet markets in Europe, liquid biofuels). However, we make some assumptions that are common across all scenarios so that we may better compare the differential impacts across the scenarios. First, we equalize the amount of feedstock used by each facility at 1,000 bone dry tons (BDT) per day. We used a price of $50/BDT in all scenarios and assumed that each plant would operate for 350 days per year, yielding a total feedstock of 350,000 BDT per year. This capacity figure was used to scale various direct input figures computed from primary data obtained from private companies in similar lines of business, as described in Table 1.

Table 1. Summary of direct inputs and data sources by scenario.[1]

Scenario	Input Amounts($$)	Source(s)
1. Electricity Production	Output/Sales in (2013$): $31,214,815 Computed from annual output of 445,925,926 kWh sold at $0.07/kWh wholesale price.	Annual electricity production based on rescaled figures from Craven County Wood Energy.
	Employment: 31 direct operations jobs	Scaled from Craven Energy figures.
	Employee Compensation: $3,427,439 Multiplied direct employment by IMPLAN employee compensation figure for sector 31 (Electricity Production).	IMPLAN
	Construction: $89,010,035	Scaled from Craven Energy plant total CAPEX of $81 million in 1991 dollars. Adjusted for plant size and non-local equipment purchases.
2. Wood Pellets for Export	Output/Sales in (2013$): $34,027,000 Notes: Computed from annual output estimate of 350,000 tons of pellets at a price of $97.22[2] wholesale.	Argus-Biomass Pellet Spot Price. Pirraglia et al. (2010) (Transportation costs) Output figures confirmed by comparison with Enviva reported data.
	Employment: 63 direct operations jobs	Scaled from Enviva Southampton plant figures.
	Employee Compensation: $2,947,061 (63 X $46,431 total payroll costs per worker)	Wage figures based on average of wage data from Enviva Southampton and Wilson County Plant.
	Construction: $33,382,146	Averaged CAPEX per unit of output for Enviva Southhampton and Wilson County plants and scaled to our size plant. Adjusted for plant size and non-local equipment purchases.
	Transportation/Port Inputs: IMPLAN Sector 334: 5 direct jobs. IMPLAN Sector 335: $10,948,000	Estimated based on transportation costs figures in Pirraglia et al. (2010) and NC Maritime Strategy (2012).
3a. Biofuels (Enzymatic)	Output (w RIN credit) : $72,333,333[3] Output (w/o RIN credit): $59,500,000 Based on 23.3 MGY estimated capacity and $2.55/gal ethanol price and $0.55 RIN credit.	Output scaled from Chemtex International 20 MGY plant. Price figures from BCNC. Confirmed with NREL JEDI data.
	Employment: 76	Scaled from Chemtex International data. Confirmed with NREL JEDI data.
	Employee Compensation: $4,360,417	Scaled from Chemtex International data. Confirmed with NREL JEDI data.
	Construction: $113,400,000	Scaled from Chemtex International data.
3b. Biofuels (Thermochemical)	Output (w RIN credit & co-product revenue) : $61,100,000 Output (w/o RIN credit): $43,350,000 Based on 17 MGY estimated capacity and $2.55/gal ethanol price and $0.55 RIN credit.	Output scaled based on TRI International figures. Price figures from BCNC. Confirmed with NREL JEDI data.
	Employment: 50	Scaled based on TRI International data. Confirmed with NREL JEDI data.
	Employee Compensation: $3,737,500	Scaled based on TRI International data. Confirmed with NREL JEDI data.
	Construction: $132,000,000	Scaled based on TRI International data. Adjusted for plant size and non-local equipment purchases.

Notes: (1) All scenarios apply a 70/30 split between hard and soft construction costs. Hard costs are assigned to IMPLAN Sector 35 (construction of new nonresidential manufacturing structures) while soft costs are assigned to Sector 369 (architectural, engineering, and related services). For the indirect impacts we use the lower figure of output without the RIN credit since there are not input costs associated with producing the credit itself. (2) This price figure was discounted from a spot price of $128.5/ton price at the Port of Wilmington (Source: Argus-Biomass Pellet Spot Price) by excluding the amount paid to transportation companies to move product from Pitt County to Wilmington. Transportation costs per mile were taken from the report by Pirraglia et al. (2010). (3) This cost figure was based on information reported in Pirraglia et al. (2010).

We further assume that there are no capacity constraints on local producers of the woody biomass feedstock (i.e., hardwoods), and that local suppliers provide their products from a standing inventory that would not otherwise be used elsewhere in the economy to a degree that would result in price changes. This assumption also means that we do not include extra household income effects for farmers or landowners who source the hardwood feedstock, since they are assumed to simply shift sales to our proposed plants. We feel confident making these assumptions given the dormant forest industry in eastern North Carolina and the abundance of available biomass.

For all construction impacts the construction period is assumed to take three years. Therefore, each final adjusted direct construction expenditure is divided by three to spread the construction spending over three years. The final construction impacts should be interpreted as temporary and occurring over a three-year period. In other words, an impact of 100 jobs is actually 100 job-years for three years. For construction, hard costs − the direct payments to contractors, construction labor, and materials − were allocated to IMPLAN sector 35, "construction of non-residential-manufacturing buildings." Soft costs were modeled in sector 369, "architectural and engineering services."

To compute the direct economic impacts of each alternative, data were gathered directly from existing facilities that matched each scenario (Table 1). Table 1 also outlines how we calculated the inputs for the IMPLAN model and the source for each input.

To compute the indirect effects of each scenario's economic activity, we generated new production functions for each alternative by modifying a preexisting IMPLAN industry sector to better reflect the renewable energy content of each activity. Changes to the production function are appropriate when the national average coefficients (representing the distribution of spending in the industry) are inaccurate due to the arrival of a uniquely different industry to the region – in this case the alternative biomass-based renewable fuels. We confirmed that the magnitude of these alterations was reasonable by comparing the resulting indirect purchasing shares with additional sources such as the National Renewable Energy Laboratory's Jobs and Economic Development Indicator (JEDI) model (NREL, 2007). Table 2 summarizes the key changes made to the indirect purchasing relationships for each cognate IMPLAN sector for each scenario. In all scenarios, we zeroed out all the fossil fuel-based commodity inputs to the respective sectors and then included the purchase of woody biomass inputs in the IMPLAN commodity categories "forest, timber, and forest nursery products" (3015) and "logs and roundwood" (3016). By assumption, the amount of woody biomass inputs that each plant—regardless of scenario—purchases is the same and is equivalent to the cost of 1,000 bone dry tons per day for 350 days of operations. This amount comes to $8,750,000, as we assumed an input price of $50 per BDT delivered. Since this price input (provided by Biofuels Center of North Carolina [BCNC] staff) was the *delivered* price, it includes payments to trucking companies, which convey the wood to the plant. We assumed a 50% price split between truckers and wood producers, and thus we also included a figure of $8,750,000 for the commodity code "truck transportation services" (3335).

Table 2. Summary of customization to IMPLAN sectors for indirect analysis.

Scenario	IMPLAN Sector	Modifications
Electricity Production	Electricity Production (31)	Set all fossil fuel related commodity shares to 0. Added input costs of biomass and transportation by truck to 3015 and 3335 and recalculated coefficients (shares) for these commodities.
Wood Pellets	Miscellaneous Wood Products (103)	Set all fossil fuel related commodity shares to 0. Added input costs of biomass and transportation by truck to 3015 and 3335 and recalculated coefficients (shares) for these commodities.
Liquid Biofuels	IMPLAN Sector 115 Petroleum Refineries (adjusted in consultation with NREL JEDI Model)	Set all fossil fuel related commodity shares to 0. Added input costs of biomass and transportation by truck to 3015 and 3335 and recalculated coefficients (shares) for these commodities.

The result of these modifications are new production functions that reflect a set of coefficients that measure the commodity inputs required to produce one dollar of output. Note that these coefficients do not sum to one, as not all of the total dollar amount of revenue is spent on input commodities. The remainder is considered "value added," which is in turn divided between wages paid to workers, taxes owed, and profits (or repayment of capital). To determine the exact dollar figures for the "industry spending pattern" that make up all of the indirect purchasing we simply multiply the total direct output figures for each scenario by this set of coefficients. This step makes up the second step of the "analysis-by-parts" methodology.

Lastly, we set the local purchase coefficients (LPC) for wood products and transportation by truck – the two key commodities of interest – to 100 percent since we are assuming that all biomass is sourced within the study region. All other commodity LPC values are set to the value calculated by IMPLAN for the Pitt County regional model.

The final step in conducting the "analysis-by-parts" is to include as a direct input the value of employee compensation so that the IMPLAN model can calculate the induced effect. The overall induced effect includes not only the impact from direct activity but all subsequent rounds of spending generated by indirect impacts as well.

3.2. Model assumptions

The study area for all of the operations and construction phases of this analysis is Pitt County, North Carolina. Since this is a single county region, we assume that all direct labor and feedstock demands are filled locally (within the county). Since we are concerned primarily with differential impacts across the three main scenarios, expanding the study region to include more counties for sourcing biomass feedstock would only change the overall impacts in a parallel manner. For the pellet production facility, we additionally analyze impacts at the Port of Wilmington by creating an additional single region study area for New Hanover County, North Carolina, where additional port-related activity is expected to occur. Below we discuss any additional assumptions used for the individual scenarios.

Woody biomass to electricity generation facility

The construction assumptions for this model were scaled from the total capital expenditures of $81 million, in 1991 dollars, for the existing Craven County Wood Energy (CCWE) plant near New Bern, NC. These numbers were adjusted for plant size and non-local equipment purchases and inflation. Next, we assumed a 70/30 percent split between hard and soft costs. The final figure after adjusting was $89,010,035.

The total output from operations was computed from annual electricity output of 445,925,926 kWh sold at $0.07/kWh wholesale price. These production numbers, as we all as employment estimates, were adapted from information provided by Craven Energy and rescaled to correspond with the 1000 ton/day woody biomass input. Employee compensation was derived from multiplying IMPLAN employee compensation for Sector 31, the electricity production sector. We were unable to obtain direct wage data from Craven or a similar plant.

Wood pellet export facility

In order to determine the total construction costs for the wood pellet facility, capital expenditures were averaged per unit of output for the Enviva wood pellet facility in Southhampton and Wilson Counties and scaled to the 1,000 tons/day plant size. These costs were adjusted for non-local equipment purchases, and a 70/30 split between hard and soft costs was assumed.

The sales figure of $34,027,000 was computed from an annual output estimate of 350,000 tons at a price of $97.22 per ton, based off the Argus-Biomass Pellet spot price and accounting for transportation costs as reported in Pirraglia et al. (2010). These costs were confirmed from numbers supplied for the Enviva plants. Wage figures were taken from averages supplied in Enviva press releases of their Southeastern U.S. plants.

To estimate the impact of the expanded activity occurring to handle exporting of the pellet outputs to Europe, we built a new regional model for New Hanover County. The direct impacts were estimated at five new jobs in the "transportation by water" sector (334), and an additional $10.95 million in output in the "transportation by truck" sector (335). These direct inputs were derived from estimates of the share of total pellet price per ton that flows to shippers based on a cost estimate of $13.6 cost per mile per ton[2] assuming a distance of 115 miles from Pitt County to the Port of Wilmington[3]. The direct jobs figure was adjusted based on estimates provided by the NC Maritime Strategy (North Carolina

[2] This cost figure was based on information reported in Pirraglia et al. (2010).

[3] According to Google Maps driving directions from Greenville, NC to the Port of Wilmington by road (http://maps.google.com).

Department of Transportation, 2012) report for handling wood pellet cargo.

Biofuel facility

Construction inputs were scaled from Chemtex International capital expenditure data to the woody biomass input. Construction costs were scaled based on TRI International data. These costs were adjusted for plant size and non-local equipment purchases. Both biofuel plant outputs were based on a $2.55/gallon ethanol price and $0.55 RIN credit.

Model inputs for the enzymatic plant were based on a 23.3 million gallons per year (MGY) estimated capacity from 1,000 tons/day of woody biomass. The output figure was scaled from a Chemtex International 20 MGY plant. Price figures were supplied from BCNC and confirmed with NREL JEDI data.

The thermochemical plant had an estimated capacity 17 MGY, which was adapted and scaled from TRI International figures. Employment and employee compensation data were also adapted from TRI International figures. Price figures were supplied from BCNC and were confirmed with NREL JEDI data[4].

4. Economic impact results

The results of the economic impact analysis performed for all scenarios and all phases are summarized in Table 3.

4.1. Pitt County 1,000 T/D biomass to electric power facility

This analysis calculates the regional economic impact of a biomass burning electrical generating facility that uses 1,000 BDT per day of woody biomass feedstock. We estimate that this plant will provide over 445,000 MWh of electricity, yielding annual sales of approximately $31.2 million. Plant operation is expected to create a total of 314 jobs in the region and over $62 million in total economic activity in Pitt County.

Operations model results

These results indicate that the plant will employ 31 people directly. While this direct employment figure is low, recall that electrical power generation is one of the most capital intensive sectors in the country, regardless of fuel source.

However, this direct figure only includes workers who work inside the plant itself. The analysis shows that the additional spending on woody biomass and transportations services and other inputs produces an additional 221 jobs created in industry sectors outside the biomass electrical plant itself. Thus, while the employment multiplier is very high (approximately 10), all the logging positions are included in the indirect category.

This plant is also projected to generate a total of $13.5 million in labor income to workers throughout the regional economy, with $3.4 million accruing to workers directly employed at the facility. This results in an average payroll (including fringe and all unemployment insurance payments) per worker of approximately $109,000.

Construction model results

Based on the IMPLAN model, the construction of this plant is estimated to create 259 temporary construction jobs annually for three years of construction. Due to the multiplier effect, a total of 371 jobs (including the 259 direct jobs) are estimated to be created in the region. The multiplier of 1.43 indicates that for every individual employed directly by this project, an additional 0.43 jobs are supported in the region. Labor income in the region is estimated to increase $15.8 million, and output is estimated to increase $41.5 million.

4.2. Pitt County 1,000 T/D biomass to wood pellet export facility

This analysis calculates the regional economic impact of a facility that converts 1,000 BDT per day of woody biomass feedstock to wood pellets and exports 100% of the output to Europe via the Port of Wilmington. We estimate that this plant will provide over 350,000 tons of wood pellets per year, yielding annual sales of approximately $34 million.

The operation of the plant is expected to create a total of 409 jobs in the region and over $69.8 million in total economic activity in Pitt County**.** The construction of the facility would produce an additional 139 jobs on an annual basis for three years. The resulting increase in activity at the Port of Wilmington from exporting the wood pellets is estimated to produce an additional 146 jobs in Hanover County, where the port is located.

Operational model results

These results indicate that the plant will employ 63 people directly, which is over twice the estimated direct employment of electricity generation. The employment multiplier for this facility is 6.44, which means that for every job with the plant, over 5 additional jobs are created in the local economy. This

[4] See www.nrel.gov/analysis/jedi/about_jedi_biofuels.html.

multiplier indicates that there will be 409 total additional jobs resulting from the operations of the plant (including direct employment). The estimated average annual salary for each worker directly employed with the plant is $46,431. Total labor income will increase by $16.2 million, and total output will increase by $69.8 million.

Port operations phase

The IMPLAN model indicates that 65 additional jobs will be created at the Port of Wilmington due to the increased business from the pellet facility. The job multiplier for port operations is 2.23, meaning that for every direct job at the port an additional 1.23 jobs will be created in New Hanover County. Due to the multiplier effect, a total of 146 jobs are projected to be created from increased activity at the port. The total labor income is estimated to increase $7 million and the total output is estimated to increase by $20.8 million as a result of increased activity at the port from the pellet facility. Table 3 lists these figures combined with the operations phase.

Construction model results

Based on the IMPLAN model, the construction of this plant is estimated to create 97 temporary construction jobs annually for three years of construction. Due to the multiplier effect, a total of 139 jobs (including the 97 direct jobs) are estimated to be created in the region. The construction multiplier is again 1.43. Labor income in the region is estimated to increase $5.9 million, and output is estimated to increase $15.5 million.

4.3. Pitt County 1,000 T/D biomass to liquid fuels plant – enzymatic process

This analysis calculates the regional economic impact of a facility that converts 1,000 BDT per day of woody biomass feedstock to liquid fuel through an enzymatic process. We estimate that this plant will provide over 23.3 million gallons of fuel per year, yielding annual sales of approximately $72.3 million. As a result of construction and operations from this facility, 879 jobs will be created in the region and there will be an additional $159.1 of regional economic output.

Operational model results

These results indicate that the plant will employ 76 people directly, which is the highest direct employment thus far in the analysis. The analysis shows that the additional spending on transportation and inputs creates an additional 321 jobs outside the biofuel plant, resulting in a multiplier of 5.2.

This plant is also projected to generate a total of $16.7 million in labor income to workers throughout the regional economy, with $4.4 million accruing to workers directly employed at the facility. This results in an average payroll per worker of approximately $57,500.

Construction model results

Based on the IMPLAN model, the construction of this plant is estimated to create 333 temporary construction jobs annually for three years of construction. Due to the multiplier effect, a total of 482 jobs (including the 333 direct jobs) are estimated to be created in the region, which translates to a multiplier of 1.45. Labor income in the region is estimated to increase $20.8 million, and output is estimated to increase $53.5 million.

4.4. Pitt County 1,000 T/D biomass to liquid fuels plant – thermochemical process

This analysis calculates the regional economic impact of a facility that converts 1,000 BDT per day of woody biomass feedstock to liquid fuel through a thermochemical process. We estimate that this plant will provide 17 million gallons of fuel per year, yielding annual sales of approximately $61.1 million. As a result of the operations from this facility, 362 jobs will be created in the region and there will be an additional $93.3 million of regional economic output. The construction of the facility will produce an additional 561 jobs annually over the three year construction period.

Operational model results

These results from the IMPLAN model indicate that the plant will employ 50 people directly, which is about 2/3 of the employment from the traditional biofuel facility, a result of the thermochemical process being more capital intensive than the traditional enzymatic process. It is important to note that we do not model the extra revenue that may possibly be generated from by-products of the production process. We decided to keep an apples to apples comparison with scenario 3a (enzymatic biofuel).

The analysis shows that the additional spending on woody biomass and transportation services and other inputs produces an additional 312 jobs in the regional economy in addition to the jobs directly with the plant. The jobs multiplier is thus relatively high at 7.23.

Construction model results

Based on the IMPLAN model, the construction of this plant is estimated to create 387 temporary construction jobs annually for three years of construction. Due to the multiplier effect, a total of 561 jobs (including the 287 direct jobs) are estimated to be created in the region, translating again to a multiplier of 1.45. Labor income in the region is estimated to increase $24.1 million, and output is estimated to increase $31.8 million as a result of plant construction.

Table 3. Economic Impact of Biomass Alternatives for Pitt County, NC

Operations Phases:	**Scenario 1- Electric Power Facility**			**Scenario 2- Wood Pellet Facility**			**Scenario 3a- Liquid Biofuels Facility- Enzymatic**			**Scenario 3b- Liquid Biofuels Facility- Thermochemical**		
Impact Type	**Jobs**	**Labor Income ($M)**	**Output ($M)**	**Jobs**	**Labor Income ($M)**	**Output ($M)**	**Jobs**	**Labor Income ($M)**	**Output ($M)**	**Jobs**	**Labor Income ($M)**	**Output ($M)**
Direct Effect	31	3.4	31.2	128	7.0	46.9	76	4.4	72.3	50	3.7	61.1
Indirect Effect	221	8.0	25.0	318	12.5	32.2	245	9.7	25.0	240	9.5	24.3
Induced Effect	62	2.1	6.7	109	3.7	11.6	77	2.6	8.3	72	2.5	7.8
Total Effect	314	13.5	63.0	555	23.3	90.7	397	16.7	105.6	362	15.7	93.3

Construction Phases:	**Scenario 1- Electric Power Facility**			**Scenario 2- Wood Pellet Facility**			**Scenario 3a- Liquid Biofuels Facility- Enzymatic**			**Scenario 3b- Liquid Biofuels Facility- Thermochemical**		
Impact Type	**Job Years**	**Labor Income ($M)**	**Output ($M)**	**Job Years**	**Labor Income ($M)**	**Output ($M)**	**Job Years**	**Labor Income ($M)**	**Output ($M)**	**Job Years**	**Labor Income ($M)**	**Output ($M)**
Direct Effect	259	11.8	29.4	97	4.4	11.0	333	15.4	37.4	387	17.9	43.6
Indirect Effect	40	1.6	4.3	15	0.6	1.6	54	2.1	5.7	63	2.4	6.7
Induced Effect	73	2.5	7.9	27	0.9	3.0	96	3.3	10.3	111	3.8	12.0
Total Effect	371	15.8	41.5	139	5.9	15.6	482	20.8	53.5	561	24.2	62.3

Notes: All dollar figures in millions of 2013 dollars. Operations phases figures listed in panel A indicate ongoing annual impacts of each alternative, while figures listed for the construction phase are considered a one-time impact normalized to one year for comparison purposes. Operation phase figures for scenario 2 also includes impacts from the logistics activities associated with moving pellets to the export facility in New Hanover County, NC. Source: Authors analysis of IMPLAN 3.1 data.

5. Conclusion

Overall, the various proposed alternatives for biomass-based economic development would result in significant increases in employment and output in Pitt County, NC. First, since all scenarios were fixed to use 1000 BDT/Day of woody biomass, each project will result in approximately 220 jobs created in the logging and transportation sectors. In the analysis conducted in this paper, these jobs all appear in the indirect category since they are a result of purchases made by the main plant operations. Regardless of scenario, these indirect logging and transportation jobs represent high-quality employment opportunities for residents of eastern North Carolina.

Despite their commonalities, there are also critical differences in the scenarios proposed here. The electricity production scenario is projected to produce the lowest level of job creation, due primarily to the lower number of workers directly employed in the facility. This makes sense, as the utility sector is one of the most capital-intensive sectors and requires relatively fewer workers in the operations phase. Compared to the pellet facility, the electricity production facility is relatively expensive to build but results in fewer construction jobs than either biofuels scenario. The other issue with electricity production is that the total direct output predicted is lower ($63 million) than the alternative scenarios. This is due to the relatively low wholesale price of electricity assumed in the model ($0.07/kWh). In fact the competition of relatively cheap natural gas for electricity production threatens the financial viability of direct biomass-based generation. Rather than competing directly with natural gas based generation, we view the prospects for increased capacity from alternative base load electricity generation to come from the phase-out of coal-fired power plants.

The wood pellet scenario generates the highest number of jobs in the operations phase—409 including the direct, indirect, and induced effects—but is predicted to generate fewer construction jobs (97 jobs/year for three years). The relatively lower capital expenditure required to build a 1,000 BDT/day pellet factory makes this alternative more attractive to investors, but yields a lower economic impact for the regional economy. We believe that the market for wood pellets is currently attractive and makes the proposed facility size a reasonable business proposition. However, there are ongoing risks to the global pellet market that make the long-term viability of this alternative more uncertain. The current market price for pellets is highly dependent upon demand in Europe, in particular the United Kingdom. This demand is predicated on climate legislation that could limit the use of wood pellets. Thus, we characterize this scenario as subject to considerable policy risk beyond the control and influence of local stakeholders. Lastly, current major pellet production in North Carolina is exported through Virginia, not Wilmington or Morehead City. Thus, for this scenario to achieve its full potential economic impacts in North Carolina, the state needs to make significant infrastructure investments to improve the capacity of local ports and to improve rail access from fuel source locations to export facilities.

Both biofuels alternatives analyzed here represent a higher overall economic impact compared to electricity generation or wood pellet production. The higher impacts are driven primarily by that fact that liquid biofuels are simply a more valuable product that can be sold at a higher price which, with the addition of RIN credits available to producers, makes this alternative attractive from an investor's point of view. The production of liquid biofuels is a relatively mature market and there is already an existing infrastructure for getting the product to market. The key difference between the enzymatic and thermochemical production scenarios is the differential conversion rate between raw materials and outputs, which results in a higher sales figure for the enzymatic-based facility. This yields a slightly higher number of jobs in the operations phase. However, since the thermochemical facility requires a higher capital expenditure, the construction figures are slightly higher.

From a long-term job creation perspective, pellet production and enzymatic biofuel production are the most advantageous. However, the small number of construction jobs and the lower capital investment associated with pellet plants suggests that biofuel production will have a greater overall economic impact. Moreover, the uncertainty around the biomass electricity industry in the U.S. and Europe suggests that both domestic wood pellet to electricity generation and wood pellet production for export to Europe face significant challenges. Of these three options, using wood for liquid biofuel production may have the greatest economic impact. However, building a utility-scale, liquid biofuels processing capacity designed to primarily use heartwood and sapwood (as opposed to wood residues, agricultural waste, or even crops) may face long-term challenges from technological hurdles, wood price volatility, logistic concerns, feedstock competition from construction, pulp, etc., or other factors.

References

Aksoy, B., H. Cullinan, D. Webster, K. Gue, S. Sukumaran, M. Eden, and N. Sammons. 2011. Woody biomass and mill waste utilization opportunities in Alabama: transportation cost minimization, optimum facility location, economic feasibility, and impact. *Environmental Progress & Sustainable Energy* 30(4): 720-732.

Cebula, R.J. 2012. US residential electricity consumption: the effect of states' pursuit of energy efficiency policies. *Applied Economics Letters* 19(15): 1499-1503.

Cebula, R.J., and N. Herder. 2010. An empirical analysis of determinants of commercial and industrial electricity consumption. *Business and Economics Journal* 1(1): 1-7.

Daniel, G., B.C. English, and K. Jensen. 2007. Sixty billion gallons by 2030: Economic and agricultural impacts of ethanol and biodiesel expansion. *American Journal of Agricultural Economics* 89(5): 1290-1295.

Dincer, O., J.E. Payne, and K. Simkins. 2014. Are state renewable portfolio standards contagious? *American Journal of Economics and Sociology* 73(2): 325-340.

Guerrero, B.L., J.W. Johnson, S.H. Amosson, P.N. Johnson, E. Segarra, and J. Surles. 2011. Ethanol production in the southern high plains of Texas: Impacts on the economy and scarce water resources. *Journal of Regional Analysis and Policy* 41(1): 22-32.

Hodge, T.R. 2011. The effect of ethanol plants on residential property values: evidence from Michigan. *Journal of Regional Analysis and Policy* 41(2): 148-167.

Khanna, M., C.L. Crago, and M. Black. 2011. Can biofuels be a solution to climate change? The implications of land use change-related emissions for policy. *Interface Focus* 1(2): 233-247.

Matisoff, D.C. 2008. The adoption of state climate change policies and renewable portfolio standards: regional diffusion or internal determinants? *Review of Policy Research 25*(6): 527-546.

National Renewable Energy Laboratory. 1999. Lignocellulostic Biomass to Ethanol Process Design and Economics Utilizing Co-Current Dilute Acid Prehydrolysis and Enzymatic Hydrolysis Current and Futuristic Scenarios. NREL/TP-580-26157

National Renewable Energy Laboratory. 2007. Thermochemical Ethanol via Indirect Gasification and Mixed Alcohol Synthesis of Lignocellulosic Biomass. NREL/TP-510-41168

North Carolina Department of Transportation. 2012. *NC Maritime Strategy Final Report*. North Carolina.

Payne, J.E. 2009. On the dynamics of energy consumption and employment in Illinois. *Journal of Regional Analysis and Policy* 39(2): 126-130.

Pirraglia A., R. Gonzalez, and D. Saloni. 2010. Techno-economical analysis of wood pellets production for U.S. manufacturers. *BioResources* 5(4): 2374-2390.

Rabe, B. 2007. Race to the top: The expanding role of US state renewable portfolio standards. *Sustainable Development Law & Policy* 7(3): 10-16.

Swenson, D. 2006. Input-outrageous: the economic impacts of modern biofuels production. 2006 Implan Proceedings. Retrieved from http://implan.com/.

Swenson, D. 2007. Understanding biofuels economic impact claims. Iowa State University. Retrieved from www.econ.iastate.edu/research/webpapers/paper_12790.pdf

Swenson, D., and L. Eathington. 2006. Determining the regional economic values of ethanol production in Iowa considering different levels of local investment, Iowa State University. Retrieved from: www.econ.iastate.edu/research/other/p11230.

Schlosser, J.A., J.C. Leatherman, and J.M Peterson. 2008. Are biofuels revitalizing rural economies? Projected versus actual labor market impacts in the Great Plains. Working Paper presented at the American Agricultural Economics Association Annual Meeting, July 27-29, 2008.

Yin, H., and N. Powers. 2010. Do state renewable portfolio standards promote in-state renewable generation. *Energy Policy* 38(2): 1140-1149.