An Analysis of Expanding Renewable Energy Markets in Minnesota: Implications for Rural Economic Development

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EXECUTIVE SUMMARY

Minnesota (MN) is a national leader in agricultural production. However, the relative economic impact of MN's production agriculture has declined, as evidenced by population outmigration from rural to urban areas. A revitalization of Minnesota's rural economy is possible, thanks to a rich resource-base and entrepreneurial activity in the renewable energy sector. The private sector has taken the lead in developing ethanol plants and wind farms throughout Minnesota. In 2007, the State Legislature and Governor enacted legislation to put Minnesota on a path to have 25% of its energy produced from renewable sources by the year 2025. Minnesota statute also sets a goal of increasing the amount of ethanol blended into gasoline to 20 percent by 2013.

Development of Minnesota's renewable energy sector has a real potential to serve as an engine for rural economic growth. Farm households, rural businesses and rural communities can benefit from rural development because of new and higher-wage employment, new markets for agricultural commodities and more vibrant regional economies. To research the economic potentials, we perform an in-depth analysis using primary survey data and secondary data. Our findings suggest that the growth of the renewable energy sector can serve as a key avenue for value-added agriculture to advance Minnesota's rural economy. Expanding renewable energy markets, such as ethanol, can create positive impacts on rural employment and household income, the profitability of farm-related businesses, and other businesses connected to Minnesota's rural areas.

We conduct demand function analysis of alternative energy sources to estimate the factors that drive market shares or expansion of these energy sources. The market share of coal is driven by its own price and by the prices of electricity and LPG because they are used as

alternative energy for heating purpose. The market share of natural gas is driven by its own price, and the prices of electricity and LPG for the same reason. The market share of oil is driven by nearly all of the other energy because of the extensive use of oil, and the oil market's volatile character. The market share of electricity is also driven by the prices of most energy sources. Electricity is generated with other fuels as inputs, and electricity is also widely used in lighting and heating. Market share of LPG is influenced by its own prices and by the prices of natural gas and electricity, because LPG can be substitute for natural gas as a heating source. The market share of biomass (wood) is solely influenced by the price of LPG for the reason that it may be used as a supplement to LPG in rural areas.

Survey results from a sample of Minnesota's ethanol producers (one of the fastest growing renewable energy sources in Minnesota) reveal that policies to support the use of renewable energy are extremely important. On the average, policies to sustain feasible natural gas prices are considered to be very important by the respondents. Another variable rated as "somewhat important" in ethanol market expansion is the government subsidy to ethanol plants. Subsidies for ethanol have been a hotly debated item in US Congress (Valesco, 2010). However, The U.S. also enjoys one of the lowest gasoline prices in the world because of limited taxes placed on imported gasoline. This indirect subsidy on gasoline should be compared with the ethanol subsidy to facilitate efficient policy design

Scenario Method Analysis provides a novel approach to identify driver and dependent factors that should be considered for the short-run (direct effects) and long-run (indirect effects with second- and third-order interaction). Our long-term analysis of indirect effects suggests the strongest influence on expanding ethanol markets and rural development will be efficient production technology. Improved technology will affect long-term demand, supply, and ethanol price. Research to improve production technology for renewable energy is highly encouraged.

REPORT FINDINGS

- This study required that we perform a review of the existing literature and available data on the economic performance of the ethanol industry in Minnesota. In 2007, data collected by the Minnesota Department of Agriculture (MDA) demonstrated that the output value of ethanol production in Minnesota was $1.68 billion. Using regular economic multipliers, an estimated $2.27 billion of total economic activity was generated and 4,305 more jobs were created. Among these new positions, 1,445 jobs were directly created in the ethanol industry, 913 job positions were produced in related fields (e.g., corn farm workers) and 1,948 jobs were created because of the growing economy generated by associated with ethanol production.
- Ethanol is simply one of a variety of energy sources in Minnesota (MN). To properly identify recommendations for an efficient MN energy policy, we investigated price-elasticities and income-elasticities for MN's most important energy sources. Coal, oil, natural gas, electricity and liquefied petroleum gas/ethanol blend (LPG) are the major alternative energy sources used in the residential sector in Minnesota. We used a ***Linear Approximate / Almost Ideal Demand System*** (LA/AIDS) model to estimate price elasticity and income elasticity for these energy uses. Summary results show that all income elasticities are positive, as expected, but vary significantly depending on the type of energy. An expected inverse price elasticity of demand failed to show in some cases; however the results are intuitively instructive in providing policy alternatives for the government regarding allocating energy in a more environmentally-friendly way.

- We examined the demand functions for alternative energy sources separately, and analyzed key factors that drive the market shares of these energy sources. The market share of coal is driven by its own price, and by the prices of electricity and LPG, because they are used as alternative energy for heating purposes. The market share of natural gas is driven by its own price, and the prices of electricity and LPG for the same reason. The market share of oil is driven by nearly all of the other energy sources because of the extensive use of oil throughout Minnesota's economy, and the volatile characteristics in oil supply market. The market share of electricity is also driven by the prices of most energy sources, because electricity is generated with other fuels as inputs, and it is widely used in lighting and heating. The market share of LPG is influenced by its own-price, and by the prices of natural gas and electricity, because LPG can be used as substitute for natural gas in heating purpose. The market share of biomass (wood) is solely influenced by the price of LPG for the reason that it may be used as supplement to LPG in rural areas.
- Coal has the highest fuel emission coefficient, which means that it is the least environmentally-friendly energy source; local and/or state governments may want to mitigate the environmental effects of coal by providing incentives for clean coal use or encourage the substitution of other "green" renewable sources. Because coal usage is price-inelastic, increasing the price of coal is not an effective strategy to reduce the quantity-demanded for coal. Natural gas is price-inelastic and income elastic. Because of the high energy efficiency of natural gas, government may want to encourage usage of natural gas by improving technology and machines that utilize natural gas. Oil is both price and income elastic;

therefore consumption of oil can be altered through price incentives or taxes. Electricity is neither price nor income elastic due to its fundamental usage in household lighting. To encourage efficiency, electricity users should be provided with knowledge of prices during periods of peak-time and off-peak-time usage. LPG is income-elastic and price-inelastic. This indicates that people are unlikely to switch from the use of natural gas to use of LPG unless their total expenditure on energy increases. Finally, biomass (especially wood) has high-price elasticity and low income-elasticity. Note that wood ranks No.2 in the fuel emission coefficient (not very environmentally-friendly); if policies are developed to minimize the adverse environmental impacts of wood-burning, tax incentives could be considered because wood consumption has an elastic response to price changes.

- We surveyed ethanol plant operators to identify the predominant organizational structure of the markets used to produce renewable energy in Minnesota. We placed particular emphasis on ethanol because it is the fastest growing renewable energy source.
- The ethanol plants included in our survey sample averaged 39 full-time positions for employment, and a 6.25 average for part-time jobs. In total, the sampled ethanol plants employed about 349 people, and the majority of the people who filled these positions lived in rural areas. This survey result is an indication that ethanol provides steady full-time work and some part-time employment for rural communities in Minnesota.
- Our survey respondents noted that policies to support the use of renewable energy are extremely important. Subsidies were considered to be somewhat important.

Both the level of demand for ethanol, and the access to better production technology, were perceived as extremely important to our survey respondents. Also, lower corn prices and the availability of supply stations for ethanol were both seen as very important. The ethanol plant managers in our survey also considered the impact of renewable energy on the environment to be very important, and they appreciated the role ethanol can play as a renewable energy source. Finally, tariffs (taxes) on foreign ethanol were considered to be extremely important. In order words, our survey respondents perceived that local firms need to be protected from imported ethanol. All the variables in this category have low standard deviations (1.12 or less), an indication that all respondents see the issues related to an expanding renewable energy market in a similar manner.

- Our survey asked respondents to rate the importance of renewable energy production on rural development. The response indicates that, on the average, the following factors are perceived by these plant managers as "extremely important:" future rural development, Minnesota's rural economy, improving production and land use, improve rural quality of life, and creating higher income jobs.
- As part of our study, we interpreted our survey results by using ***Micmac Scenario Method Analysis. Micmac Scenario Method Analysis*** involves developing a database of important variables/factors from the existing literature and/or the survey, and analyzing those factors to determine the major "drivers" and "influence variables" that will affect policy or strategy.
- We employed the ***Micmac Scenario Method Analysis*** to create a *Matrix of Direct Influences* ***(MDI)***. ***MDI*** helps identify those factors are the most important drivers

and dependent variables that can change ethanol production and use. Public policy makers can use the ***MDI*** to help identify strategies that optimize the socio-economic impacts of the renewable energy sector. The ***MDI*** matrix in our study indicated that two factors had both strong-driver and dependent-factor influences: government subsidies, and the availability of ethanol from cane sugar. These factors should be further and carefully analyzed for efficient policy design.

- We also employed the ***Micmac Scenario Method Analysis*** to take into account second- and third-order interactions, and created a *Matrix of Potential Direct Influences* ***(MPDI)***. The ***MPDI*** analysis suggested that the strongest influence on expanding ethanol markets and enhancing rural development will be ***efficient production technology***. Production technology is the main variable that will affect demand, supply, and ethanol price in the long run. The ***MPDI*** results indicate that research on improving efficient production technologies for renewable energy should be highly encouraged.

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BACKGROUND

Minnesota is a national leader in agricultural production. Minnesota is the 7th largest agricultural producer in the U.S. The state is known for both its high quality and natural capacity in the production of grain, livestock, meats, food products, and alternative agricultural products. This production capacity and superior management contribute to Minnesota's reputation as a dependable supplier of basic agricultural commodities. However, in recent years, the rapid emergence of value-added agriculture has almost over-shadowed the role of production agriculture in Minnesota. This trend is not unique to Minnesota, as value-added agricultural markets and new end-user demands have seen dramatic expansion throughout the entire United States. One of the emerging opportunities in value-added agriculture is renewable energy or biomass-based fuels. The most highly developed and widely publicized renewable energy is ethanol. Minnesota is currently home to 21 ethanol plants with a combined production capacity of more than 1 billion gallons of ethanol (Figure 1) (MDA, 2010). Most of the 21 ethanol plants are built in the southern and western regions of the State, where Minnesota's top corn-producing counties are located. Renville is the No. 1 corn county with 43.6 million bushels of production, followed by Martin (41.2 million bushels), Faribault (39.2 million bushels), Redwood (38.3 million bushels), and Mower (34.4 million bushels). Other forms of renewable fuels and power sources are also emerging. In addition to corn and other available inputs, what factors will help facilitate the expansion of renewable energy markets in Minnesota?

Minnesota has the resource-base and the entrepreneurial spirit to position itself as a leader in the renewable energy sector. The private sector has taken the lead in developing ethanol plants and wind farms throughout the entire state. In 2007, the Minnesota Legislature and

Governor enacted legislation to put Minnesota on a path to have 25% of its energy produced from renewable sources by the year 2025. Minnesota statute also sets a goal of increasing the amount of ethanol blended into gasoline to 20 percent by 2013.

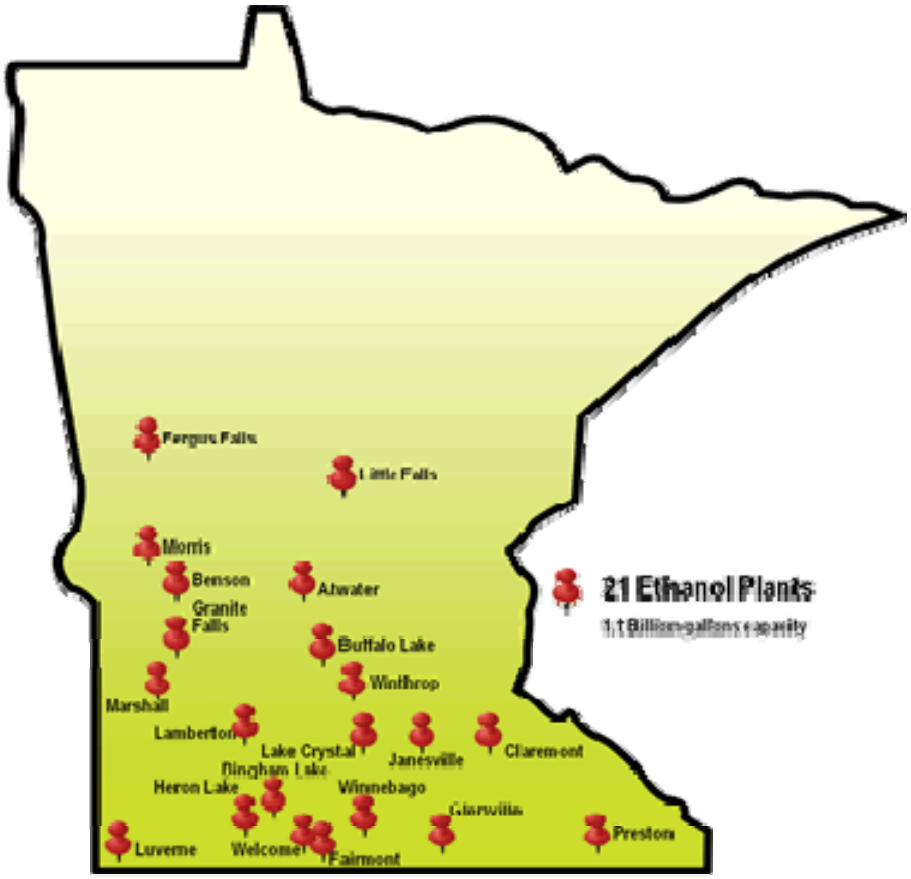

Figure 1. Distribution of Ethanol Plants in Minnesota. Source: MDA, 2010.

Studies have shown that farm households, rural businesses and rural communities will benefit from the expansion of renewable energy in the form of higher-wage employment, business formation, and new markets for agricultural commodities (Swenson 2006; USDA, ERS 2007). The more recent literature emphasizes that the positive impacts of value-added investments in ethanol production and other forms of renewable energy on job creation are real, but those impacts should not be overstated (Swenson 2006, 2007, 2008). The renewable energy sector is likely to receive more support from its many stakeholders if the industry does not over-

promise the benefits, and publishes studies that are both credible and based on the proper use of the available economic data and models (Swenson 2008). The agricultural sector has real potential to promote renewable energy markets and to strengthen Minnesota's rural economies. Therefore, there is a need to identify and assess the major factors and strategies that would sustain the advancement of the renewable energy sector and rural economic development in Minnesota.

Proposed Objectives for this Study

It is important to assess the new economic potentials associated with the growth of the renewable energy sector. As a result, we will address the following four objectives:

1. Identify how market opportunities in renewable energy are likely to influence changes in the Minnesota's agricultural economy, with particular attention to ethanol – an important renewable energy for Minnesota.
2. Identify and assess the private market opportunities and public policy impacts associated with a growing renewable energy sector, with a special focus on identifying factors that drive market share in alternative forms of energy used in Minnesota.
3. Investigate the potential impacts of market structure (e.g., the role of locally-owned cooperatives, small businesses, large corporate entities, etc.) on market behavior and performance of a growing renewable energy sector in Minnesota.
4. Assess the potentials of market participants and public policy makers to engage in strategies that can optimize the socio-economic impacts of the renewable energy sector, especially with respect to the enhancement of a sustainable rural economy and quality of life in Minnesota.

In this study, we will also address the following research questions:

1. How might emerging changes in value-added agriculture (especially bio-fuels) affect the role of production agriculture in Minnesota, as well as the economic development of Minnesota's rural economy?
2. Can leaders in the private and public sectors develop policies that would encourage income growth, employment, and competitive advantage in Minnesota's energy sector? If yes, what policies should be recommended, and what would be the anticipated impacts of those policies?
3. To what extent can growth in value-added agriculture become a significant rural development strategy for the future, and how important is local control and ownership of the renewable energy sector to realizing the full potential impact on rural economic growth and vitality?
4. What is the role of local ownership and control on the ability of rural economies to realize the full economic potentials associated with the growth of the renewable energy sector?

Hypothesis for this Study

Development of Minnesota's renewable energy sector has a real potential to serve as an engine for rural economic growth. Farm households, rural businesses and rural communities can benefit from rural development because of new and higher-wage employment, new markets for agricultural commodities and more vibrant regional economies. That is, growth of the renewable energy sector can serve as a key avenue for value-added agriculture to advance Minnesota's rural economy. Expanding renewable energy markets, like ethanol, have the potential of generating positive impacts on rural employment and household income, the profitability of farm-related

businesses, and other businesses connected to Minnesota's rural areas.

REVIEW OF LITERATURE

Agricultural Production and Ethanol Percent of Corn Processing

According to ERS/USDA's Family Farm Report (2007), ninety eight percent of U.S. farms are family farms, and the remaining two percent are non-family farms, which produces about 15 percent of the value of agricultural outputs. Most of the family farms operate in the rural areas. Yet, the importance of the agricultural sector in rural economies has continued to decline in the number of farm households. In 1980, there were 104,000 in Minnesota, but this number has declined to 79,000 in 2007 (USDA: National Agricultural Statistics). In Minnesota, 27.8 million acres of total farmland are devoted to agriculture.

The "multiplier effect" of Minnesota's agricultural production and processing generates about $53 billion in economic activity for the state (MDA). Agriculture is the second largest employer in the state. In 2002, Minnesota's farm and farm related employment accounted for approximately 15% of total jobs in the state. In the non-metro areas, farm and farm related employment accounted for about 24% of all jobs. The metro areas had significant employment in the farm and farm related businesses in 2002, accounting for approximately 13% of all jobs. Table 1 presents Minnesota farm and farm related employment from 1985 – 2002. Table 1 shows a declining trend in agricultural employment in the non-metro areas. This trend can be partly attributed to the migration of young people to the metro areas in search of better paying jobs. Farm household income relative to average U.S. household income has a declining trend as shown in Figure 2.

Food and agriculture remains the leading economic contributors to the Minnesota economy. In addition, food and agriculture account for nearly 14 percent of the state's value

added income, and 14 percent of the state's personal income and employment (Minnesota Department of Agriculture). Rural employment trend has shown consistent decline since 1985, and this trend is expected to continue. The future of rural communities looks bleak unless there are significant changes in local and regional institutions, infrastructure and entrepreneurial capacity.

The growth of the renewable energy sector offers some hope. Based on the 2007 output value of ethanol production in Minnesota, $1.68 billion of ethanol was produced (MDA). A total of $2.27 billion was generated through economic multipliers and 4,305 more jobs were created. Among these new positions, 1,445 jobs were created in the ethanol industry, 913 job positions were produced in related fields (e.g., corn farm workers) and 1,948 jobs were created because of the growing economy generated by ethanol production. Figure 3 shows that the ethanol percent of corn processing continues to increase.

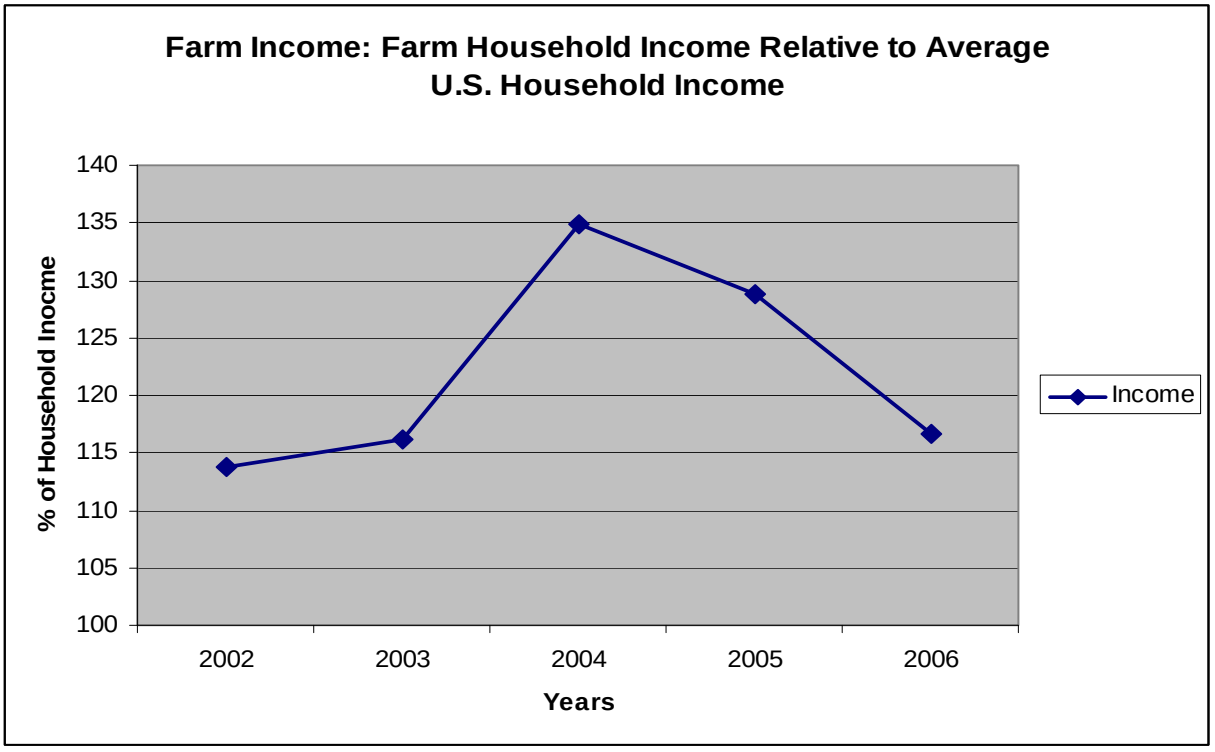

Figure 2: Ratio of Farm Household Income Receivers to Average U.S. Household Income. Source: USDA-ERS

Table 1: Minnesota Farm and Farm Related Employment (1985-2002)

Metro & non-metro estimates may not add to total employment because a small number of jobs are not classified by location. Metro and non-metro estimates are based on the June 1993 metro area definitions.

Farm					

Source: USDA-ERS

Industries	1985			1990			1995			2000			2002		
	Metro	Non-metro	Total	Metro	Non-metro	Total	Metro	Non-metro	Total	Metro	Non-metro	Total	Metro	Non-metro	Total
Farm Produce	1.9	15.5	5.8	1.4	12.4	4.4	1.2	10.1	3.5	1.06	8.69	2.99	1.03	8.40	2.9
Ag Service	0.1	0.4	0.2	0.2	0.4	0.2	0.2	0.5	0.3	0.24	0.45	0.3	0.26	0.48	0.32
Ag Input Industry	0.3	1.4	0.7	0.3	1.4	0.6	0.3	1.5	0.6	0.16	0.94	0.36	0.18	0.96	0.38
Ag Processing& Marketing	1.4	4.4	2.3	1.2	4.2	2.0	1.1	4.0	1.9	1.04	3.84	1.75	0.97	3.7	1.66
Ag Wholesale & Retail Trade	9.4	9.9	9.5	9.5	10.2	9.7	9.0	9.7	9.2	9.48	10.05	9.63	9.68	10.09	9.79
Indirect Ag Business	0.3	0.4	0.4	0.3	0.4	0.4	0.3	0.4	0.4	0.31	0.40	0.33	0.33	0.34	0.33
Total Farm & Farm Related Employment	13.6	32.0	18.8	12.9	29.0	17.2	12.1	26.2	15.9	12.3	24.37	15.35	12.46	23.96	15.37
All of the Employment	86.4	68.0	81.2	87.1	71.0	82.8	87.9	73.8	84.1	87.7	75.63	84.65	87.54	76.04	84.63

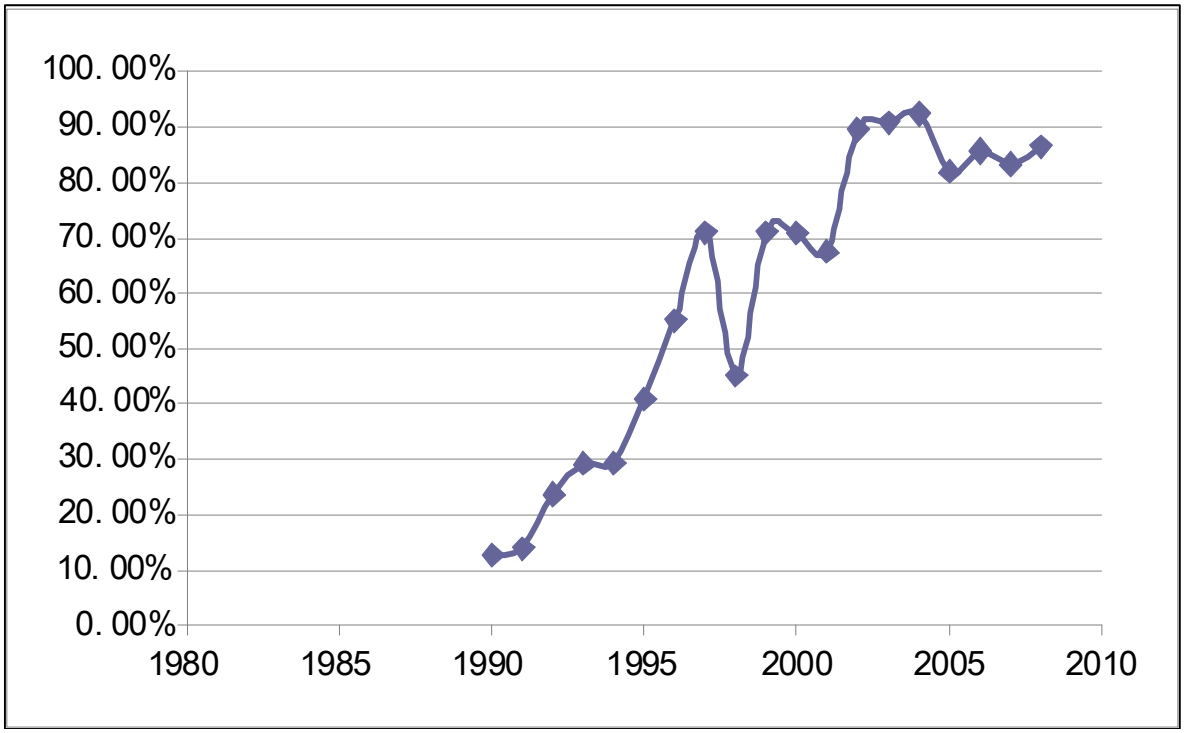

Figure 3: Ethanol Percent of Corn Processing in Minnesota. Source: MDA

Policies mandating gasoline and ethanol-blends have played a significant role in increasing supply and demand for ethanol. Early as in 1986**,** 40% of the state's gasoline was blended with 10% ethanol, and little ethanol was produced in Minnesota (MDA). Legislation reduced the pump tax credit to 2 cents and initiated a 20 cent per gallon cash incentive payment for ethanol produced in the state. The 20-cent ethanol producer payment legislation provided the security required by lenders to invest in small farmer-owned ethanol plants (MDA). Projections from the Minnesota Department of Agriculture revealed that as production increased through the years, consumption of ethanol grew as well but not as fast as the growth of supply (Figure 4). Therefore supply met demand in 2001 and continued to grow, resulting in excess of supply.

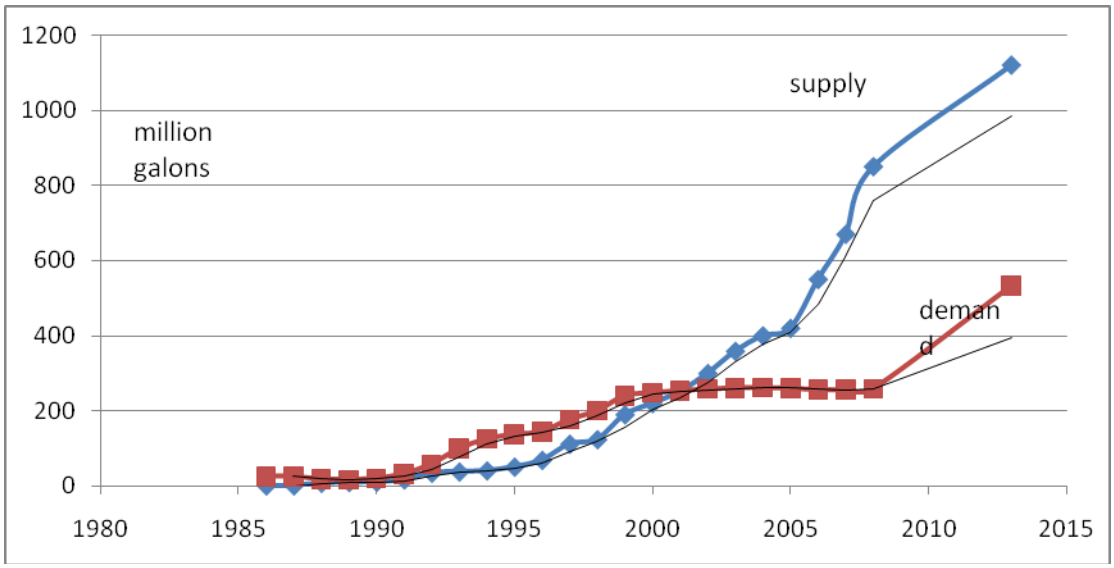

Figure 4: Demand and Supply of Ethanol in Minnesota. Source: MDA

Method for Objective 1: Increased demand for renewable energy like ethanol would be vitally important to economic development of rural Minnesota. From the literature review, we can answer the question, "How might emerging changes in value-added agriculture (especially bio-fuels) affect the role of production agriculture in Minnesota, as well as the economic development of Minnesota's rural economy?" There are strong indications that expanding renewable energy could alleviate emerging agricultural problems in Minnesota, by providing additional use for primary agricultural commodities and higher paying jobs in rural Minnesota. This review addresses our ***Objective 1*** of the study, "Identify how market opportunities in renewable energy are likely to influence changes in the Minnesota's agricultural economy, with particular attention to ethanol – an important renewable energy for Minnesota." However, it is important to identify and analyze the roles(s) locally-owned cooperatives, small businesses, large

corporate entities, etc., would have on market behavior and performance of a growing renewable energy sector in Minnesota. We address these issues in the methodology and results sections.

METHODOLOGY

Method for Objective 2: *Identify and assess the private market opportunities and public policy impacts associated with a growing renewable energy sector, with a special focus on identifying factors that drive market share in alternative forms of energy used in Minnesota.*

We perform an analysis of energy elasticity in the residential sector of Minnesota using a ***Linear Approximate / Almost Ideal Demand System*** (LA/AIDS) model. This model has been used extensively for complete demand analysis. The specific sub-objectives in this section were to determine *own-price elasticity* and *income elasticity* for primary energy consumed in Minnesota and to identify what factors are driving the market share of alternative energy use in Minnesota. Coal, oil, natural gas, electricity and Liquefied petroleum gas/ethanol blend (LPG) are the major energy sources used in the residential sector in Minnesota. With data on price and expenditure of these energy sources, we used an LA/AIDS model to estimate price elasticity and income elasticity for these energy uses. Summary results show that all income elasticities are positive, as expected, but vary significantly depending on the type of energy. An expected inverse price elasticity of demand failed to show in some cases; however the results are intuitively instructive in providing policy alternatives for the government regarding allocating energy in a more environmentally- friendly way. Efficiency use of these energy sources are also examined in this section.

Minnesota's population and total energy consumption place the State in the middle of national rankings. The residential sector is Minnesota's largest natural gas consumer, accounting for over one-third of State consumption. Over two-thirds of Minnesota households

use natural gas as their primary heating fuel during the State's long, cold winters. This is also the major input in ethanol production. Coal-fired power plants typically account for roughly three-fifths of Minnesota's electricity generation. Minnesota receives most of its coal supply by rail from Montana and Wyoming. Minnesota has two oil refineries in the Minneapolis-St. Paul area for processing crude oil that comes primarily from Canada. In an effort to keep pace with growing State demand for petroleum products, Minnesota recently completed construction on a new, 300-mile pipeline to carry additional Canadian crude oil to the State's refineries (Minnesota, DOE). Plans for two additional oil pipelines, running from northwestern Minnesota to Superior, Wisconsin, were recently approved by the Minnesota Public Utilities Commission. In February 2007, Minnesota adopted a renewable portfolio standard that requires one-fourth of Minnesota's power to come from renewable sources by 2025 (DOE website).

Energy consumed in the residential sector is usually used in the following way: heating, air conditioning, refrigeration, lighting and electronics. According to Annual Energy Report 2008 released by the EIA in 2009, primary energy usage and percentage is shown in Figure 5.

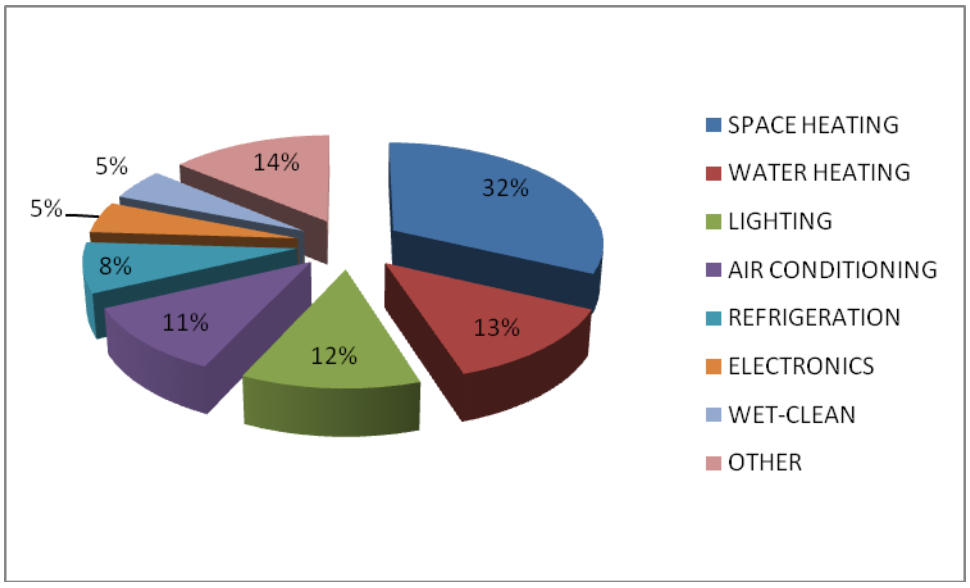

Figure 5: Primary Energy Use in Residential Sector of US. Source: Annual Energy Review 2008

Forty-five percent of the energy was used in heating, 20% was used in lighting and electronics, 20% was used in refrigeration and air conditioning and other use. Data shows that natural gas, oil, biomass and electricity are alternative fuels for heating purpose, LPG and electricity are used for refrigeration and air conditioning, electricity is mainly used for lighting purpose. Major issues surrounding the use of these alternative energy sources include their economic efficiency, long-term sustainability, and their environmental friendliness.

Figure 6 shows total carbon dioxide emissions by the residential sector in the US in 2007. It shows natural gas generated the largest share of CO_2 emissions in the residential sector in 2007. But this doesn't mean that natural gas is less energy efficient than the other fuels because natural gas has the largest share in energy used for heating. Figure 7 presents energy efficiency coefficient by unit.

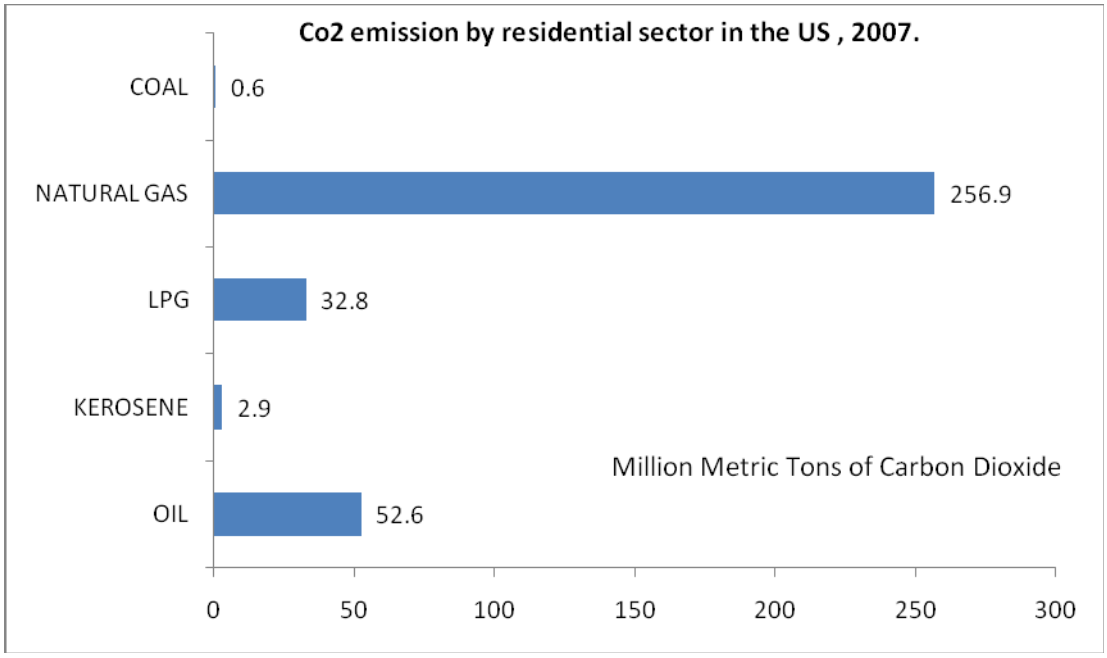

Figure 6: CO_2 Emissions in the US, 2007. Source: Energy Annual Report 2008 by EIA.

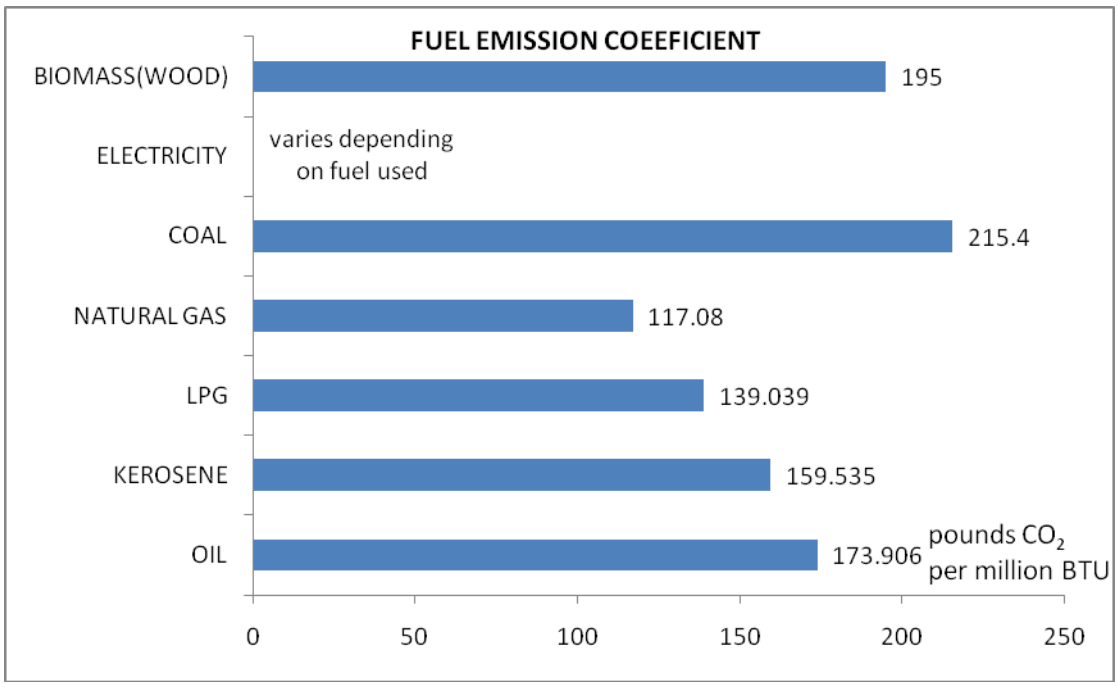

Figure 7: Fuel Emission Coefficient (pounds of CO_2 per million BTU).
Source: Energy Annual Report 2008 by EIA.

From Figure 7 we can see that with the same amount of fuel (e.g., 1 million BTU), coal generates the most CO_2 (215.4 pounds) while natural gas generates the least (117.08 pounds). Energy efficiency is therefore ranked (from high to low) with natural gas first, then LPG, kerosene, oil, biomass and coal. Natural gas is the most efficient and coal is the least efficient. To meet the energy demand for renewable energy in a manner that is economically efficient, elasticities regarding prices of energy and total income have to be analyzed. With the information about households' willingness to substitute alternative sustainable sources, government agencies and private sector firms could adopt efficient policies or provide sufficient incentives for households to switch their demand towards more efficient and "green" energy sources. The LA/AIDS model used to determine elasticities is usually specified as in Equation 1.

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln P_j + \beta_i \ln\left(\frac{X}{P}\right) \quad (1)$$

Where w_i is the expenditure share of alternative energy used, I; P is a price index of the group; P_j is the price of jth energy source; and X is total expenditure by Minnesota residence. The Price index is defined in Equation 2 as:

$$\ln P = \alpha_0 + \sum_j \alpha_j \ln P_j + \frac{1}{2} \sum_j \sum_j \gamma_{ij} \ln P_j \ln P_j \quad (2)$$

Using the price index from equation (2) often raises empirical difficulties, especially when aggregate annual time-series data are used. Therefore, we use Stone's price index as a linear approximation, following Blanciforti and Green. Stone Index is defined in Equation 3 as:

$$\ln P = \sum w_i P_i \quad (3)$$

An AIDS model with Stone Index as a linear approximation for price index is called the LA/AIDS model. There are some restrictions to the LA/AIDS model: adding up, homogeneity and symmetry. The conditions have to be satisfied in the estimation of a complete demand system. These restrictions are imposed using Limdep CLS function during estimation.

Price elasticity:

A general definition of the uncompensated price elasticity of demand from the AIDS and LA/AIDS is demonstrated in Equation 4:

$$\epsilon_{ij} = \frac{d\ln Q_i}{d\ln P_j} = -\delta_{ij} + \frac{\gamma_{ij}}{w_i} - \frac{\beta_i}{w_i} \frac{d\ln P}{d\ln p_j} \quad (4)$$

δ_{ij} is the Kronecker delta, where as δ_{ij} =1for i=j, δ_{ij}=0 for i≠ j. Green and Alston (1990) have shown that LA/AIDS demand elasticities are expressed in Equation 5 as:

$$\epsilon_{ij}(LA) = -\delta_{ij} + \frac{\gamma_{ij}}{w_i} - \frac{\beta_i}{w_i\left(w_j + \sum_{k=1}^{n} w_k \ln p_k (\epsilon_{kj} + \delta_{kj})\right)} \quad (5)$$

When $\frac{d\ln P}{d\ln p_i} = w_i$, the price elasticities can be written in Equation 6 as:

$$\varepsilon_{ij}\,(LA) = -\delta_{ij} + \frac{\gamma_{ij}}{w_i} - \frac{\beta_i}{w_i} w_j \quad (6)$$

Equation 6 is the expression for price elasticity we used. Expenditure elasticity, which is the percentage change in quantity with respect to percentage change in total expenditure spent on an alternative energy source, is estimated with Equation 7.

$$\varphi_i = 1 + \frac{\beta_i}{w_i} - \frac{\beta_i}{w_i} \quad (7)$$

The data used in this section is aggregated-level energy data in the residential sector in Minnesota from 1970 to 2007. The data include price and expenditure for coal, natural gas, distilled oil, electricity, LPG, biomass and kerosene. Price is measured in Nominal Dollars per million BTU, and expenditure is measured in Million Dollars. A total number of 532 observations are provided. All data was acquired from Department of Energy website.

Descriptions of variables can be seen in the following:

Table 2: Variable Descriptions for Expenditure Share Estimations.

Variables	Description
lnp1	log price of coal in Minnesota
w1	expenditure share of coal in Minnesota
lnp2	log price of natural gas in Minnesota
w2	expenditure share of natural gas in Minnesota
lnp3	log price of oil in Minnesota
w3	expenditure share of oil in Minnesota
lnp4	log price of electricity in Minnesota
w4	expenditure share of electricity in Minnesota
lnp5	log price of LPG in Minnesota
w5	expenditure share of LPG in Minnesota
lnp6	log price of biomass in Minnesota
w6	expenditure share of biomass in Minnesota
Lnp7	Log price of kerosene
Ln(X/P)	Approximation for energy consumption in Minnesota

Estimation Results for Objective 2:

Data is estimated with Limdep using SUR (seemingly unrelated regression) command.

Restrictions are imposed in the estimation. Results are shown in Table 3.

Table 3: LA/AIDS Model Estimates of Energy in Minnesota, 1970-2007

	Coal	T	Natural Gas	t	Oil	t	Electricity	t	LPG	t	Biomass	t
costant	-0.093	-2.244	0.114	0.621	-0.444	-1.664	2.111	8.162	-0.619	-4.610	0.015	1.183
ln(p1)	0.004	1.949	0.008	0.821	0.053	3.760	-0.069	-4.998	-0.004	-0.502	-0.001	-0.749
ln(p2)	-0.001	-0.414	0.187	12.004	-0.108	-4.779	0.008	0.346	-0.077	-6.758	-0.001	-0.788
ln(p3)	0.009	0.600	0.027	0.410	0.463	4.768	-0.529	-5.623	0.021	0.440	0.007	1.511
ln(p4)	0.011	2.588	-0.112	-5.863	0.055	1.993	0.002	0.087	0.036	2.578	-0.002	-1.227
ln(p5)	-0.009	-2.029	-0.058	-2.946	-0.018	-0.645	-0.032	-1.139	0.118	8.216	-0.003	-2.493
ln(p6)	-0.017	-1.058	-0.047	-0.661	-0.474	-4.582	0.648	6.465	-0.091	-1.756	-0.001	-0.122
ln(p7)	0.003	1.457	-0.006	-0.623	0.029	2.193	-0.028	-2.213	-0.004	-0.573	0.000	0.088
ln(X/P)	0.014	2.264	0.068	2.399	0.023	0.549	-0.219	-5.485	0.103	4.945	-0.002	-0.863
ED	0.625	-1.171	-0.445	-7.069	3.814	3.809	-0.777	-19.922	0.431	2.138	-1.131	-1.041
H	6.517	2.675	1.227	12.988	1.236	2.872	0.575	7.415	2.329	8.655	0.626	1.447
R	51.01%		94.82%		89.13%		64.74%		75.49%		74.75%	

Generally speaking, the estimation has a good fit with R-square ranging from 51% to 95%, indicating that a LA/AIDS model can represent Minnesota's demand for energy in the residential sector relatively well. As expected in normal commodities, all expenditure elasticities are positive, meaning that as income increases, residents tend to spend more money on energy. However the elasticity varies from 0.57 to 6.52, showing that as income increases, demand for different types of energy increase with significant variability. For price elasticity we focus on own-price elasticity. We found some elasticities were negative as expected; meaning that the prices of energy are negatively correlated with demand for energy. However, coal, oil and LPG, have positive elasticity, indicating that these three kinds of energy have some trait similar to the demand of a "luxury good," demand increases as the own-price increases.

Natural gas and LPG are income elastic but price inelastic, showing that consumption for these two energy sources responds more to income and less to prices change. Oil is both income and price elastic. This is not surprising given the fact that oil market is volatile. Biomass (mostly wood in this case) has a high price elasticity but a low income elasticity, indicating that consumption for biomass corresponds to its price change sensitively but not so much to income change. Electricity has a low elasticity for both income and price. This is understandable as electricity is the most commonly used energy source to produce household lighting, and people tend not to substitute other power sources to replace electricity in spite of the continuous change in price and income. Figure 8 is a graph for the price changes for alternative energy use in Minnesota's residential sector.

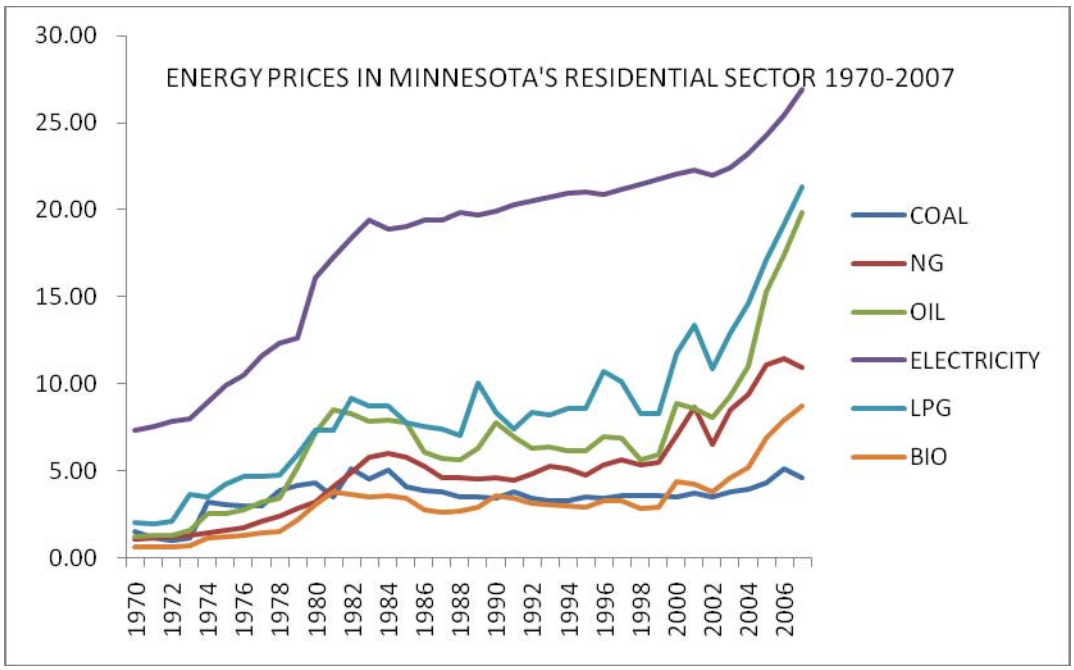

Figure 8: Trends in Energy Prices in Minnesota's from 1970-2007. Source: DOE website

From the graph we can see that in general energy prices are growing up, with price for electricity higher above the others. Prices for some energy, like coal and biomass tend to grow steadily and remain at a low level. On the other hand, prices for natural gas, oil and LPG tend to fluctuate more over the years. We discuss the demand system for each source in the succeeding section.

Coal is one of the true measures of the energy strength of the United States as one quarter of the world's coal reserves are found within the United States. Coal is also the workhorse of the nation's electric power industry, supplying more than half of the electricity consumed by Americans (DOE website). Minnesota had 46 coal-fired generating stations in 2005, with 5,676 MW of capacity, representing 43.8% of the state's total electric generating capacity. Minnesota ranks 22nd out of the 50 states in terms of coal-fired electric generating capacity (Sourcewatch, 2010). From the **LA/AIDS** Estimation below we can see that Expenditure Share (W) of coal is

influenced significantly by its own price, price of electricity, price of LPG, and the consumption of total energy.

Estimation of the Expenditure-Share (W) of Coal:

W (Coal) = -0.093*+0.004*lnp1-0.001lnp2+ 0.009lnp3+0.011*lnp4-0.009*lnp5

-0.017lnp6+0.003lnp7+0.014*ln(X/P)

[* implies coefficients are significant at t>2]

In the above Estimation of W for Coal, we observe that as price of oil goes up, the budget share for coal increases as well. By examining the price elasticity for coal (0.625), we observe that when its own-price increases by 1 dollar, coal consumption increases by 0.625 trillion BTU. This is not what we usually expect in demand. However, as we can see from the Figure 8, coal price is the most steady, and when price of coal increases, prices of other energy sources increase as well, making coal the relatively less expensive source and a major demand driver. The budget share of coal is also influenced by prices of electricity and LPG, and by total consumption. As discussed above, coal is the major input for electricity. Therefore it makes sense that the price of coal is correlated with price of electricity. It also makes sense that when total consumption of energy increases, people are going to spend more on coal.

Natural gas is 90 percent efficient compared with electricity, which is only 27 percent efficient. It also burns cleaner than other fossil fuels so it is safer for the environment. Over two-thirds of Minnesota households use natural gas as their primary heating fuel during the State's long, cold winters (DOE website). Figure 9 shows the breakdown of types of fuels used to heat Minnesota homes in 2005. As we can see, the majority of homes (67%) were using natural gas. This means that the majority of homeowners are affected by a rise in natural gas prices.

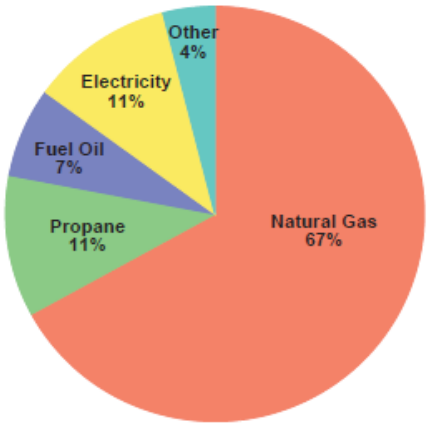

Figure 9: Breakdown of Energy Used in Heating Minnesota Homes in 2005
Source: Minnesota Government website: www.state.mn.us/mn.

We found the price elasticity for Natural gas to be -0.445, which indicates that when price of NG increases by 1 dollar, consumption falls by 0.455 trillion BTU. At the same time, income elasticity is found to be 1.227, quite elastic, showing that when household income increases, people tend to consume more natural gas. Figure 8 shows that price of natural gas has been mirroring the price of crude oil. This case is more common in the industrial sector as companies can switch between using natural gas or petroleum products, depending on the price of each source. As a result, when oil prices go up, industries tend to choose natural gas, which in turn increases the demand for natural gas and raises the price.

Unfortunately, the strong relationship between price for oil and price for natural gas is not detected in the demand function for natural gas.

Estimation of the Expenditure-Share (W) of Oil:

W (Oil) = -0.444+0.053*lnp1-0.108*lnp2+0.463*lnp3+0.055*lnp4-0.018lnp5-0.474*lnp6

+0.029*lnp7+0.023

[* implies coefficients are significant at t>2]

As we can see from the Oil Expenditure Share (W) relationship above, oil price is most sensitive to prices of alternative energy. Therefore we calculate the cross price elasticity of oil

with respect to all the other energy as in Table 4.

Table 4: Cross Price Elasticity for Oil

	POIL	t
PCOAL	0.557	3.755
PNG	-1.202	-4.191
PELE	0.456	2.105
PLPG	-0.211	-0.654
PBIO	-4.950	-4.581

Table 4 shows that oil price is positively related with coal price and price of electricity, while negatively correlated with prices of natural gas and biomass (elasticity for LPG is not significant). The strong relationship between oil and natural gas can be found here as cross elasticity for oil with respect to natural gas is -1.202, meaning every $1 increase in natural gas price will cause oil price to fall by $1.2. According to Table 4, oil price is more sensitive to the price of wood. The reason may be that in the residential sector, natural gas, oil and wood are used for heating purpose. However, from Figure 8, we can see that natural gas has the largest share as heating energy (up to 70%), leaving oil and wood to compete for the remaining share. Therefore wood is a 'rival' with relevant power, and has more influence on oil.

As expected, the market share of electricity is negatively correlated with price of coal. As the major input for electricity, coal influences electricity-usage in that if coal price increases, then the price of electricity will increase accordingly; causing demand to fall and therefore decrease the share of electricity. However as the major resource for lighting, electricity does not respond strongly to its own price change or to income change. This is supported by the fact that both price and income elasticity are low (-0.777 and 0.575).

LPG is a flammable mixture of hydrocarbon gases used as a fuel in heating appliances and vehicles (Wikipedia). Predominantly in Europe, LPG provides a low-carbon alternative to traditional rural heating fuels, such as electricity and heating oil (kerosene). LPG is also a

popular cooking energy for countries such as India, Brazil and China. According to our results, LPG is price inelastic but income elastic. Therefore people will tend to use more LPG as total income increases.

The only variable that is significant in influencing market share of biomass is the price of LPG. As price of LPG goes up, people tend to spend less money on biomass, specifically wood in this case. The reason is not clear. Our guess is that as both wood and LPG are mostly used in rural areas and may be complements. Therefore, when the price of one increases, it will cause the consumption of its complement to fall. Price elasticity for biomass is high as -1.131, meaning that people tend to substitute for the consumption of wood when the price of wood is high. Income elasticity, on the other hand, is at 0.626, indicating that households are not income elastic and that they will not increase the use of wood proportionally (at least not in the same rate) as income increases.

Summary Discussion for Objective 2

A major question about renewable energy presented earlier is "Whether Minnesota leadership in the private and public sectors can develop policies that would encourage income growth, employment, and competitive advantage in Minnesota's energy sector?' If yes, what policies should be recommended, and what would be the anticipated impacts of those policies?" By looking at each demand function for alternative energy sources separately, we get a general idea of the factors that drive market shares of these energy sources. Market share of coal is driven by its own price, and by the prices of electricity and LPG, because they are used as alternative energy for heating purposes. The market share of natural gas is driven by its own price, and the prices of electricity and LPG for the same reason. The market share of oil is driven

by nearly all of the other energy sources because of the extensive use of oil throughout Minnesota's economy, and the volatile characteristics in oil supply market. The market share of electricity is also driven by the prices of most energy sources. First, electricity is generated with other fuels as inputs. Second, electricity is widely used in lighting and heating. The market share of LPG is influenced by its own-price, and by the prices of natural gas and electricity, because LPG can be used as substitute for natural gas in heating purpose. The market share of biomass (wood) is solely influenced by the price of LPG for the reason that it may be used as supplement to LPG in rural areas.

By comparing the income and price elasticity of alternative energy, we conclude that coal has low price elasticity and high income elasticity. The fact that coal has the highest fuel emission coefficient, which means that it is the least environmentally-friendly energy source; local and/or state governments may want to mitigate the environmental effects of coal by enforcing policy or providing incentives for clean coal use or substitute with other environmental renewable sources. It should be noted that the consumption of coal does not respond sensitively to its own price increases; therefore, increasing the price of coal may not be an effective strategy to reduce the quantity-demanded for coal. Like coal, natural gas is price inelastic and income elastic. Because of the high energy efficiency of natural gas, government may want to encourage usage of natural gas by improving technology and machines that utilize natural gas. Oil is both price and income elastic; therefore consumption of oil can be altered through price incentives or taxes. Electricity is neither price nor income elastic due to its fundamental usage in household lighting. Efficient use of electricity can be facilitated by providing consumers with knowledge of prices during periods of peak-time and off-peak-time usage. LPG is income elastic while price inelastic. This indicates that people are unlikely to switch from the use of natural gas to use of

LPG unless their total expenditure on energy increases. Finally, biomass (especially wood) has high price elasticity and low income elasticity. Note that wood ranks No.2 in the fuel emission coefficient (not very environmentally-friendly), therefore in order to limit the use of wood, government can simply use tax incentives on wood consumption because wood consumption responds to price changes sensitively.

Method for Objective 3: *Investigate the potential impacts of market structure (e.g., the role of locally-owned cooperatives, small businesses, large corporate entities, etc.) on market behavior and performance of a growing renewable energy sector in Minnesota.*

Survey for Primary Data Collection

We designed a survey to identify the predominant organizational structure of the markets used to produce renewable energy in Minnesota. We placed particular emphasis on ethanol, the fastest growing renewable energy source. The survey instrument is presented in Appendix 1. Questions were asked to elicit participants' perceptions of their impacts on the expansion of renewable energy markets and development of the rural economy in Minnesota. Telephone and e-mail surveys were used to obtain information. Nine of the 20 ethanol plants in Minnesota responded to the survey. Most of the respondents are predominantly from the Southwest region of the State. The data was collected during the period of February and April of 2010. The survey had two major sections. Information on size of operation, ownership structure, and rural development assessment were asked to elicit information from ethanol producers as to "*the extent to which growth in value-added agriculture is a significant rural development strategy for the future of Minnesota, and the importance of local control and ownership for the renewable energy sector to realize the full potential of rural economic growth and vitality.*"

Good performance of ethanol facilities is critical for the development, economic growth, and vitality of rural Minnesota. In order to determine the benefits of expanding the renewable energy market in Minnesota, it is pertinent to evaluate the performance of renewable energy providers in the Minnesota. Table 5 summarizes the variables used in this section of the study. Information collected included company size, main product(s), and input use. Other information collected was ownership structure and rural development assessment. All the respondents reported that ethanol is their main product they produced. The average production/sale of ethanol is 63.75 million gallons per year. The total production for the sample is 510 million gallons per year, about half of the state's production.

All of the respondents reported Dried Distillers Grain (DDG) as a second product they produce. The mean (average) annual production/sale of DDG is 7.82 million gallons per year, resulting in a total output of approximately 62.52 million gallons for the sample. About thirty percent of the respondents indicated that they also produce other products such as CO2, WMDG ("wet cake" Distillers Grain) and Crude Concentrate. The standard deviation for ethanol production is 29.2 million gallons per year indicating larger dispersion around the mean. The standard deviation for DDG and other byproducts are 4.9 million gallons per year and 1.56 million gallons per year respectively, indicating smaller dispersion around the mean.

According to the survey, all respondents reported having full-time and part-time employees. The average full-time employment for the sample is 39 positions, and the average number of jobs in part-time employment is 6.25. In total, the sampled ethanol plants employed about 349 people, most of whom are from the rural areas. The standard deviation for full-time employment and part-time employment is 9.97 and 4.11 respectively. This is an indication that

ethanol provides steady full-time and part-time employment to rural communities in Minnesota. The respondents indicated that they have contributed to rural job creation and will continue to do so. Therefore, the expansion of renewable energy production will benefit the rural communities in the form of higher wage employment, substituting declining wages from production agriculture.

The survey indicates that most of the ethanol plants are predominantly owned by cooperatives (44.4%) and limited liability corporations (55.6%). The survey participants also indicated that they have contributed to increased revenue for farmers and rural communities in Minnesota; by providing a steady market for corn, having revenue from processed corn return to farmer-patrons of the cooperatives, and providing other services to farmers. They indicated the importance of extremely critical factors that will help them to continue expansion of the renewable energy markets in Minnesota.

On facilitating expansion of the renewable energy markets, respondents noted that policies to support the use of renewable energy are extremely important. On the average, feasible gas prices are considered to be very important by the respondents. Another variable that was considered in facilitating expansion of the market is the availability of government subsidies that support the development and operation of ethanol plants. Estimates of the variables measured in the survey of Minnesota Ethanol Plants are presented in Table 5 below.

Variables	Description	Mean	Standard Deviation	Total (millions of gallons)
Products	Ethanol (millions of gallons)	63.75	29.2	510
	DDG (millions of gallons)	7.82	4.9	62.5
	Others (millions of gallons)	2.2	1.56	6.6
Employment	Number of full time employees	39	10	312
	Number of part-time employees	6.25	4.11	37
Inputs	Corn	44.93	21.8	NA
	Natural gas	6.3	3.6	NA
	Other	2.1		NA
Ownership Structure	1 = Cooperative 2 = Limited Liability Corporation 3 = Family Owned 4 = Other	1.6	0.53	NA
Contribution to Rural Job Creation	1 = Yes 2 = No	1.0	0	NA
Contribution of Revenue to Rural Communities	1 = Yes 2 = No	1.11	0.33	NA
Facilitating Expansion of Renewable Energy Markets	Policy to support use 1 = Not At All Important 5 = Extremely important	4.7	0.5	NA
	High gas price 1 = Not At All Important 5 = Extremely important	3.6	0.88	NA
	Government subsidy 1 = Not At All Important 5 = Extremely important	3	1.12	NA
	Demand for ethanol 1 = Not At All Important 5 = Extremely important	4.89	0.33	NA
	Lower corn price 1 = Not At All Important	3.44	0.76	NA

Table 5. Empirical and Statistical Estimates of the MN Ethanol Plant Survey Variables

On the average, the respondents to our survey considered government subsidies to be somewhat important.

Subsidies for ethanol have been a hotly debated item in US Congress (Valesco, 2010). However, this debate should be put in context. The U.S. enjoys one of the lowest gasoline prices in the world because of limited tariffs placed on imported oil used to produce gasoline. On the other hand, the US currently has high tariffs on imported ethanol (this tariff means that Brazil, an exporter of sugarcane-based ethanol, cannot competitively supply ethanol to the US). From a pure economic perspective, the imports of petroleum-based gasoline to the US are indirectly subsidized because those petroleum imports are practically exempt from import tariffs, while other forms of energy (e.g., imported sugarcane-based ethanol) face a stiff tariff. Finally, corn-based ethanol that is domestically-produced in the US does receive federal (and sometimes state-level) government subsidies. The combination of all these incentives and counter-incentives means that the US currently has a complex and often-inconsistent economic energy policy. We levy import tariffs in some cases, but not in others. We also have specific government subsidies for selected energy sources.

If we really want to have an efficient policy design, then more can be done. We could consider comprehensive or global strategies where the playing field could be leveled for market competition among the various alternative energy sources.

Summary of Survey Responses

The respondents considered demand for ethanol as extremely important. Lower corn prices are considered to be very important and better production technology is considered to be extremely important by the respondents. Technology to lower natural gas use in ethanol production or other inputs will improve market performance. The respondents also indicated that

availability of supply stations for ethanol is very important. The impact of renewable energy on the environment was considered to be very important. Producers of ethanol appreciate the role ethanol can play as a renewable energy source. Finally, tariffs (taxes) on foreign ethanol were considered to be extremely important. In order words, local firms need to be protected. All the variables in this category have low standard deviations (1.12 or less), an indication that all respondents see the issues to help them expand renewable energy market in a similar manner. The survey asked respondents to rate the importance of renewable energy production on rural development. The response indicates that on the average, the factors are extremely important: future rural development, Minnesota's rural economy, improving production and land use, improve rural quality of life, and creating higher income jobs. Respondents indicated that subsidizing farm revenue is somewhat important. All variables in this category have standard deviations of 1.00 or less, again indicating that all respondents have similar views towards their ability to contribute to rural economic development. The degree of importance of these factors is further analyzed in a scenario method framework to acquire in-depth knowledge of strategies that will help of the renewable energy sector to the enhancement sustainable rural economy and quality of life in Minnesota. These analysis and discussions are presented in objective 4.

Method for Objective 4: *Assess the potentials of market participants and public policy makers to engage in strategies that can optimize the socio-economic impacts of the renewable energy sector, especially with respect to the enhancement of a sustainable rural economy and quality of life in Minnesota.*

Data from the survey in Objective 3 were used to develop ***Micmac Scenario Method Analysis***, to assess core drivers and dependent variables that could be used to formulate

strategies to optimize the socio-economic impacts of the renewable energy sector. ***Scenario Method Analysis*** involves developing a database of important variables/factors from existing literature or survey, determining the importance (e.g., using a Likert-Scale as we did in our survey research for Objective 3), and analyzing them to determine major variables or "drivers" and "influence variables" that will affect policy or strategy. The method derives second- and third-order interactions between factors from three environments: *internal firm environment, external environment, and the competitive market environment.* The ***MicMac Software*** is used to perform the analysis.

List of Variables Used and their Description

Variables that could influence supply/demand and market conditions for renewable energy (e.g., ethanol) in the US market were identified from the survey and the literature. (http://en.wikipedia.org/wiki/Ethanol_fuel). The list of variables is displayed in Table 6. The description of each variable is presented in Table 7 (See Tables 6 and 7 below).

Table 6. Variables Included in MicMac Scenario Analysis

1. Demand for Ethanol (EDemand)
2. Price of Ethanol (Price)
3. Miles per Gallon with Ethanol blend (MPG)
4. Effects on current engine systems (Eng Effect)
5. Supply of Ethanol (Supply)
6. Station Availability (Stations)

7. Tariffs on Imported Ethanol (Tariffs)
8. Subsidies for US Ethanol (Subsidies)
9. GHG/Carbon reduction (GHG reduce)
10. Exchange Rate with Brazil (Forex)
11. Low Carbon Fuel Standards (LCFS)
12. Production Technology (Prod Tech)
13. Energy Efficiency Balance (EnergBal)
14. Land Limitations to produce corn (Land Limit)
15. Corn price (Corn)
16. Availability of Sugar Cane Ethanol in the U.S. (Sugar Cane)

Table 7. Description of Variables for MicMac Analysis

	Variables	Description
Competitive Environment	EDemand	Demand for Ethanol within the United States
	Price	Price per gallon of Ethanol at gas stations in the United States
	MPG	Miles per gallon with Ethanol as compared to gasoline on average. Ethanol currently gets lower gas mileage as compared to gasoline in most cars.
	Eng Effects	Effects of Ethanol on current engine systems are negative such as rust induced damage and difficulty starting in low temperatures common in much of the United States
	Supply	Total Supply in gallons of Ethanol in the US market
	Stations	Total number of gas stations that sell E85 mixes in the US
Internal Firm Environment	Prod Tech	The state of the technological processes used to produce ethanol. Advances such as cellulosic ethanol production may increase the efficiency in yield per acre or reduce GHG emission since less land could be used in production. New advances in the production process also have the potential to lower the price of ethanol and increase energy balance/efficiency measures
	Corn	The use of corn in ethanol production
	Sugar Cane	The use of sugar cane in ethanol production
	EnerBal	Energy Balance or net energy gain in the production of ethanol, i.e., for every unit of energy expended in production of ethanol, how many units of energy are created. For US corn based ethanol the ratio is estimated at 1:1.3 whereas for Brazilian sugar cane ethanol the ratio is estimated to be 1:8-9. Innovation in the production technology could potentially increase these ratios.
	Land Limits	Limits on the production of ethanol

		due to the limits of the amount of land that could be used for production fuel versus food. If all the land used to produce corn in the US were used to produce ethanol, it would displace only 12% of US gasoline consumption
External Environment	Tariffs	The level of tariffs of foreign produced ethanol especially Brazilian sugar cane based ethanol
	LCFS	Low Carbon Fuel Standards or similar measures set by US states such as California. Currently, US corn based ethanol will not meet California's LCFS standards and therefore will limit the amount of US corn based ethanol mixed into gasoline in the vital California market. Gasoline companies will have to pay steep tariffs to import Brazilian sugar cane ethanol
	GHG reduce	Total Green House Gas/Carbon reduction that will be entailed in the use of ethanol. Current debates question whether corn based ethanol reduces green house gas emissions or increases them. Most say sugar cane based ethanol reduces or has zero effect on GHG emissions
	Subsidies	Subsidy in dollars per gallon for US produced ethanol
	Forex	Foreign exchange rate with the Brazilian real. A strong or weak dollar could have large implications for the import of Brazilian sugar cane based ethanol

Matrix Analysis of Important Variables in the Ethanol Market

Figure 10 (below) shows results of the ***"Matrix of Direct Influence (MDI),"*** describing the direct relationship between the variables. As expected, ethanol price has strong influence on demand (3) and supply (3) of this renewable energy. However, a closer examination of the price column reveals that price, on the other hand, is also strongly influenced by tariffs on imported ethanol, government subsidies to support ethanol output, production technology, energy efficiency balance, corn prices, and the availability of imported ethanol from cane sugar.

Strategies to sustain higher/lower prices should carefully evaluate these factors. Higher ethanol prices may have a strong influence on lowering the demand for ethanol but increases the supply. In addition to higher prices, expanding ethanol markets (increases in supply) will be strongly influenced by demand, tariffs, subsidy, production technology, land availability to grow more corn, and the availability of ethanol from corm sugar. This suggests that any discussion to eliminate the ethanol subsidy should be closely examined and potential welfare implications should be analyzed. The ***Matrix of Potential Direct Influence*** (Figure 11) yields similar but slightly different results.

	1 : Demand	2 : Price	3 : MPG	4 : Eng Effect	5 : Supply	6 : Stations	7 : Tariffs	8 : Subsidies	9 : GHG reduce	10 : Forex	11 : LCFS	12 : Prod Tech	13 : EnergBal	14 : Land Limit	15 : Corn	16 : Sugar Cane
1 : Demand	0	3	0	0	3	2	2	3	P	0	0	2	0	0	2	2
2 : Price	3	0	0	0	3	2	0	1	0	0	0	2	0	0	1	1
3 : MPG	3	1	0	0	2	1	0	0	3	0	1	0	1	0	0	0
4 : Eng Effect	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5 : Supply	3	3	0	0	0	3	1	2	0	0	0	1	0	0	0	0
6 : Stations	3	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
7 : Tariffs	3	3	0	0	3	1	0	1	0	0	0	0	0	0	2	3
8 : Subsidies	2	3	0	0	3	1	2	0	0	0	0	3	1	0	3	2
9 : GHG reduce	2	0	0	0	2	1	0	1	0	0	2	1	0	0	1	1
10 : Forex	1	2	0	0	2	0	0	0	0	0	0	0	0	0	0	2
11 : LCFS	2	0	0	0	2	1	1	0	0	0	0	1	0	0	1	1
12 : Prod Tech	3	3	2	2	3	2	1	3	3	0	3	0	3	3	3	3
13 : EnergBal	3	3	3	0	2	1	0	0	3	0	2	0	0	2	2	3
14 : Land Limit	2	1	0	0	3	0	1	1	0	0	0	2	0	0	3	3
15 : Corn	2	3	0	0	1	0	3	3	2	0	0	1	1	0	0	2
16 : Sugar Cane	2	3	0	0	3	0	3	3	3	0	0	0	3	0	2	0

Figure 10: Direct Influence Matrix *(MDI)*
Influences range from 0 to 3, with the possibility to identify potential influences:
0: No influence
1: Weak
2: Moderate influence
3: Strong influence
P: Potential influences

The ***Matrix of Potential Direct Influences (MPDI)*** (see below, Figure 11) represents direct and potential influences and dependences factors. It complements the MDI by also considering second- and third-order interaction, an indication of foreseeable future relations.

	1 : Demand	2 : Price	3 : MPG	4 : Eng Effect	5 : Supply	6 : Stations	7 : Tariffs	8 : Subsidies	9 : GHG reduce	10 : Forex	11 : LCFS	12 : Prod Tech	13 : EnergBal	14 : Land Limit	15 : Corn	16 : Sugar Cane
1 : Demand	0	3	0	0	3	2	2	3	3	0	0	2	0	0	2	2
2 : Price	3	0	0	0	3	2	0	1	0	0	0	2	0	0	1	1
3 : MPG	3	1	0	0	2	1	0	0	3	0	1	0	1	0	0	0
4 : Eng Effect	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5 : Supply	3	3	0	0	0	3	1	2	0	0	0	1	0	0	0	0
6 : Stations	3	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
7 : Tariffs	3	3	0	0	3	1	0	1	0	0	0	0	0	0	2	3
8 : Subsidies	2	3	0	0	3	1	2	0	0	0	0	3	1	0	3	2
9 : GHG reduce	2	0	0	0	2	1	0	1	0	0	2	1	0	0	1	1
10 : Forex	1	2	0	0	2	0	0	0	0	0	0	0	0	0	0	2
11 : LCFS	2	0	0	0	2	1	1	0	0	0	0	1	0	0	1	1
12 : Prod Tech	3	3	2	2	3	2	1	3	3	0	3	0	3	3	3	3
13 : EnergBal	3	3	3	0	2	1	0	0	3	0	2	0	0	2	2	3
14 : Land Limit	2	1	0	0	3	0	1	1	0	0	0	2	0	0	3	3
15 : Corn	2	3	0	0	1	0	3	3	2	0	0	1	1	0	0	2
16 : Sugar Cane	2	3	0	0	3	0	3	3	3	0	0	0	3	0	2	0

Figure 11: Potential Direct Influence Matrix *(MPDI)*
0: No influence
1: Weak
2: Moderate influence
3: Strong influence

Figure 12 (see below) jointly compares strength/weakness of driver and influence variables as they impact the market for ethanol. The results in Figure 12 are derived from the *Matrix of Direct Influences **(MDI)*** in Figure 10. Figure 12 provides further evidence on what factors are the most important drivers and dependent variables that can change ethanol production and use. Public policy makers can use the ***MDI*** to help identify strategies that optimize the socio-economic impacts of the renewable energy sector. Ultimately, better-designed renewable energy strategies should help the State of Minnesota to produce sustained rural economic development

and enhance the quality of life for its citizens. The four sections of Figure 12 are: 1) the upper right hand quadrant, with factors having both strong driver and dependence effects, 2) the lower right hand quadrant, with factors having strong dependence but weak driver effects, 3) the upper left hand quadrant, with factors having strong driver impacts, but weak dependence effects, and 4) the lower left hand quadrant, with factors having both weak driver impact and dependence effects.

Only two factors have both strong-driver and dependent-factor influences based on the MDI: government subsidies, and the availability of ethanol from cane sugar. These factors should be further and carefully analyzed for efficient policy design.

However, when second- and third-order interactions are considered, corn price and demand also become strong drivers and dependent variables (Figure 13). In the lower right hand quadrant of Figure 13, the expansion of ethanol markets and its potential impacts on rural development will depend strongly on corn price, price of ethanol, demand for ethanol, and supply. However, these four factors have strong dependence but weak driver effects. Figure 13, derived from the ***MPDI***, suggests that tariffs and the availability of stations have significant future importance with when second- and third-order interactions are considered.

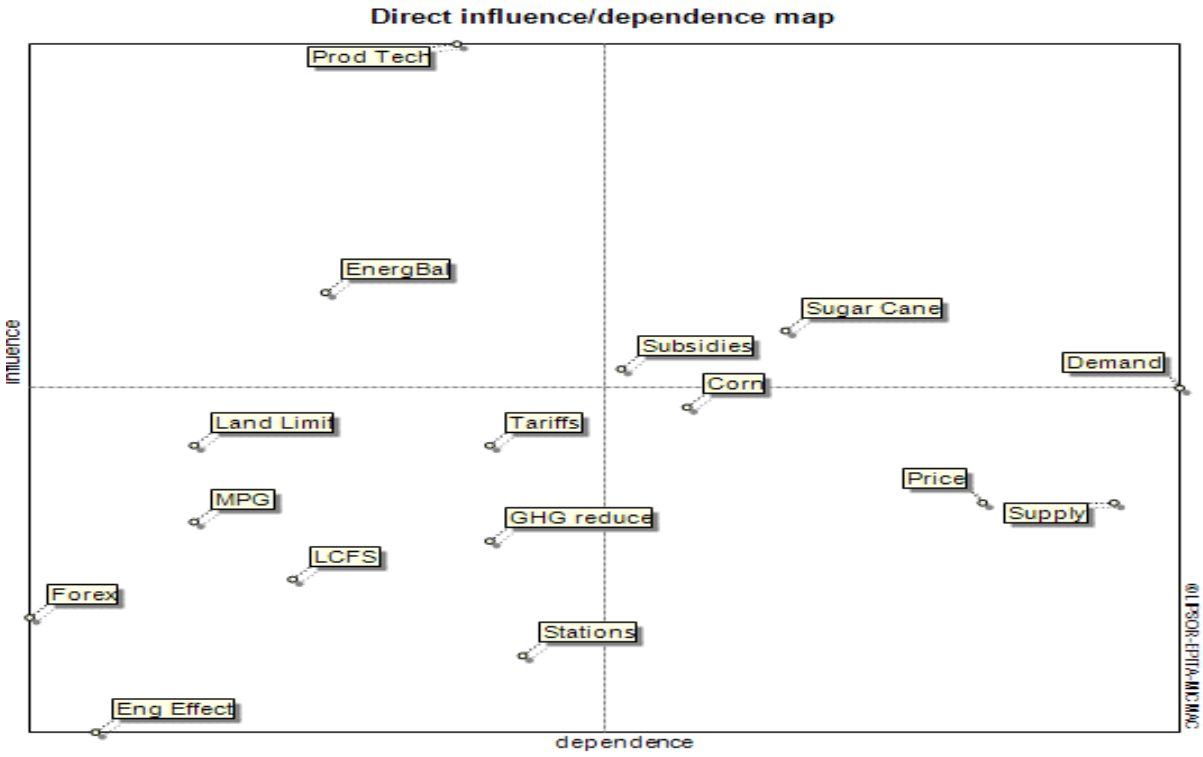

Figure 12: Driver and Dependent Factors from MDI

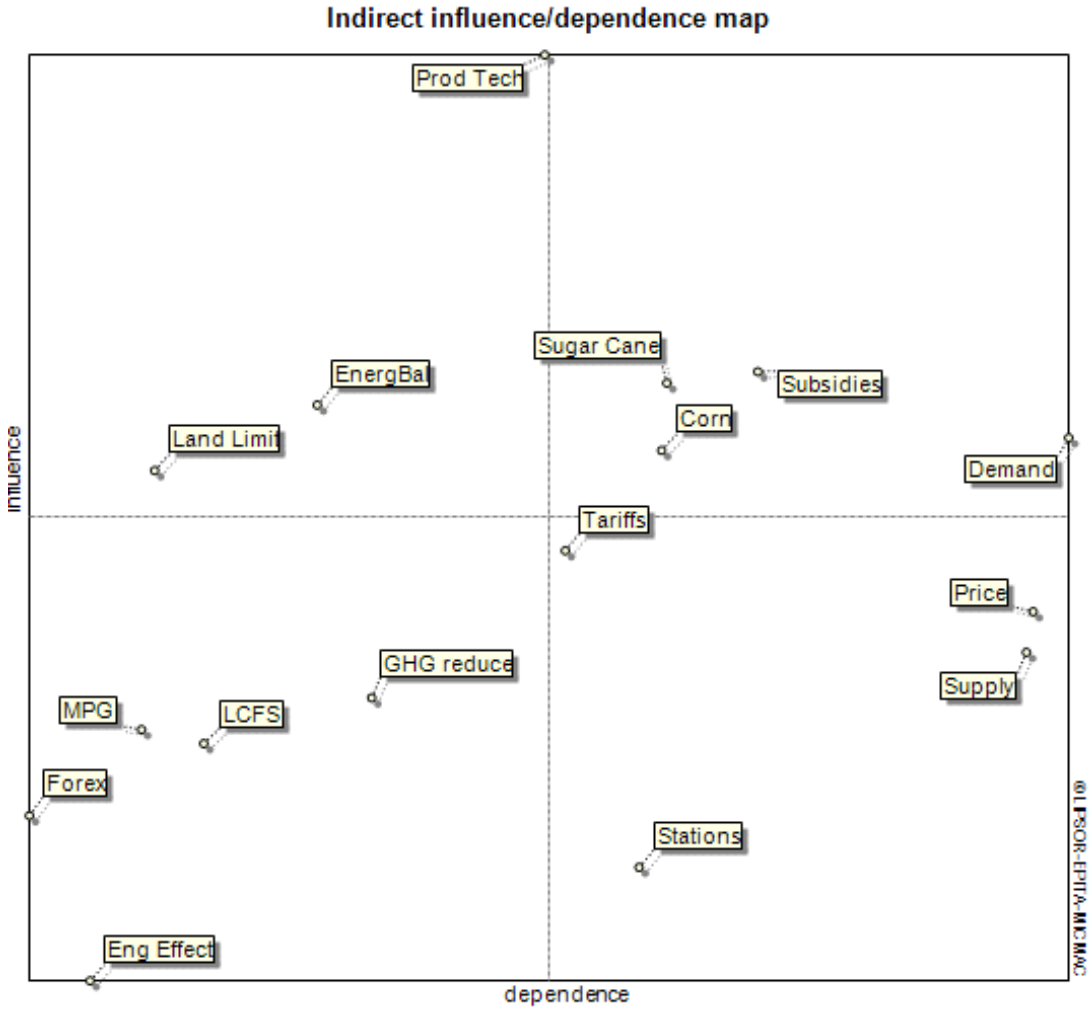

Figure 13: Driver and Dependent Factors from MPDI

Results in the upper left hand quadrant of Figure 13 suggest factors that have strong driver and but weak dependence effects. Production technology, efficient energy, and land to increase corn production are factors that should be carefully examined in other studies/ analyses to design effective strategies and policies.

Figures 14 and 15 emphasize the most important variables of the system. Figure 14 identifies how each factor affects other factors directly. For example, the availability of land to grow more corn will directly impact only corn prices and the possibility to import ethanol from sugarcane. Figure 15, which is the indirect influence graph, suggests the strongest influence on expanding ethanol markets and enhancing rural development will be ***efficient production technology***. This is the main variable that will affect demand, supply, and ethanol price in the

long run. Research on improving efficient production technologies for renewable energy is highly encouraged.

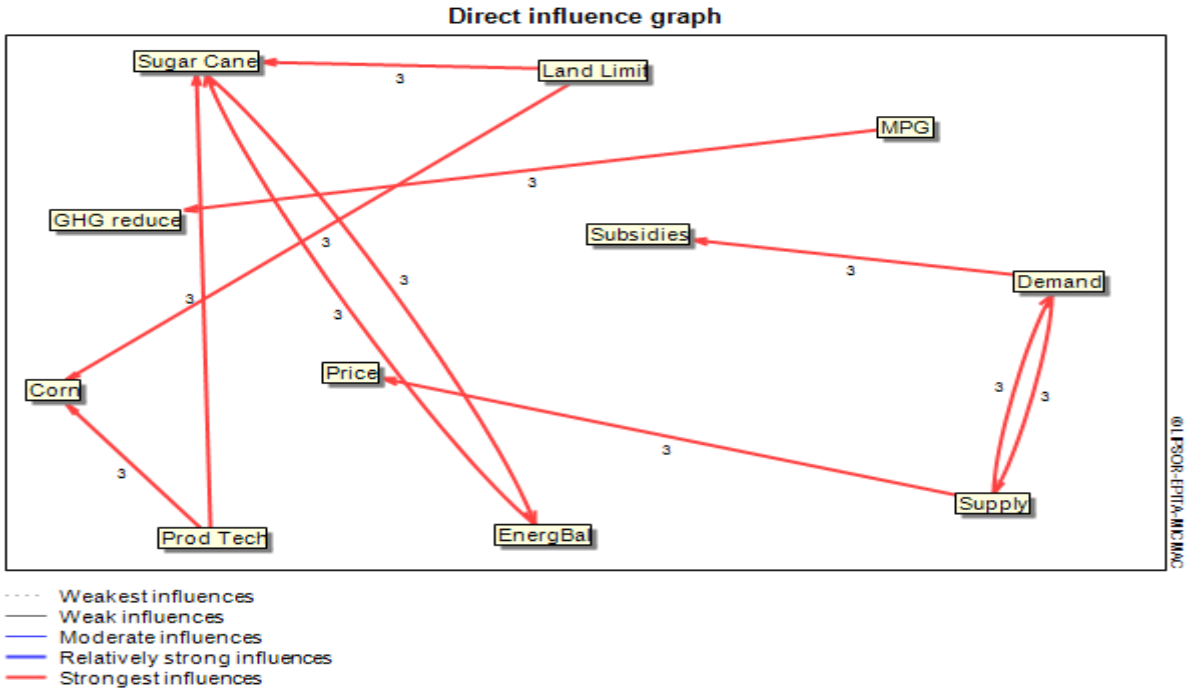

Figure 14: Direct Influence Graph

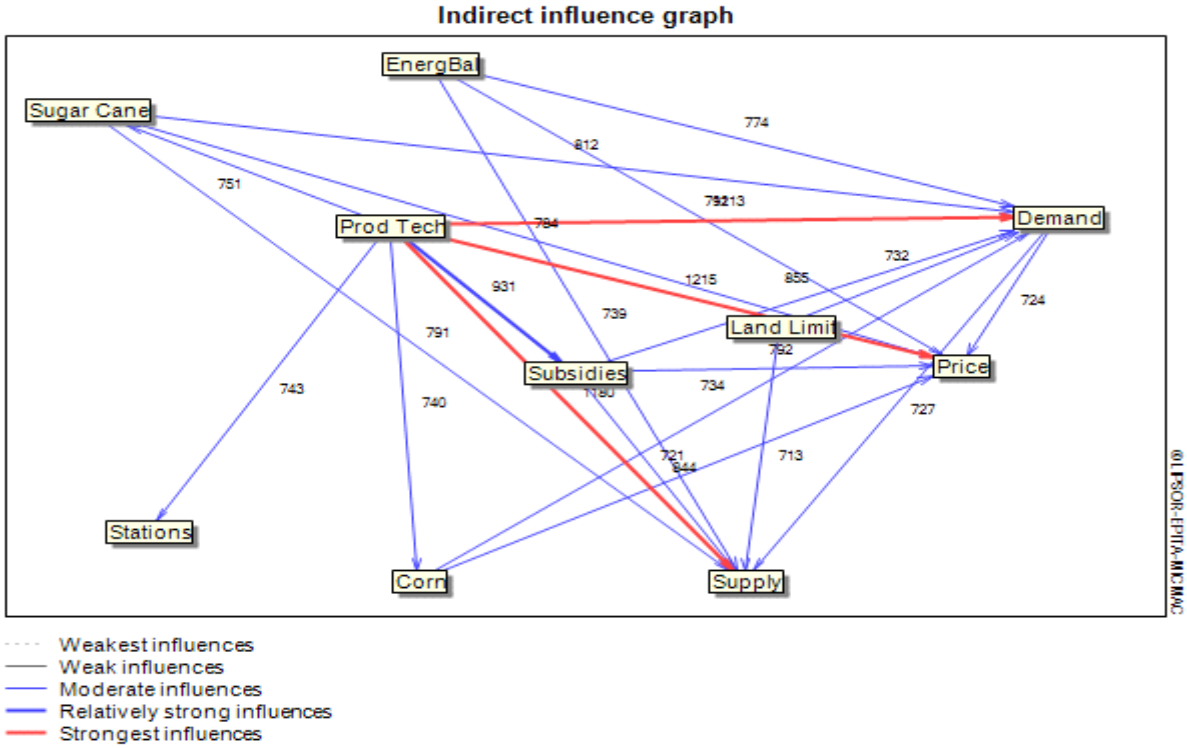

Figure 15: Indirect Influence Graph

CONCLUSION AND IMPLICATIONS

Minnesota is a national leader in agricultural production. However, revenue from primary agricultural commodities continues to decline, encouraging the outmigration of young farmers from rural to urban areas to seek higher paying jobs. Minnesota has the resource-base and the entrepreneurial spirit to position itself as a leader in the renewable energy sector, and reverse the trend of lower income jobs in rural communities. The private sector has taken the lead in developing ethanol plants and wind farms throughout the entire state. In 2007, the Minnesota Legislature and Governor enacted legislation to put Minnesota on a path to have 25% of its energy produced from renewable sources by the year 2025. Minnesota statute also sets a goal of increasing the amount of ethanol blended into gasoline to 20 percent by 2013.

Development of Minnesota's renewable energy sector has a real potential to serve as an engine for rural economic growth. Farm households, rural businesses and rural communities can benefit from rural development because of new and higher-wage employment, new markets for agricultural commodities and more vibrant regional economies. We have provided an in-depth analysis using primary survey data and secondary data. Our findings suggest that the growth of the renewable energy sector can serve as a key avenue for value-added agriculture to advance Minnesota's rural economy. Expanding renewable energy markets, like ethanol, have the potential of generating positive impacts on rural employment and household income, the profitability of farm-related businesses, and other businesses connected to Minnesota's rural areas.

By looking at each demand function analysis for alternative energy sources separately, we get a general idea of the factors that drive market shares or expansion of these energy sources. The market share of coal is driven by its own price and by the prices of electricity and LPG because they are used as alternative energy for heating purpose. The market share of natural gas is driven by its own price, prices of electricity and LPG for the same reason. The market

share of oil is driven by nearly all of the other energy because of the extensive use of oil, and the volatile characteristics in oil supply market. The market share of electricity is also driven by prices of most energy sources. First, electricity is generated with other fuels as inputs. Second, electricity is widely used in lighting and heating. Market share of LPG is influenced by its own prices and by the prices of natural gas and electricity, because LPG can be used as substitute of natural gas in heating purpose. The market share of biomass (wood) is solely influenced by the price of LPG for the reason that it may be used as supplement to LPG in rural areas.

Survey results from ethanol producers (one of the fastest growing renewable energy in Minnesota) reveal that policies to support the use of renewable energy are extremely important. On the average, policies to sustain feasible natural gas prices are considered to be very important by the respondents. Another variable that was considered in facilitating expansion of the market is the government subsidy to ethanol plants. On the average, ethanol producers in our survey considered subsidies to be somewhat important. Subsidies for ethanol have been a hotly debated item in US Congress (Valesco, 2010). It should however be noted that this debate should be put in context. The U.S. enjoys one of the lowest gasoline prices in the world because of limited taxes placed on imported gasoline. This indirect subsidy on gasoline should be compared with the ethanol subsidy to facilitate efficient policy design. Eliminating or introducing taxes on gasoline and ethanol imports should be a global strategy, one in which the playing field could be leveled for all countries and products.

Scenario Method Analysis provides a novel approach to identify driver and dependent factors that should be considered for the short-run (direct effects) and long-run (indirect effects with second and third order interaction). The indirect influence graph suggests the strongest influence on expanding ethanol markets and enhancing rural development will be efficient production technology. This is the main variable that will affect demand, supply, and ethanol price in the long run. Research on improving efficient production technologies for renewable

energy is therefore highly encouraged.

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APPENDIX 1: SURVEY INSTRUMENT

Sample Questions for Agribusiness Producing Renewable Energy

Company Name: _____

Location/Address: _____

Company Size, Main Product(s), & Input Use

1. Please provide a list of your main product (s) and annual sales
   Product 1_____ Annual Sales ($) _____
   Product 2_____ Annual Sales ($) _____
   Product 3_____ Annual Sales ($) _____

2. Please provide a list of your main input (s) and annual expenses
   Input 1_____ Annual Expenses ($) _____
   Input 2_____ Annual Expenses ($) _____
   Input 3_____ Annual Expenses ($) _____

3. How many full-time employees do you have? _____ Number
4. How many Part-time employees do you have? _____ Number

Ownership & Rural Development Assessment

5. Please identify the ownership structure of your firm
   a. Cooperative
   b. Limited liability corporation
   c. Family owned
   d. Other (please specify) _____

6. My firm has contributed in creating rural jobs Yes_____ No _____

7. If no in question 6 please explain why? _____
   _____

8. My firm has contributed in increasing revenue for farmers and rural communities in Minnesota Yes_____ No _____

9. If no in question 6 please explain? _____
   _____

10. On a scale of 1-Not At All Important, to 5-Extremely Important, please rate the importance of the following attributes on facilitating expansion of renewable energy markets:

	NOT AT ALL IMPORTANT	NOT VERY IMPORTANT	SOMEWHAT IMPORTANT	VERY IMPORTANT	EXTREMELY IMPORTANT
Policies to support use	**1**	**2**	**3**	**4**	**5**
High gas price	**1**	**2**	**3**	**4**	**5**
Gov't subsidy	**1**	**2**	**3**	**4**	**5**

Demand for ethanol	**1**	**2**	**3**	**4**	**5**
Lower corn price	**1**	**2**	**3**	**4**	**5**
Better production technology	**1**	**2**	**3**	**4**	**5**
SUPPLY STATIONS	**1**	**2**	**3**	**4**	**5**
Environmentally-friendly	**1**	**2**	**3**	**4**	**5**
Tariffs on Foreign Ethanol	**1**	**2**	**3**	**4**	**5**

11. On a scale of 1-Not At All Important, to 5-Extremely Important, please rate the importance of renewable energy production on rural development:

	NOT AT ALL IMPORTANT	**VERY IMPORTANT**	**SOMEWHAT IMPORTANT**	**VERY IMPORTANT**	**EXTREMELY IMPORTANT**
Future rural development	**1**	**2**	**3**	**4**	**5**
Minnesota's rural economy	**1**	**2**	**3**	**4**	**5**
Subsidizing farm revenues	**1**	**2**	**3**	**4**	**5**
Improve production land use	**1**	**2**	**3**	**4**	**5**
Improve rural quality of life	**1**	**2**	**3**	**4**	**5**
Creating higher income jobs	**1**	**2**	**3**	**4**	**5**

Thanks for Completing This Survey!