THE ECONOMIC IMPACT OF GENERATING ELECTRICITY FROM BIOMASS IN IOWA: A GENERAL EQUILIBRIUM ANALYSIS

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Many people believe that obtaining energy from renewable sources would generate a large number of new jobs. Two reasons are often cited to support this belief. First, Providing renewable energy is more labor intensive than producing fossil fuels and nuclear power. The U.S. Congress Office of Technology Assessment (OTA, 1980), for example, estimated that deriving energy from forestry residues was 1.5 to 3 times as labor-intensive as using coal. The Council on Economic Priorities in New York (1979) compared the job-creation potential of a solar/conservation strategy and two proposed nuclear power plants on Long Island, New York. They found that solar energy alone would create nine times as many jobs per unit of energy produced as nuclear power. California Public Policy Center (1978) similarly found that active solar systems would generate more than twice as many jobs as either nuclear power or liquified natural gas. Brower and his colleagues in the Union of Concern Scientists (Brower et al., 1993) estimated that 200 MW of wood-fired power plants in Ohio, using trees grown locally as energy crops, would create nearly 500 more permanent new jobs in the state than if local coal were used to supply the same new generating capacity.

Second, the renewable energy would increase regional self-sufficiency and local self-reliance. Morris (1982) observed that when energy comes from conventional fossil and nuclear sources, spending on energy is the worst expenditure in terms of its impact on the local economy--85 cents on a dollar leaves the economy. The picture will be very different for renewable energy. Unlike conventional fossil and nuclear fuels which have a high level of geographic concentration, renewable energy resources are widely available. Use of locally produced renewable energy instead of imported fuels helps to retain energy dollars in the local economy and stimulate the growth of local industries. It also reduces a region's vulnerability to energy price hikes and supply instability. Denzler (1994) estimates that about two-thirds of dollars spent over the life of a typical biomass power plant will be within the local and regional economies, to purchase fuels and to hire workers for operations and maintenance. According to the Southeastern Regional biomass Energy Program, the activities associated with the use of industrial wood energy generated over 71 thousand jobs and $1 billion personal income for the Southeast region in 1987 (TVA, 1990).

Most empirical research on job creation potentials of renewable energy are case studies. Researchers typically estimate the job impact by calculating the labor requirements of producing

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renewable energy and determining how much of those requirements will be met locally. This type of studies is static partial analysis in the sense that it does not account for the cost differences of providing energy from different sources and the macroeconomic impact of energy-cost changes. It is often more expensive, for example, to generate electricity from renewable sources than from coal. Substituting the renewable for coal in power generation, therefore, would increase electricity cost. As electricity price rises, the demand for electricity would drop, the production of electricity would decline, and so would the labor requirements. Furthermore, a higher electricity price means higher costs of living and production would increase which would have a recessionary effect on the regional economy. A recent study by Clemmer (1995) shows that although renewable energy investments produce over three times more jobs, income and economic activity than the same amount of electricity generated from coal and natural gas power plants in Wisconsin, displacing conventional electricity investments with renewable energy technologies has a very small impact on Wisconsin's economy as a whole--less than 0.1 percent in terms of employment and real disposable income.

In this paper, we apply a dynamic economic simulation model of the Iowa economy, developed by Regional Economic Models, Inc. (REMI), to conduct a general equilibrium analysis of the economic impacts of generating electricity from switchgrass in Iowa. Of the money spent on resources to generate electricity, more than 90 percent of them flows to the out-of-state suppliers which is a tremendous burden on the state economy (Iowa Energy Center, 1992). The outflow of dollars to pay for this energy includes over $300 million for purchased coal, which provides fuel for 85 percent of all electricity generated in the state (EIA, 1992). To reduce this economic leakage, the state government of Iowa has been promoting the investments in energy efficiency and encouraging the development of renewable energy supply. One of the most important sources of renewable energy in Iowa is biomass (Browers et al., 1993). In a comprehensive study of the potential for biomass energy in Iowa, Brown et al. (1994) identify switchgrass as one of the most cost-effective biomass fuels for generating electricity. We, therefore, focus on the economic impact of switchgrass electricity. The methodology presented in this paper can be used to analyze economic impacts of other renewable energy technologies.

MODELING APPROACH

In modeling economic impacts of renewable energy projects, analysts must, explicitly or implicitly, answer the following two questions:

1. What is the regional economy likely to be in the future without the proposed renewable energy projects?

2. What is the likely future of the regional economy if the proposed renewable energy projects are implemented?

The answer to the first question is often called a baseline forecast (BF), and the answer to the second one, a simulation forecast (SF). The economic impact (E) of a renewable energy project, then, can be defined conceptually as: E = SF - BF. In this study, we use the Iowa Economic and Demographic Forecasting Model developed by Regional Economic Models, Inc (hereafter refereed to as the REMI model) to generate the baseline forecast and to simulate the likely impacts of generating electricity from switchgrass on the Iowa's economy.

REMI Model

The REMI model is a dynamic multiregional, multisectoral economic simulation model. It is a general equilibrium model--changes in one sector of the economy are allowed to affect other sectors, which then feed back to the original sectors. The model is structured based on mainstream economic theories (Treyz, 1980, 1989, 1993; Treyz and Stevens, 1985). It can be calibrated to any combination of counties or states in the United States and has been widely used in regional economic analyses (Lin et al., 1992). REMI modelers apply an open-economy, Keynesian accounting system to set up a regional economic account and an extended economic-base analysis to determine the relationship between the region and the nation. They then use an input-output model to identify interindustry relationships and a flexible production function to estimate the substitutions among capital, labor materials, and fuels. The parameters of each equation in the model are estimated using historical data for all states and the United States. Key features of the REMI model are its significant sectoral and occupational detail and its sensitivity to factors such as product and factor price changes, regional exports and imports, population changes, and interindustry linkages.

The REMI model for each region is calibrated using three main data bases: cross-sectional data available for the national economy, time-series data for the region, and information on regional trade and purchase patterns. The model builders use the regional purchase coefficients to regionalize the national input-output table (Stevens, Treyz, and Lahr, 1989). The regionalization is done at a very disaggregate level of about 500 industries which are then aggregated to 53 sectors. The resulting regional input-output table is then used to determine the regional interindustrial linkages. These linkages, which trace the extent to which each sector generates demand for goods and services from other sectors, serve as a basis for calculating multiplier effects and quantifying economic impacts. The multipliers in the REMI model, however, are not constant and different from those in the input-output model. They vary depending on the price and quantity adjustment in both factor and product markets. The economic impacts also change over time because wage changes, product price adjustments, and population movements act to balance supply and demand for the relevant occupations and factor inputs in the long run.

In the REMI model, the performance of a regional economy, to a large extent, depends on (1) the performance of the national economy, (2) comparative advantages of the region in terms of production costs, and (3) exogenous factors, such as construction projects, population migration, and government policies. The economic impacts of an exogenous factor can be estimated using either of two types of policy variables: regular and translator. A regular policy variable reflects an exogenous shock to a particular part of the economy, such as changes in overall price level, changes in export market, changes in investment behavior, or changes in labor market. A translator variable represents exogenous changes in a specific sector through a combination of regular policy variables. The model has over 1000 policy variable and makes a forecast for over 2000 variables, including gross sate product by final demand sectors and by industries and employment and cost of doing business for 53 industries, for the period of 1969 through 2035.

Developing Scenarios

There are several different technologies available for generating electricity from biomass (Brown et al., 1994). Based on the literature review and expert consultation, we decide to focus on modeling economic impacts of co-firing switchgrass along with the existing fuel in a coal-fired power plant, which looks quite promising for Iowa in the near future. Switchgrass can be burned in this way up to about 10 percent of the mixed fuel with only a slight modification of the fuel-handling system at power plants. We assume, therefore, that there is no significant construction cost associated with co-firing. We also assume that all the cost of co-firing switchgrass will be financed through electricity price increases. Accounting for the sources of financing is important because the resources allocated to producing biomass electricity have an opportunity cost. These assumptions can and should be modified if, for example, there are major facility construction and modification and if the federal government provides funding for switchgrass electricity.

The yield and production cost of switchgrass vary with locations. In Iowa, the yield estimates range from 2.5-4.9 tons per acre and the production costs range from about $220 per ton in Chariton to $260 per ton in Ames. As shown in Table 1, land is the largest cost of producing switchgrass and accounts for almost all of the production cost difference between Chariton and Ames.

Table 1. First year production costs for switchgrass production (per acre):

(Unit: $)	High Cost (Ames)	Low Cost (Chariton)
seed	24.50	25.20
fertilizer (excl Nitrogen)	23.98	23.98
Herbicide	3.95	3.95
machinery fuel	4.99	4.99
R & M	18.01	18.01
fixed cost	43.35	43.34
labor	9.38	9.38
interest	4.76	4.78
transportation	13.78	13.03
land	115.00	80.00
total establishment	$261.70	$226.68

Source: Brown et al., 1994

To assess the potential economic impacts of co-firing switchgrass in coal-fueled electric power plants, we develop five scenarios with different assumptions about the percentage of coal replaced by switchgrass and the yield and cost of switchgrass. As shown in Table 2, the five scenarios are:

- Scenario 1: low replacement of coal (1%), low switchgrass yield (2.5 ton/acre), and low production cost ($226/acre).
- Scenario 2: low replacement of coal (1%), low switchgrass yield (2.5 ton/acre), and high production cost ($261/acre).
- Scenario 3: low replacement of coal (1%), high switchgrass yield (4.9 ton/acre), and low production costs (assumes use of added nitrogen).
- Scenario 4: low replacement of coal, high switchgrass yield per acre, high production costs (assumes use of nitrogen).
- Scenario 5: high replacement of coal, low switchgrass yield per acre; low production costs.

Economic impacts of adopting these renewable energy options are analyzed relative to a "do nothing" status quo in which Iowa's electric utility sector continues to rely on coal from outside the state. We use "do nothing" as a reference point because Iowa has excess electric generation capacity and there is no need for major facility expansion in the near future.

Table 2. Scenarios for Generating Electricity from Switchgrass

Scenario	**Replacement Of Coal (% of electricity)**	**Switchgrass Yield (tons/acre)**	**Switchgrass Production Cost ($/acre)**
1	L ow (1%)	Low (2.5)	Low (226)
2	Low (1%)	Low (2.5)	High (261)
3	Low (1%)	High(4.9)	Low (226)
4	Low (1%)	High(4.9)	High (261)
5	High (10%)	Low (2.5)	Low (226)

Assessing Economic Impacts

We model the economic impacts of co-firing switchgrass in coal-fueled power plants by simulating the effect of the following four changes on Iowa's economy:

1. Increased Demand for Switchgrass as a result of burning switchgrass in electric utilities.

2. Increased Production of Switchgrass which requires the provision of factor inputs such as land, labor, fertilizer, herbicide, seed, and so on.

3. Reduced Demand for Coal. A portion of coal will be replaced by switchgrass which reduces Iowa's dependence on imported coal.

4. Electricity-Price Increases. Because electricity from switchgrass is more costly than that from coal, electricity prices will have to be increased to finance generation cost increases. This will increase the cost of living and production.

The four changes affect the Iowa's economy simultaneously. Their combined effect determines the economic impacts of generating electricity from switchgrass.

The data inputs for each scenario is prepared in seven steps. First, we obtain information on current total electric generation capacity (Kw) and electricity production (Kwh) in Iowa. Second, we obtain information on the quantity and percentage of electricity generated from coal and its fuel requirement. Third, we determine what percentage of coal (Btu) would be replaced by switchgrass based on the modeling scenario. Fourth, we calculate the amount of dry switchgrass required by comparing energy content (Btu) of dry switchgrass with that of average coal used in Iowa's electric utilities. Fifth, we convert tons of dry switchgrass into switchgrass production and acreage. Sixth, we estimate cost and input structure of switchgrass production, transportation, and processing. Finally, we estimate the impact of replacing coal with switchgrass on electricity prices based on cost ($/Btu) difference between switchgrass and coal and the replacement percentage.

RESULTS FROM THE MODEL

Before we present our modeling results, it is important to point out that scenarios are not predictions. We do not attempt to forecast the future level of biomass-generated electricity in Iowa. Nor do we try to predict the exact economic consequence of adopting biomass electric generation technology. The main purpose of our modeling is to assess the potential economic impacts of switchgrass-generated electricity in Iowa under different assumptions. Our modeling results, therefore, should be interpreted as an indication of relative magnitude of economic impacts or one likely economic consequence of switchgrass electricity generation, not as an exact description of economic impacts or the only possible economic consequence.

With these caveats in mind, Table 3 shows the REMI model baseline projection for the Iowa's economy into the year 2015. The baseline projection provides a reference point for calculating the changes in employment, income, and output associated with co-firing switchgrass in coal-fired power plants. It helps us to place the estimated economic impacts in perspective. From the table, we see that the largest employment sectors in Iowa are services and retail, followed by durable goods manufacturing and finance/insurance/real estate (F.I.R.E.). The twenty-year forecasts are based on the Bureau of Economic Analysis national projection, REMI analysis of the relative costs of doing business in Iowa, and analysis of historical trends (since 1972) in Iowa economic patterns and their sensitivity to business costs. There are projected losses of jobs in farming, federal government, and durable goods manufacturing (especially

Metals, Machinery, and Instruments). These are offsetted by projected employment gains in fiance-insurance-real estate, services and non-durable goods (especially food products, printing and plastic/rubber products).

Table 3. Baseline Forecast of Iowa Economy

($ million)	1995	2000	2005	2010	2015
Gross Regional Product	82,258	92,337	101,379	109,065	115,905
Disposable Income	58,314	63,729	68,658	72,229	75,656
Employment	17,826,780	1,884,761	1,968,278	2,000,026	2,015,137
Breakdown of Jobs					
Farm/Agric Service	139,441	132,928	127,014	122,465	117,830
Mining & Minerals	2,705	2,559	2,367	2,247	2,113
Construction	81,494	85,495	87,996	91,398	94,939
Dural Goods	134,100	133,015	126,977	117,422	107,028
Non-Dural Goods	110,202	116,458	120,865	118,966	115,481
Transport & Public Util	73,243	76,520	78,672	79,662	79,979
Finan, Insur & R.E.	125,661	135,890	143,915	150,553	155,788
Wholesale Trade	93,506	98,427	101,672	103,857	104,753
Retail Trade	309,074	315,932	321,869	322,694	321,866
Services	477,706	540,407	600,235	632,056	654,706
State & Local Govt	205,090	217,340	226,743	228,395	230,195
Federal Govt.	30,457	29,789	29,954	30,309	30,458

Figures 1 - 3 present the modeling results in terms of GDP, income and employment, respectively. Figure 4 shows the typical profile of employment effects, by economic sector.

Scenario 1 assumes one percent of the coal used in electric power generation is replaced by co-firing switchgrass on a continuing basis. Given a low switchgrass yield (ton/acre) and production cost ($ /acre), we estimate that this would increase the electricity generation cost by $3.7 million a year. It would also increase the demand for switchgrass by $8.97 million, all of which is assumed to go to Iowa producers. From the table, we see that generating electricity from switchgrass has a positive impact on the Iowa's economy. There would be a net growth of as high as 373 jobs per year of employment, &7 million of disposable income (in 1994 constant prices), and $9 million of gross regional product (GRP). Over two third of the job increase are in the farm and agriculture services sector. The average annual impacts are 315 for employment, $6 million for income, and $8 million for GRP. This represents 84 jobs per million dollars spent on switchgrass electricity, and $1.46 of income to Iowa residents for every dollar spent on switchgrass electricity.

Figure 1 GDP Impacts Millions of '95 $

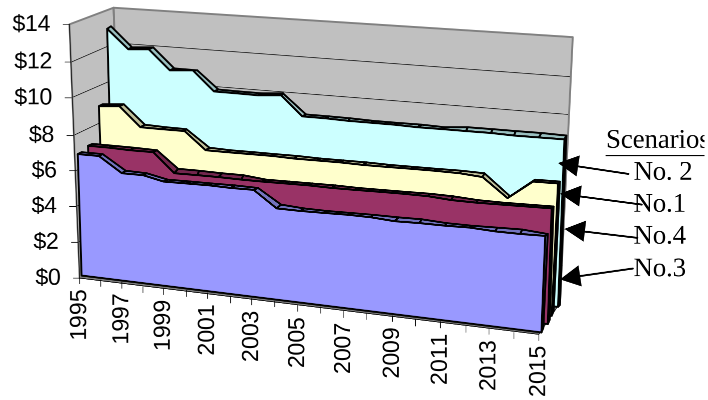


Figure 2 Income Impacts Millions of '95 $

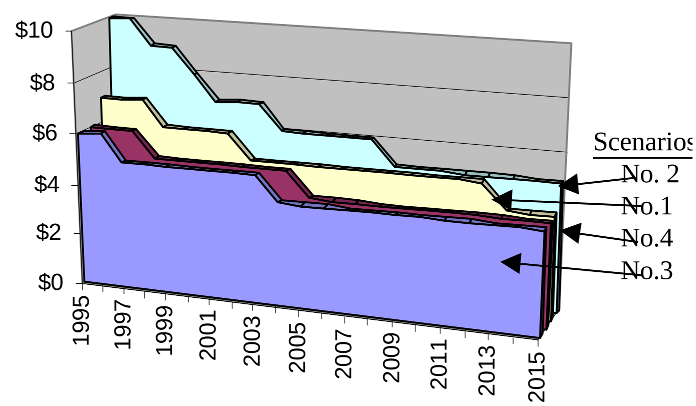
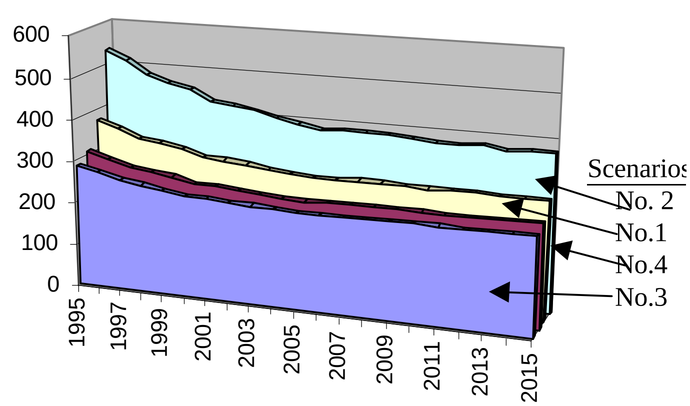


Figure 3 Employment Impacts



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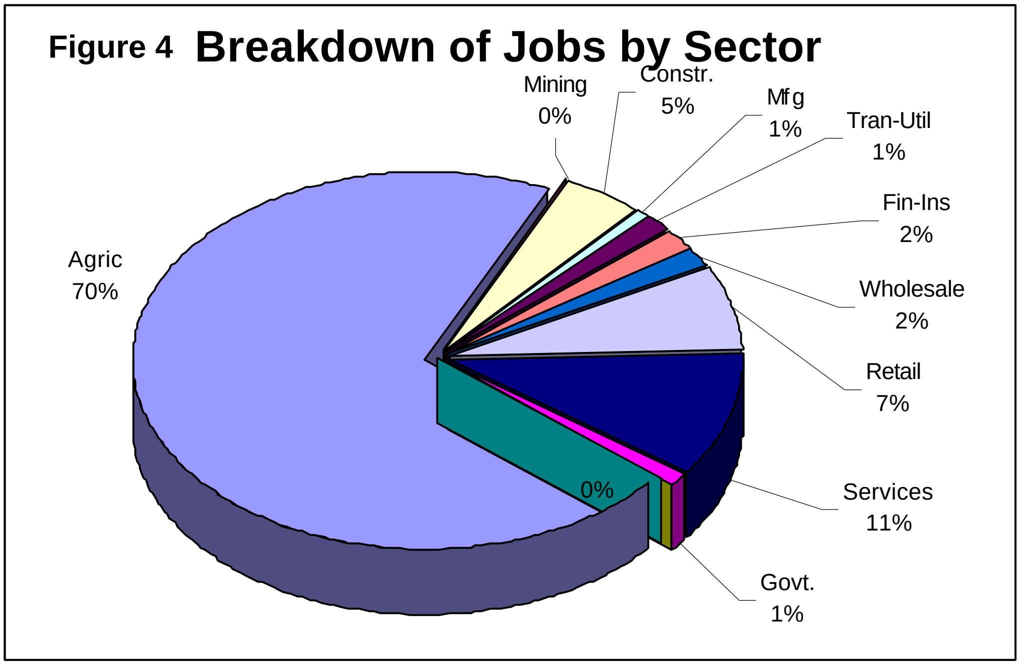

Scenarios 2-4 also assume the displacement of one percent of coal used in electric power generation with switchgrass, under different assumptions about the crop yield and production cost. The results are roughly similar to those of Scenario 1. The estimated annual employment gains for different scenarios ranges from 230 to 530 jobs. Gross regional product increases by $5-13 million (in 1994 constant prices) for different years; and the annual real disposable income up by $4-10 million (in 1994 constant prices). Because we assume no up front capital construction for co-firing switchgrass, there are no dramatic differences between short-term and long-term results. Rather, the model predicts generally stable employment and income level with the positive economic impacts slowly falling over time as labor markets and labor prices adjust to reach a new supply-demand equilibrium.

A priori, one would expect that the economic benefit of co-firing switchgrass increases with higher switchgrass yield and lower production cost. Surprisingly, our modeling results indicate just the opposite. At a constant 1 percent coal replacement rate (Scenarios 1-4), the largest job, income, and output gains occur in Scenario 3 which assumes low switchgrass yield and high production cost, and the smallest benefits are under Scenario 4 which assume high yield and low production cost. This is because high switchgrass cost has two opposing economic effects. First, it increases the cost of electricity which has a negative macroeconomic effect. second, it increases the spending on switchgrass produced locally which substitutes the imported coal, improves trade balances, and has an expansionary effect on the economy. In Iowa, the second effect appears to be more important. The economic loss due to higher electricity cost is more than offset by the "import substitution" effect of supplying switchgrass locally in place of money previously flowing out of the state to purchase coal.

To see how the economic impacts change with greater utilization of biomass power generation technology, we run Scenario 5 in which 10 percent of the coal used in power generation is replaced by burning switchgrass. The results, which is shown in Table 4, indicate a much larger economic benefit to the Iowa's economy. There would initially be a net growth of 3732 jobs, $74 million per year of additional disposable income, and $90 million per year of gross regional product. While the net gains would diminish 25% over the next 8 years due to effects of rising prices, thereafter the long-term impacts persist.

Table 4 Economic Impacts of Generating Switchgrass Electricity in Iowa, Scenario 5.

Overall Effect (Millions, '95 $)	**Year 1**	**Year 5**	**Year 10**	**Year 15**	**Year 20**
Gross Regional Product	90	73	66	66	65
Disposable Income	74	57	47	45	44
Employment	3,732	3,047	2,792	2,803	2,806
Breakdown of Employment					
Farm/Agric Service	2,643	2,261	2,192	2,256	2,272
Mining & Minerals	2	2	2	2	2
Construction	170	129	105	99	97
Dural Goods	6	4	2	2	2
Non-Dural Goods	18	13	9	8	8
Transport & Public Util	53	43	38	37	36
Finan, Insur & R.E.	68	48	36	32	31
Wholesale Trade	66	52	45	45	44
Retail Trade	264	179	124	109	105
Services	404	290	218	196	191
State & Local Govt	38	27	20	17	17
Federal Govt.	0	0	0	0	0

Although these appear to be very significant economic impacts, they are nevertheless modest relative to the totals, as shown in Table 5. At 10% switchgrass co-firing in the coal-fueled power plants, the employment increase for every year is about 0.02 percent to the projected baseline total state employment. Similar percentage hold true for income (less than 0.01 percent above the baseline) and output (less than 0.01 percent above the baseline) as well.

Table 5. Impact as a Percent of Baseline

Overall Effect (Billions, '95 $)	**Year 1**	**Year 5**	**Year 10**	**Year 15**	**Year 20**
Gross Regional Product	0.01%	0.01%	0.01%	0.01%	0.01%
Disposable Income	0.01%	0.01%	0.01%	0.01%	0.01%
Employment	2.09%	16.17%	14.18%	14.01%	13.92%
Breakdown of Employment					
Farm/Agric Service	189.54%	170.09%	172.58%	184.22%	192.82%
Mining & Minerals	7.39%	7.82%	8.45%	8.90%	9.47%
Construction	20.86%	15.09%	11.93%	10.83%	10.22%
Dural Goods	0.45%	0.30%	0.16%	0.17%	0.19%
Non-Dural Goods	1.63%	1.12%	0.74%	0.67%	0.69%
Transport & Public Util	7.24%	5.62%	4.83%	4.64%	4.50%
Finan, Insur & R.E.	5.41%	3.53%	2.50%	2.13%	1.99%
Wholesale Trade	7.06%	5.28%	4.43%	4.33%	4.20%
Retail Trade	8.54%	5.67%	3.85%	3.38%	3.26%
Services	8.46%	5.37%	3.63%	3.10%	2.92%
State & Local Govt	1.85%	1.24%	0.88%	0.74%	0.74%
Federal Govt.	0.00%	0.00%	0.00%	0.00%	0.00%

Our finding of no significant impact does not mean that co-firing switchgrass in coal-fueled power plants has no economic impact. What it dos tell us is that there is no significant *macroeconomic* effects for *the Iowa economy as a whole*. It is possible that the co-firing switchgrass will generate large economic benefits for some industries or communities. Job and income gains, for example, may be distributed overwhelmingly to a few sectors, where they represent a much larger percentage of the total baseline projection values. From Table 9, we see that over 70 percent of the job gains resulting from increased spending on switchgrass are in farm and agriculture sector, whose job gain is about 2 percent of the baseline employment forecast. For most other sectors, job losses are statistically too small to be reliable, even when we take a more disaggregated look at the numbers.

CONCLUSION AND DISCUSSION

It is widely believed that substituting renewable energy to conventional fossil and nuclear energy will create a large number of new jobs. Several case studies suggest that renewable energy can generate several times as many jobs per unit of energy produced as conventional fossil-fueled and nuclear power plants. In his now famous *Soft Energy Paths: Toward a Durable Peace*, Lovins (1977) states that every joule of fossil and nuclear fuels fed into new power stations reduces jobs in the U.S. economy and generating electricity from renewable sources can save many jobs. Deudney and Falving (1983) argues that maximizing job creation potentials should be the primary objective of renewable energy development.

"Too often neglected is the impact that different energy alternatives have on employment. A basic measure of economic and psychological well-being, employment is an essential standard against which renewable energy's viability should be measured and toward which renewable energy development should be directed. . . . With 36 million people entering the global work force each year, technologies must be judged by their ability to create jobs as well as to supply energy. (p. 301)"

In this paper, we examine the macroeconomic impacts of co-firing switchgrass in coal-fueled power plants in Iowa. Our modeling results show that generating switchgrass electricity does produce employment, income, and output gains. The magnitude of those gains, however, is very small. Even in Iowa which has low switchgrass production cost and imports almost all the coal it uses, replacing 10% of the coal used in electric power generation with switchgrass would increase the total employment, gross state product, and disposal income by only about 0.1-0.2 percent annually. Similar results are found in an analysis of macroeconomic impacts of renewable energy program in Wisconsin (Clemmer, 1995). There appears to be a paradox. While the micro-level comparison of alternative energy technologies suggests that renewable energy has large job creation potentials, its overall macroeconomic impacts seems to be small.

There are two possible explanations for this paradox. First, unlike conventional fossil fuel and nuclear technologies, renewable energy sources are diverse and decentralized. Each individual renewable energy source is small relative to the total energy supply. When placed in the context of macroeconomy, its economic impact tends to be lost in the "ocean". In other words, the development of a single renewable energy technology seldom has significant *macroeconomic* effects. Second, most micro-level studies of job creation potentials of alternative energy technologies are based on the assumption that total energy consumption would be the same. They do not account for the effect of alternative technologies on energy prices and the effect of energy-price changes on total energy consumption and macroeconomy. Because the renewable technology is often more expensive than conventional fossil fuel and nuclear power, its application tends to increase the energy costs thus, ceteris paribus, reducing energy consumption. Furthermore, high energy costs have negative macroeconomic impacts. The development of renewable energy, therefore, should not be viewed just as a substitution of energy technologies, but as a re-direction of resources and modification of economic activities. Through backward and forward linkages, renewable energy expenditures will result in changes in the circular flow of the economy, affecting both producers and consumers. In this process, some businesses grow, while others decline. The net economic impacts are often very difficult to predict ex ante.

Our finding of no significant macroeconomic impact at the state level from co-firing switchgrass in coal-fueled power plant does not means that the Iowa should not encourage the development of biomass energy. There may be large enough economic benefits for some communities, industries, or utilities which can justify the investment in biomass energy technology. More importantly, there are many motivations for promoting renewable energy technologies. Economic development is only one of them, and it is often not the primary motivation. Other motivations, such as diversifying energy resource base, reducing environmental pollution, buying technological options for the future, and enhancing self-reliance and energy security, may be more important. They may also be in conflict with the objective of maximizing economic benefits. Job creation potential, therefore, should not be the only or even primary criterion used to evaluate renewable energy technologies.

This study is a first step. Much more empirical work needs to be done before the economic impacts of renewable energy technologies can be adequately understood. In future studies, we hope to conduct similar analyses for other renewable energy technologies and to expand our study to include other states.

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