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Energy, Agriculture, and GHG Emissions: The Role of Agriculture in Alternative Energy Production and GHG Emission Reduction in North Dakota

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ABSTRACT

Energy, agriculture, and GHG emissions are highly interrelated. Several agricultural commodities are currently used as feedstock for biofuel production to replace fossil fuels. As the largest consumer of energy, the U.S. has taken several initiatives to reduce the use of fossil fuels, achieve energy security, and reduce GHG emissions. The industrial community of the U.S. invested heavily in biofuel and wind energy production. North Dakota has highest potential in producing wind energy and biomass from dedicated energy crops. Unfortunately these resources are not fully utilized for producing renewable energy. North Dakota is an energy intensive economy and per capita energy consumption is higher than other states. This technical bulletin provides a comprehensive report on the energy production and related emissions in the United States with special emphasis on North Dakota. The bulletin also discusses various alternative methods to reduce GHG emissions to meet the regulatory standards with a special emphasis on North Dakota. The study found that North Dakota produces the cheapest electricity and a major share is consumed outside the state. The price of electricity does not include negative externalities associated with burning lignite coal. North Dakota uses its potential to produce wind and corn ethanol to a great extent. The state level policies and financial supports are directed to wind industry and energy efficiency measures. The current renewable portfolio standards and non-compliance adversely affect the renewable energy industry in North Dakota.

Keywords: Renewable energy, Wind power, Ethanol, Greenhouse gas emissions, Agriculture

HIGHLIGHTS

Traditionally, energy is considered as an input for agricultural production. In the new era of renewable energy production, the relationship between energy and agriculture sector became more interdependent. A major portion of energy produced in the U.S is sourced from fossil fuels and is accompanied with the emission of GHGs and toxic materials. Electricity generation, transportation, and industries are the sectors that emit the major share of GHG in the U.S. North Dakota is blessed with abundant resources of wind and biomass. North Dakota can play a significant role in the production of renewable energy. This report discusses several alternative methods to reduce GHG emissions to meet the environmental standards in the United States with special emphasis on North Dakota.

Renewable energy production in the United States has increased significantly with the installation of new corn-based ethanol refineries and investments in wind energy sector. Unfortunately, the current growth rate in renewable energy production is not even sufficient to meet the additional requirements for the future. The ban of MTBE in selected states and Energy Independence and Security Act of 2007 requirements supported the ethanol industry in the U.S. A well-defined mandate reduces the uncertainties in the biofuel industry and is more effective than incentives. North Dakota consumes 120 million bushels of corn and produces 348 MGY of ethanol from six biorefineries. North Dakota provides a production incentive per gallon, governor's counter-cyclical ethanol incentive, and a blender pump program to support the ethanol industry.

New integrated biorefineries started production in different regions of the U. S and are equipped with advanced conversion technologies to utilize multiple cellulosic feedstocks and produce multiple outputs including cellulosic ethanol. Biopower substitutes electricity produced from fossil fuels and reduces the emission of GHGs from stationary sources. Biomass cofiring is an effective strategy to reduce CO_2 emissions and in terms of climate change policies, cofiring is more desirable than cellulosic ethanol.

The U.S. is the leading country in the production of wind energy. North Dakota ranks first in wind energy potential and hosts 790 wind towers with a production capacity of 1221.96 MW. Within a period of 5 years, wind production capacity has increased more than 17 fold. In addition to newly created permanent jobs, North Dakota receives $2.72 million as property tax revenues, and $3.64 million as land owner payment from the wind energy sector.

North Dakota is an energy intensive economy and has extensive reserves of coal and petroleum. The state pays the lowest price for electricity (6.58 cents per kWh) by utilizing the abundant natural reserve of coal. The current pricing of electricity excludes all negative externalities associated with coal firing. Unfortunately, more than 60% of electricity is sold outside North Dakota and the negative externalities associated with electricity production stays within the state.

North Dakota has set voluntary goals to incorporate 10% of renewable energy in the energy portfolio by 2015. To achieve this goal, North Dakota Industrial Commission took several measures to promote the growth of renewable energy industries. Through the programs of American Recovery and Reinvestment Act (ARRA), North Dakota has received $69.10 million for promoting energy efficiency measures and producing renewable energy. Even though agriculture constitutes 10% of North Dakota's economy, investments in bioenergy production is not given importance in ARRA programs till date.

North Dakota has 21.0 million dry tons of biomass available per year. Based on the cropping pattern, several counties in the state are capable to supply thousands of tons of non-cellulosic and cellulosic feedstocks for producing biofuels. This study shows that production potential for energy dedicated crops is not fully utilized in the grasslands.

Policy makers differ in their opinion regarding the effect of renewable energy production on the economic performance of the state. Large state economies with better economic growth rate can act as a buffer for higher renewable energy prices and can support the deployment of renewable energy. Educational level and other demographic characteristics play a crucial role in the promotion of renewable energy. Mandatory green power options and disclosure rules significantly affect green energy sales. The presence of fossil fuel deposits and cheap electricity prices reduce the deployment of renewable energy.

Carefully designed and timely implemented policy measures will help to establish a strong biobased industry in North Dakota. RPS standards with binding targets and penalties for non-compliance will promote renewable electricity generation. A strong commitment, market efficiency, and infrastructure facilities are essential for renewable energy production.

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INTRODUCTION

Energy use and related GHG emissions are showing an increasing trend throughout the world. The U.S. pledge in Copenhagen to reduce emissions (17% below 2005 levels by 2020) shows the commitment to embrace environment friendly renewable energy sources. According to President Obama, one among the five pillars of the country's financial future is new investments in renewable energy and technology. The American Recovery and Reinvestment Act (ARRA) of 2009 has already invested heavily in energy efficiency measures and renewable energy production (H.R. 1-24). It is evident that energy, agriculture, and GHG emissions are highly interrelated. Even though total emissions from agricultural related activities are only 7% (WRI, 2010), the feedstocks for producing bioenergy are farm-based and are supplied by the farming community.

Biofuels such as ethanol and biodiesel are produced using agricultural crops. Environment friendly farming practices reduce atmospheric carbon dioxide by sequestering carbon into the soil. Carbon that is fixed during photosynthesis in the form of starch, sugar, and different forms of cellulose is released back to the atmosphere during energy production. This makes biobased energy production carbon-neutral. Scientists and policy makers strongly believe that a scalable amount of fossil fuel can only be substituted using cellulosic biomass feedstocks. Research continues to look to invent economically competitive technologies to produce cellulose based biofuels and chemicals. Therefore increasing the share of renewable energy in the energy portfolio of the nation can lead to the reduction of atmospheric carbon and boosts the income of rural farming community. This report briefly narrates the energy production and related emissions in the United States with special emphasis on North Dakota. The report also discusses various alternative methods to reduce GHG emissions to meet the regulatory standards.

An Overview of Energy Production and GHG emissions

In 2007, United States consumed 101.55 quarillion btu and the overall energy consumption has increased 3.4 % during the last five years (EIA 2010a). In the U.S., 85% of the total energy produced is by using fossil fuels (Table 1). Petroleum products constitute the major share of fossil fuels (39.2%) followed by natural gas (23.3%), and coal (22.4%). Even though the share of renewable energy in the portfolio is less than 7%, the production of biofuels and bioenergy increased substantially in the last five years. This increase in biofuel production is attributed to the installation of new corn-based ethanol refineries in the major corn producing states. The production of bioenergy from biomass is mainly from the wood industry using unmerchentable wood and wood waste. During the period of 2003 to 2007, investments in the wind energy sector has doubled its generation capacity. Even with these developments, the current growth rate in renewable energy production is not sufficient to meet the additional energy requirements for the future.

Table 1 U.S. Energy Consumption by Energy Source, 2003-2007

Energy Source	Energy (Quadrillion Btu) 2003	Energy (Quadrillion Btu) 2007	Percentage Change
Total	98.21	101.545	3.4%
Fossil Fuels	84.08	86.212	2.5%
Coal	22.32	22.776	2.0%
Natural Gas	22.90	23.637	3.2%
Petroleum	38.81	39.773	2.5%
Nuclear Electric Power	7.96	8.415	5.7%
Renewable Energy	6.15	6.813	10.8%
Biomass[1]	2.82	3.596	27.7%
Biofuels	0.41	1.024	147.3%
Waste	0.40	0.430	7.2%
Wood Derived Fuels	2.00	2.142	7.0%
Geothermal Energy	0.33	0.349	5.4%
Hydroelectric Conventional	2.83	2.446	-13.4%
Solar/PV Energy	0.06	0.081	26.6%
Wind Energy	0.12	0.341	196.5%

[1]Includes biofuels, waste (landfill gas, MSW biogenic, and other biomass), wood and wood derived fuels. Note: The totals may not equal sum of components due to independent rounding. Source: EIA April 2010a: U. S. Energy Consumption by Energy Source. http://www.eia.gov/cneaf/solar.renewables/page/trends/table1.html

The United States is the largest consumer and third largest producer of crude oil in the world. The country imports more than 60% of its crude oil consumption. The major importing countries are Canada (20.1%), Saudi Arabia (13.8%), Venezuela (10.5%), Nigeria (8.8%), and Mexico (8.7%) (EIA 2009). From the mid-80s, the decreased domestic production and increased consumption resulted in a wide demand supply gap. To meet the excess demand, the U.S. imported crude oil and petroleum products in large volume and still continues today. The Annual Energy outlook (2009) indicated that the net imports of crude oil is expected to decline in future years due to drilling in the Gulf of Mexico and increased production of biofuels (Corn-based ethanol and biodiesel) and coal-to-liquid (CTL) fuels. Large trade deficits, threats to energy security, visible forms of pollution as smoke and fog in residential areas, and growing concerns on climate change gave rise to policies that aim to reduce carbon emissions from mobile sources by switching to clean fuels.

Coal is the work horse of the nation's electric power industry and coal combustion accounts for 83% of GHG emissions in U.S.(1,962.6 Tg CO_2 Eq.). The country accounts for 19% of the global addition of atmospheric CO_2 (EPA 2010). The increasing demand for electricity results in 3.9% growth in coal consumption (EIA 2010d). The United States ranks second, next to China in coal consumption and carbon emissions (EIA 2010b). Both these nations use coal primarily for generating electricity. Along with particulate matters, coal-fired power plants account for one third of carbon dioxide, two third of sulfur dioxide and one fourth of nitrogen oxide during the transformation of coal to electricity (DOE 1999). In the absence of any binding international agreements, world coal consumption is expected to increase by 1.6% annually (EIA 2010b).

Table 2. The U.S. Coal Supply and Consumption by Sector (2009-2010)

Sector	2009 (million short tons)	2010 (million short tons)	Percentage annual change
Total Consumption	1000.4	1033.3	3.3%
Electric Power	936.5	973.2	3.9%
Coke Plants	15.3	22.0	43.8%
Residential/Commercial	3.2	3.0	-6.3%
Other Industrial	45.4	35.1	-22.7%

Source: Energy Information Administration / Short term Energy outlook- June 2010

The United States is the largest producer of natural gas with an annual dry gas production of 20,561 billion cubic feet. As the demand exceeds the production, the country imports 3,981 billion cubic feet. Natural gas is mainly consumed by electric (30%) and industrial sectors (29%). As per EIA reports, the share of natural gas for generating electricity is 21.6% and the share increased by 25% from 2003 to 2007. The emission of CO_2 per unit of energy produced from natural gas is less than that of coal. A small percent of automobiles use natural gas as fuel and as a domestically produced and low carbon emitting fuel. Table 3 shows that there is an increase in natural gas consumption as vehicle fuel (26%). As per the 2010 annual energy outlook, increasing demand for energy, less production cost, technological progress, and more number of successful wells will increase the consumption of natural gas in the future.

Table 3. The Natural Gas Consumption in the U.S. by End Use (2003-2007)

Sector	2003 (MMcf)	2007 (MMcf)	Percentage change
Total Consumption	22,276,502	23,097,140	3.6%
Lease and Plant Fuel Consumption	1,122,283	1,226,386	8.5%
Pipeline & Distribution Use	591,492	621,364	4.8%
Consumers in the U.S.	20,562,727	21,249,389	3.2%
Residential Consumption	5,079,351	4,722,358	-7.6%
Commercial Consumers	3,179,493	3,012,904	-5.5%
Industrial Consumption	7,150,396	6,648,063	-7.6%
Vehicle Fuel Consumption	18,271	24,655	25.9%
Electric Power Consumers	5,135,215	6,841,408	24.9%

Source: EIA (2010). Topics on Natural Gas Summary.

The use of fossil fuels is accompanied with the emission of GHGs and toxic materials. The sources that emit GHGs can be broadly classified as mobile and stationary. The mobile sources are mainly automobiles that use gasoline or diesel as fuels. Electric power plants, combined heat and power plants, and industrial facilities are stationary sources of emission. Coal, natural gas, and petroleum products are primarily used as feedstocks for stationary sources. Sector wise, electricity generation (40%) followed by transportation (30%) and industrial use (14%) emit the major share of GHG in the U.S. (EPA 2010). Solvents and other products (evaporative emissions), agriculture, waste, land use (change) and forestry contribute the rest. The GHG emissions increased by14% from 1990 to 2008 (EPA 2010). According to the

Environment Protection Agency (EPA 2010), the CO_2 emission reached up to 2,363.5 Tg CO_2 Eq.

In the early years, pollution control measures and regulations were aimed to reduce hazardous gases. As the atmospheric temperature increased (global warming), regulations on CO_2 emissions were given much importance. The Clean Air Act (CAA 1970) authorized the Environmental Protection Agency (EPA) to establish National Ambient Air Quality Standards (NAAQS) to limit the level of six major air pollutants that are considered harmful to health and the environment. These pollutants are sulfur dioxide (0.03 ppm1), nitrogen dioxide (53 ppb2), carbon monoxide (9 ppm), ozone (0.075 ppm), lead, and particulate matter (PM10:150 $\mu g/m^3$). Later in 1990, President Bush signed the amendments that strengthened air quality standards and expanded the regulations on hazardous air pollutants. The amendments enforced powers and penalties, established operating permits for major sources of air pollution, included provisions for stratostrophic ozone protection, and require substantial reductions in power plant emissions (Office of Health Safety and Security 2010). The Energy Policy Act of 2005 that was signed into law by President George W. Bush was an attempt to solve the growing energy problems. The Clean Energy Deployment Administration (CEDA) was established to provide financial assistance (direct loans, loan guarantees, insurance products, and purchase of debt instruments) for clean energy projects.

According to electric power research institute (EPRI, 2009), 15% of U.S. electricity generation is expected to be generated from new non-hydro renewables like wind (100 GW), biomass (20 GW), and other technologies including solar (15 GW). This portfolio needs to be modified to suit the regional conditions and availability of resources. The portfolio designed on those abundant resources in a particular geographic region increases the financial viability of renewable energy production. Even though the Department of Energy reports that North Dakota has high potential in producing biomass using dedicated energy crops, investments are not materialized to produce bioenergy production from cellulosic biomass except for Spiritwood Industrial Park. According to EIA, the state of North Dakota also ranks first in wind potential and holds the 10th position in wind energy production. If these two abundant resources are left untapped to their full potential, the greenhouse gas emitting plants in the state will have to meet the RPS requirements by purchasing the renewable energy certificates (REC) or bundled electricity that is produced outside the state. This may considerably reduce the gross state product and results in increased energy price.

This report gives an overview of GHG emissions and the increase in the share of renewable energy in the energy portfolio of North Dakota. This report also discusses several opportunities to produce renewable energy by harvesting wind and biomass to meet the voluntary RPS requirements. The report emphasizes the participation of North Dakota's farming community in achieving renewable standards and thereby increasing farm income, rural employment, and overall welfare of the society.

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1 ppm is parts per million.
2 ppb is parts per billion.

Biofuel Production in the United States

Ethanol is the most extensively produced biofuel in the world. It is produced from a variety of starch and sugar based feedstocks such as sugarcane (Brazil), Corn/Maize (U.S.), and sugar beet (Europe). The oil embargo in 1970s and Demonstration Act of 1974 motivated the research and development of starch-based and cellulose-based ethanol production in the U.S. In the later years, financial incentives were given to produce ethanol and blend into gasoline. Some of the legislations that supported ethanol production up to the mid-80s were: (1) The Energy Tax Act of 1978 that provided a subsidy of 40-cents-per-gallon, (2) The Energy Security Act of 1980 that offered insured loans, (3) The Crude Windfall Tax Act of 1980 that extended the tax credit, and (4) The Tax Reform Act of 1984 that increased the subsidy to 60 cents (EIA 2010d). Even with these financial supports, more than half of the ethanol plants went out of business by 1985.

The ban of (Methyl tert-butyl ether) MTBE in 18 states including California increased the demand for ethanol. MTBE was replaced by ethanol as an oxygenate in gasoline. The EPA developed and implemented a set of regulations known as Renewable Fuel Standards (RFS) for ensuring the mandated share of renewable fuel to be sold in the U.S. The Energy Policy Act (EPAct) of 2005 created the RFS program with a blending mandate of 7.5 billion gallons of renewable fuel by 2012. Later, EISA of 2007 was enacted to support a viable, sustainable, and domestic biomass industry to produce biofuels, bioproducts, and biopower. This legislation is considered as a major turning point for achieving a steady growth in the biofuel industry. The mandatory RFS was expanded as a part of EISA that required a minimum of 36 billion gallons of renewable fuels to be blended in the transportation fuel by 2022 (EERE 2010). In addition to increasing the volume of biofuels, EISA included new categories of renewable fuels with separate volume requirements. The categorization is based on scientific lifecycle greenhouse gas performance threshold standards. The ban of MTBE in selected states and EISA (2007) increased the production of biofuels by 300% (EIA 2010d). This shows that mandate driven renewable energy production is more effective than incentive driven energy production. A well-defined mandate considerably reduces the uncertainty in biofuel demand and price.

As per EISA, out of 36 billion gallons of expected biofuel production, corn-based ethanol constitutes 11 billion gallons and cellulosic ethanol constitutes 25 billion gallons (Sissine 2007). Currently the majority of ethanol plants are corn-based and cellulose based plants constitute only a very small portion of ethanol produced. Even though corn-ethanol production provided additional income for rural economies in corn producing states, several studies criticized the production of corn-ethanol. Researchers reported a wide range of net energy value (NEV) of corn-ethanol. A study conducted by the U.S. Department of Agriculture (USDA) showed that corn-ethanol is energy efficient as it yields 34% more energy than it takes to produce ethanol (Shapouri, Duffield, and Wang; 2010). But these estimates are under the assumption of higher corn yield, lower input-output ratio, and advances in fuel conversion technologies. Hill et.al (2006) concluded that corn-ethanol yields only 25% more energy and supported the production of biodiesel as it produce 93% more energy when invested in biodiesel production. A battery of studies proved that NEV of corn-ethanol is negative (Ho 1989; Pimentel 1991; Keeney and DeLuca 1992; Pimentel and Pimentel 1996; Pimentel 2001; Pimentel 2003). Even though the range of NEV is still very much a disputable issue, it is clear without a doubt, that corn-ethanol production is not scalable to replace a considerable amount of imported petroleum products.

Even if the total amount of corn produced in the U.S. is dedicated for ethanol production, it could replace only 12% of gasoline demand. As major share of corn produced in the U.S. is used as livestock feed, diverting corn for producing ethanol increases the corn price and adversely affects beef production (USDA 2001).

A well-known simple conversion technology and useful byproducts makes corn the most competitive biofuel crop. According to Shapouri, Duffield, and Graboski (1995) one bushel of corn yields 2.5 gallons (conservative estimate) of ethanol. The conversion of ethanol also yields a significant amount of Distiller's Dried Grain with Solubles (DDGS), gluten feed, gluten meal, and corn oil. The U.S. ethanol industry is expanding and reached 12.25 billion gallons (name plate capacity) in 2009 by using more than 4.2 billion bushels of corn. The ban of MTBE, government support for ethanol blending, adherence to RFS requirements, protective tariffs, and favorable corn-ethanol price in the second half of the previous decade are the main causes for the expansion of the industry (O'Brien and Woolverton 2009). Table 4 shows that South Dakota converts 75% of corn produced to ethanol followed by Iowa (59.7%) and North Dakota (51.1%). In terms of corn-ethanol production Iowa ranks first followed by Nebraska and Illinois. The number of ethanol plants is highest in Iowa (40 plants) followed by Nebraska (25 plants) and Minnesota (21 plants). Even though the number of plants in Illinois is less (10 plants) the average production capacity is 118 million gallons per plant and is the highest among the states (O'Brien and Woolverton 2009).

Table 4. Ethanol Production and Corn Utilization in the U.S.

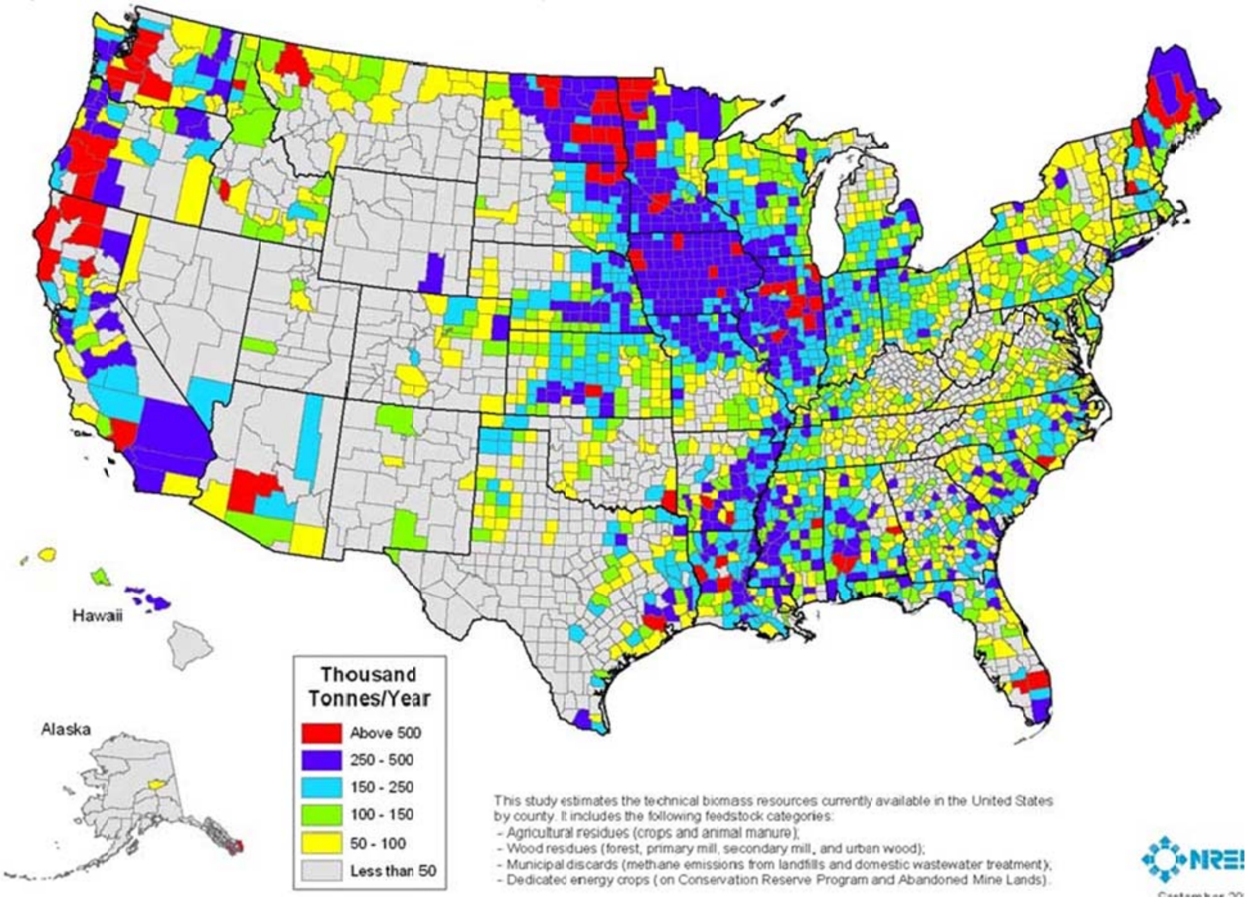
Rank	State	Name Plate Capacity (MGPY)	Operating Production (MGPY)	Corn Production (million bushels)	Percentage of Corn used for ethanol production
1	Iowa	3,537.00	3,537.00	2368.35	59.7%
2	Nebraska	1,744.00	1,719.00	1472.00	46.7%
3	Illinois	1,226.00	1,226.00	2283.75	21.5%
4	Minnesota	1,136.60	1,094.60	1138.80	38.4%
5	South Dakota	1,016.00	1,016.00	544.50	74.6%
6	Indiana	908.00	816.00	987.35	33.1%
7	Ohio	538.00	424.00	541.50	31.3%
8	Wisconsin	498.00	498.00	442.80	45.0%
9	Kansas	491.50	436.50	518.00	33.7%
10	North Dakota	358.00	348.00	272.60	51.1%

Source: http://www.neo.ne.gov/statshtml/121.htm
Source: NASS USDA. 2007 corn yield estimates. One bushel of corn produces 2.5 gallons of ethanol (conservative estimate)

According to EISA, the term 'biomass' is defined as any organic material that is available on a renewable or recurring basis. Agricultural crops, dedicated energy crops, wood waste and wood residues, plants (including aquatic and grasses), and fibers can be considered as cellulosic biomass (Mintz et.al., 2010). Carbon from the atmosphere is stored in the plant body as lignocellulosic substances (cellulose, hemicellulose and lignin). As biomass is burned, carbon will be released back into the atmosphere and the net carbon emission will be zero. According to Perlack et al. 55 million acres of cropland, idle cropland, and cropland pasture could be converted from current uses to the production of perennial grasses from which cellulosic feedstock could be harvested. Agricultural residues or low-input biomass feedstock produced on marginal lands could be converted to billions of gallons of biofuels and chemicals with lesser environmental impacts. Cellulosic biomass can be utilized mainly in two ways: biochemical conversion and thermal conversion. During the biochemical conversion process, biomass is treated with enzymes or acid and the extracted sugar is converted to ethanol using microorganisms. This complex conversion of breaking down the plant body is expensive. Thermochemical conversion to produce biofuels and other hydrocarbons includes gasification and pyrolysis.

In comparison with corn-ethanol, the current production of cellulosic ethanol is very small. As the production of corn-ethanol is close to RFS mandate, the expansion of corn-ethanol production has reached a plateau. Further increase in clean transportation fuel use can be achieved by producing cellulosic ethanol. Cellulosic ethanol is an advanced biofuel with a complex and expensive conversion technology. Unlike corn industry, cellulosic biomass industry is not organized and does not even have a well-established market. The geographically scattered production, heterogeneous nature of biomass, low bulk density, high transportation and storage cost, high initial investments, unorganized farmers, less government and institutional support, and nascent technology are the major constraints for the expansion of cellulosic ethanol industry in the U.S.

Figure 1. Biomass Resources Availability in the United States



Source: National Renewable Energy Laboratory

Biodiesel is yet another fuel that could substitute fossil fuels from mobile emission sources. EISA 2007 requires 500 million gallons and 1 billion gallons of biodiesel to be used in automobiles in the year 2009 and 2012 respectively (NDSC 2010). Biodiesel from soybeans possess high energy balance as a liquid fuel. It can also be produced from vegetable oil, recycled frying oils, and animal fat. The chemical process that converts oil and fat into methyl ester and glycerin is known as Transesterification. Glycerin is used in the manufacturing of soaps and is a major substrate in the chemical industry. Biodiesel can be blended up to 20% in any diesel engine with no modifications and also meets the requirements of American Society of Testing and Materials (ASTM). The lifecycle analysis conducted by Department of Energy (DOE) and USDA showed that for every unit of fossil energy, 4.5 units of energy is gained by producing biodiesel from soybeans (NDSC 2010). Pradhan et al. (2008) found that the mean net energy ratio (NER) on a mass basis was 2.25 and average economic sustainability ratio (ESR) was 4.43 with standard deviation of 0.38 and 0.6 respectively. Biodiesel production uses only the oil content of soybeans and the byproduct is a protein-rich meal which can be utilized as a livestock feed. In addition, biodiesel production from soybean demands less nitrogen fertilizer and other input requirements.

A new group of integrated biorefineries is introduced in different parts of the United States. The new generation biorefineries (pilot, demonstration, and commercial stages) are equipped with advanced conversion technologies. These refineries use multiple feedstocks and produce multiple outputs. The feedstocks include cellulosic biomass, non-cellulosic biomass, and algae. The cellulosic feedstocks include agricultural residues, unmerchantable timber, wood waste, municipal waste, and dedicated energy crops. Most of these refineries are designed to incorporate and process biomass of heterogeneous nature. The selection of feedstocks is mainly based on the availability and cost per ton. Transportation and storage of biomass constitute the major portion of feedstock cost. This motivates the refineries to use the biomass feedstock that is abundant in the region. Table 5 shows that majority of refineries use woody and agricultural residues. As there is no established market for biomass and not much area under dedicated energy crops, the refineries that use dedicated energy crops are comparatively less in number.

Even though integrated refineries concentrate more on biofuel production, they also produce a variety of other compounds. This includes fuels (ethanol, methanol, butanol, gasoline, jet fuel, various types of diesel, and high purity lignin), chemicals (ammonium sulphate, succinic acid, ethyl acrylate, and acetic acid) and other energy forms (heat and electricity). The diversification strategy reduces the risk associated with feedstock supply and also benefits from producing multiple outputs. Illinois hosts the maximum number of biorefineries (four) followed by California and Colorado (three each). The new generation integrated biorefineries are stationed mostly in states where the state RPS requirements are higher with binding targets rather than voluntary. For example, California, Illinois and Colorado have compliance RPS targets of 33%, 25%, and 20% respectively. The five states, North Dakota, South Dakota, Utah, Virginia, and Vermont have set voluntary goals for adopting renewable energy instead of portfolio standards with binding targets. Compliance with regulations such as RPS shows the commitment to produce renewable energy. None of the 29 integrated biorefineries are stationed in the states that adopted voluntary RPS. States like North Dakota and South Dakota were not able to attract investments in the renewable energy sector as cellulose based refineries even though they are endowed with higher biomass potential (Fig 1).

Table 5. Location, Feedstock, Product and Classification of Integrated Biorefinery Plants in the United States

SL. NO	Integrated Biorefineries	Location/State	Feedstock	Products	Classification
1	Bluefire Ethnanol, Inc.	Mecca CA	Sorted green waste Woody waste (landfills)	Ethanol	Commercial
2	Poet Project Liberty	Emmetsburg IA	Corn cobs	Ethanol, Heat	Commercial
3	Abengoa Bioenergy LLC.	Hugoton KS	Agricultural residues Switchgrass, Wood	Ethanol, Heat	Commercial
4	Range Fuels, Inc.	Broomfield CO	Unmerchantable timber Forest residues	Ethanol, Methanol	Commercial
5	Enerkem	Pontotoc MS	Municipal solid waste Woody biomass	Ethanol	Demonstration
6	Sapphire Energy Inc.	Columbus NM	CO_2, Algae	Jet fuel Diesel	Demonstration
7	Pacific Ethanol Inc	Boardman OR	Wheat straw Corn stover Poplar residuals	Ethanol	Demonstration
8	Lignol Innovations, Inc.	Grand Junction CO	Woody biomass	Ethanol High-purity lignin	Demonstration
9	New Page Corporation	Wisconsin Rapids WI	Woody biomass Mill residues	F-T diesel, Heat	Demonstration
10	Verenium Louisiana, LLC	Jennings LA	Sugar cane bagasse, Energy cane, Sorghum	Ethanol	Demonstration
11	Flambeau river biofuels LLC	Park Falls WI	Woody biomass	Ethanol	Demonstration
12	Mascoma Corporation	Kinross Charter Township MI	Woody Biomass	Ethanol, Heat Electricity	Demonstration
13	Red Shield Acquisition	Old Town ME	Woody Biomass	Butanol, Acetic acid	Demonstration

Table 5 (continued). Location, Feedstock, Product and Classification of Integrated Biorefinery Plants in the United States

14	Ineos New Planet Bioenergy jv	Vero Beach FL	Agricultural & Forest residues	Ethanol	Demostration
15	Archer Daniels Midland, Inc.	Decatur IL	Corn stover Other cellulosic feedstock	Ethanol, Ethyl Acrylate Process Heat	Pilot
16	Algenol Biofuels, Inc.	Freeport TX	CO_2, Algae, Seawater	Ethanol	Pilot
17	Amyris Integrated	Emeryville CA	Sweet sorghum	Biodiesel, Chemicals	Pilot
18	American Process	Alpena MI	Woody biomass	Ethanol	Pilot
19	Myriant Technologies, Inc.	Lake Providence LA	Sorghum grain grits Cellulosic biomass	Succinic acid, Amm.sulphate	Pilot
20	Clear Fuels Technology	Commerce city CO	Wood waste Bagasse	F-T diesel, F-T jet fuel	Pilot
21	Haldor Topsoe, Inc.	Des Plaines IL	Waste wood	Gasoline	Pilot
22	ICM, Inc.	St. Joseph MO	Corn fiber, Switchgrass Energy Sorghum	Ethanol	pilot
23	Logos Technologies	Visalia CA	Corn stover Swtichgrass Wood chips	Ethanol	Pilot
24	Renewable Energy Institute International	Toledo OH	Agriculture residues Forest residues	Synthetic Diesel	Pilot
25	Solazyme Inc.	Riverside PA	Sucrose (cane) Switchgrass Muncipal green waste	Biodiesel Diesel Jet fuels	Pilot

Table 5 (continued). Location, Feedstock, Product and Classification of Integrated Biorefinery Plants in the United States

26	UOP LLC.	Kapolei HI	Agricultural residues Woody biomass Algae	Gasoline Diesel Jet fuel	Pilot
27	Zeachem	Boardman OR	Hybrid Poplar		Pilot
28	Elevance Renewable Sciences	Bolingbrook IL	Animal fat Natural oils Seed oils	Green diesel, Chemicals	R&D
29	Gas Technology Institute	Des Plaines IL	Woody biomass Agricultural residues, Algae	Gasoline Diesel	R&D

Figure 2 Integrated Biorefinery Project Locations in the United States

Source: EERE (2010a).

A credit trading program using Renewable Identification Number (RIN) is introduced to ensure the compliance of firms to include their share of biofuels in their sales. The RIN is a 38-character numeric code assigned to the batches of renewable fuels. This code serves as a currency for trades, credits, and compliance in RFS program (EPA, April 2010). The RIN includes the information regarding assignment code, year batch produced/imported, company registration ID, facility registration ID, producer assigned batch number, equivalence value, renewable type code, RIN block starting, and RIN block ending number (EPA, April 2010). Domestically produced and imported biofuels both can have RINs and are tradable (FAPRI 2009). The RIN is applicable to all types of biofuels and represents one gallon of corn-ethanol. The equivalence value of RIN is based on the energy content of biofuel in comparison with corn-ethanol. For example, the equivalence of corn-ethanol and cellulosic ethanol is 1.0 and 2.5 respectively (Ethanol Producer Magazine 2006). Under RFS, the agency developed and released (July 1, 2010) a new system to manage RIN transactions known as EPA moderated Transaction System (EMTS). The main objective of this system is to facilitate the screening and trading of RINs. ETMS reduces the complexity in handling the manual nature of 38 digit RINs.

Biopower Production in the United States

Biopower provides the largest share of world's renewable electricity after hydropower (IEA, 2007). Biopower production reduces the emission of GHGs from stationary sources. Direct firing, cofiring and gasification are the most common methods to convert biomass into electric power or heat. Modular and small systems provide power for small communities, farms, commercial buildings, and small industries. In 2008, U.S. generated 11,000 megawatts of energy (biopower) from various biomass resources (EERE 2010). According to EERE, cofiring with coal is an effective strategy to reduce CO_2 emissions. Biopower can be used to complement intermittent renewable energy sources like wind and solar power. Cofiring is popular and represents the best available control technology (Fraas and Johansson 2009; English, Short, and Heady 1981). Even though ethanol production reduces dependence on imported oil, cofiring biomass can achieve 80% reduction in GHGs which is 2.5 times greater than cellulosic ethanol (Fraas and Johansson 2009). In terms of climate change policies, cofiring is more desirable than ethanol production.

According to the DOE, at least 182 separate boilers have cofired biomass with fossil fuels. The results of switchgrass cofiring at the Ottumwa Generation Station near Ottumwa, Iowa were promising with no slagging (Olsen 2001). MASCOMA Corporation in Michigan use woody biomass to produce electricity. There are several technical, economical, and environmental advantages of using biomass for cofiring with coal. Cofiring demands limited investment and modification on the existing plants (Associates 1997). Biomass can be used directly after subjecting to a preprocessing or pelletizing. Preprocessing does not involve the use of enzymes, catalysts and microorganisms. Ethanol production demands 7 gallons of water for producing a gallon of ethanol. There is no additional expense in transporting the end product (electricity) as the transmission lines are already established. Ethanol is more corrosive than conventional petroleum products and demands considerable investment for transportation and storage structures. As ethanol demands considerable energy input during the final purification and distillation process, the net energy value associated with cofiring is higher than ethanol. Cofiring is 2.75 times more efficient in reducing GHGs than cellulosic ethanol. Cofiring biomass reduces 1.23 tonnes of carbon dioxide emission per dry ton while cellulosic ethanol reduces only 0.41 tonnes (Frass and Johansson). Above all, biomass does not a make considerable difference in the byproduct (ash). Biomass can replace coal up to 15% in large conventional boilers and up to 100% in small biopower generators. A continuous supply of biomass need not be ensured throughout the year. Coal can be used completely to produce energy during the lean period. This reduces the risk associated with feedstock availability and the supply of end product. As cofiring biomass with coal reduces SOx and NOx emissions, additional expenses on pollution abatement can be considerably reduced. In addition, there is no intermittency in power production as in wind and solar energy. High cost of biomass and uncertainty in the supply are the major constraints in using biomass as energy feedstock.

There are several prerequisites to initiate bioenergy production. Some among these are (1) existing coal firing boilers and supporting structures, (2) local expertise for collecting and processing biomass, (3) boiler plant equipped with bag house, (4) satellite and on-site buffer storage space, (5) apparent cofiring interest and receptive plant operators and management, (6) favorable regulatory climate and state licensing procedures for biomass cofiring, (7) adequate infrastructure and cooperation of local community to accommodate additional traffic for transporting biomass (EERE, 2010). Even though several facilities qualify to undertake cofiring activities, the profitability depends mainly on coal biomass price ratio. The financial viability of the project depends on the location of the facility, origin and type of coal, and willingness of farming community to supply biomass to the facility. The technical aspects like boiler size, type, and age also affect the profitability of biomass significantly. The corrosion and loss of efficiency due to high moisture and silica deposits on the boilers, ash disposition and disposal, and change in boiler chemistry are some among the potential technical challenges associated with cofiring. The uncertainty regarding the policies that include RPS, cap-and-trade legislation, greenhouse gas impacts, and imperative tax incentives impose restrictions on biopower production (EERE, 2010).

<u>Wind Energy in the United States</u>

The records of ancient history show that wind energy has been harvested and used for various purposes that include propelling boats, pumping water, draining marshes and lakes for cultivation, and grinding grains. The introduction of electrical appliances and machineries in the day to day life of common man motivated the electric utility companies to transfer the kinetic energy of wind to electric energy. Electric power generation by harvesting wind is not new in the United States. In the 1930s, rural electrification administration program was initiated to use wind energy for meeting the demand for electricity among the geographically scattered rural customers (EERE 2010). The demand for wind power is highly correlated with the oil prices. This phenomenon was evident during the oil embargo in the 1970s. In recent years many developed and developing countries invest millions of dollars in wind farms to produce pollution free electricity and to achieve energy security.

Wind energy is the fastest growing energy source in the world. The U.S. is the leading country in the production of wind energy. Several developed countries that include Denmark, Spain, and Germany produce considerable amounts of wind power (Goggin and Antony 2010). Developing countries like India and China invested heavily in wind farms. With major investments in several nations, wind power is growing as a global generation resource and is expected to continue a rapid growth in the future (Bolinger and Wiser, 2009; IEA, 2007; BTM Conuslt, 2008; GWEC, 2008).

According to the findings of DOE, “an investment costing the average American household less than a can of soda a month, wind power could generate 20% of the nation’s electricity by 2030” (AWEA 2009; page 1). The wind power is more economical even though the initial investment is higher when compared with conventional power production methods. A 20% share of electricity production requires an incremental investment of $43 billion net present value (roughly 50 cents per household) than the no new wind scenario (AWEA 2009). Wind is a domestic source of energy characterized by several positive attributes that include zero emissions, zero marginal cost, and no water use. The wind energy production emits no pollutants, waste products, and greenhouse gases. The environmental foot print per unit of electricity produced from wind is lesser than any conventional methods.

The entire wind turbines operating in the U.S. by the end of 2009 will save 57 million tons of carbon dioxide, 200,000 metric tons of sulfur dioxide, 80,000 metric tons of nitrogen oxides, and 20 billion gallons of water annually (AWEA 2010). In the case of ethanol production, availability of water is a major constraint. In the U.S., electricity generation consumes around 50% of all water withdrawals. Wind power virtually does not require water and each MWh generated by wind save 600 gallons of water (AWEA 2009). In addition, wind energy production creates no damages to the environment through resource extraction. Depending on the wind resource and project financing, wind is one of the cheapest renewable energy sources costing between 4 to 6 cents per kWh (AWEA 2009). All these factors provide wind a strong environmental and economic edge over fossil fuels and other forms of renewable energy. Even though the wind industry is relatively immature, the cost of producing wind energy has reduced considerably in the last few decades. According to AWEA (2005), the capital cost for establishing a 50-MW wind farm is estimated to be around $65 million (1.3 million per MW). Such an investment can generate annual gross revenue of $6 million under the assumption that power is purchased at a rate of 4 cents per kWh (assuming 35% capacity factor). Wind energy production also boosts several sectors of rural economy by creating more employment opportunities, rental payments, and tax income.

In 2009, the U.S. installed 10,010 MW of wind capacity. The country ranks third in the growth of wind power production next to China (13,800 MW) and Europe (10,500 MW). These countries have made binding long-term commitments to install renewable energy (AWEA 2010). Financial incentives and policy regulations mandated from the government are necessary for energy companies to venture into the production of wind energy. The concerns about GHG emissions and climate change, federal tax incentives (for example production tax credit (PTC)), and renewable portfolio standards acted as catalysts for growth of wind power. According to Bolinger and Wiser (2009), the expirations and subsequent short-term extensions of PTC created uncertainty with a boom-and-bust cycle in the wind market. They also mentioned that the states with RPS policies constitute 55% of wind power capacity built in the U.S. The expanding investments and creation of additional jobs cannot be sustained until a renewable electricity standard is binding. The wind power sector needs policy support in the form of national renewable electricity standard (RES) or incentives to materialize the full wind energy potential of the nation. The ARRC of 2009 include Treasury Department Grant Program, extension of PTC, Energy Department Loan Guarantee Program and Manufacturing Investment Tax Credit to support wind projects (AWEA 2010).

Among the top 10 states, Texas ranks first in the production of wind energy followed by Iowa and California (Table 6). North Dakota ranks 10th position in the wind energy production even though the state ranks first in the wind energy potential. The development of wind energy sector in Texas can be attributed to a well-designed and carefully implemented RPS (Langniss and Wiser 2003). Strong political support and regulatory commitment, predictable long term purchase obligations, Credible automatic enforcement and flexible mechanisms are some among the major factors that contributed to the success of wind energy in Texas (Langniss and Wiser 2003).

Even though investments in wind energy are promising, there are several factors that increase project costs and thereby the price of wind power. Transmission limitation prevents to reap the economic, environmental, and energy security benefits of obtaining wind power (AWEA and SEIA, 2009). The Americas best wind resources are located in the plains of Dakotas that stretches to Texas, while most of the consumers live along the east and west coasts (AWEA 2010b). If there is enough transmission capacity, North Dakota alone is theoretically capable of producing enough wind energy to meet more than a fourth of U.S. electric demand (AWEA 2010c). With the current infrastructure, it is impossible to link the areas of vast wind energy potential to the areas that have significant demand for green electricity. Renewal of existing grid lines and extending the grid to newly constructed wind farms requires millions of dollars. The excess demand for advanced turbines, rising cost of construction materials, energy input for manufacturing wind turbines, and unfavorable exchange rate for the U.S. dollar severely restrict the installation of new wind farms (Bolinger and Wiser, 2009). The competitiveness in producing wind energy depends on several technical and policy related factors (AWEA 2005). These factors include; (1) wind speed at the project site, (2) improvements in the turbine design, (3) size of the wind farm, (4) optimal configuration of the turbines, (5) cost of financing, (6) policies regarding environment, (7) transmission, (8) tax, and (9) ancillary economic benefits.

Table 6. Wind Energy Production in the Top 10 State in the U. S.

Name of the State	Existing Production (MW)	Under Construction (MW)	Rank
Texas	9,707	370	1
Iowa	3,670	0	2
California	2,739	443	3
Oregon	1,920	614	4
Washington	1,914	815	5
Illinois	1,848	437	6
Minnesota	1,797	673	7
New York	1,274	95	8
Colorado	1,248	552	9
North Dakota	1,222	37	10

Source: AWEA (2010d)

The energy produced from wind is proportional to the cube of wind speed. In the last twenty years, the rotor diameter increased five folds, resulted in 55-fold increase in yearly electricity output and reduces the cost by one-sixth (Bolinger and Wiser, 2009; AWEA 2005). The efficiency in management and reduction of transaction costs increase with farm size. General Electric (GE) is the dominant manufacture of wind turbines in the U.S. followed by Siemens. The new generation turbines are advanced with reduced sound pollution. The investors consider that wind energy production is comparatively new and the investment in this sector is risky. Above all, uncertainty in the RPS requirements made investment in wind farms less desirable. Compliance on RPS creates a mandate driven demand for green electricity and reduces the uncertainty associated with the price. Production tax credit (PTC) and 5-year accelerated depreciation schedule helps to level the economic playing field for wind projects in energy market.

Renewable Energy Certificates (RECs)

Renewable energy certificates (REC), the "currency" of renewable energy represent all the environmental and non-power attributes of green electricity. These certificates are vital components of all renewable electricity products and are measured in single megawatt-hour increments (EPA 2008). In other words, REC represents a unit amount of avoided GHG emission to produce a megawatt-hour of electricity. These certificates alleviate the problem of differentiating conventional and renewable electricity. Green electricity represents a combination of two revenue streams: the first one is the revenue obtained by selling commodity electricity and the second one by selling its environment attributes as RECs. It is also possible to sell both of them as a bundle of Megawatt each. But in general, RECs are sold unbundled nationally.

RECs were first introduced by Automated Power Exchange (APX) as "green tickets" in May 1999 (APX, 1999). These tickets were designed to facilitate the markets for renewable energy and to assign a monetary value for the environmental attributes. In June 1999, the Texas legislature passed a restructuring law (Senate Bill 7) that included RPS and an energy credit-trading program (Holt and Bird, 2005). The EPA (2008) stated that RECs include the following primary attributes and information: (1) the type of renewable resource, (2) the date when it was created (vintage), (3) the vintage of the renewable generator, (4) the location of the generator, (5) eligibility of certification, and (6) GHG emission associated with generation. The price of REC varies with the region of production, source of generation, the date of production and the amount of energy produced. Bundled electricity or RECs from nearby sources are valued more as the retailers can claim the environmental benefits in the vicinity of the consumer. To ensure consumer protection, the RECs must be produced within the calendar year in which they were sold, last six months of the previous year, and first three months of the following year (Holt and Bird, 2005). The recently produced energy certificates from least emitting sources are preferred to those that are close to expiration.

RECs are highly flexible and can be sold in advance to generate an upfront revenue stream for investors. These certificates reduce the cost of transaction, provide liquidity for renewable energy attributes, secures additional revenue, and enables renewable energy production to compete with conventional energy sources. It also helps the consumers to support renewable energy initiatives. RPS compliance market offers enormous opportunities for REC trading. This creates an annual potential market for 65 million MWh of green electricity by 2010 that value around $700-$900 million (Holt and Bird, 2005). The compliance market (45 million MWh) is two times bigger than the voluntary market (20 million MWh).

The demand for REC is created by corporate organizations, federal, state, and local governments to meet the environmental goals and mandated RPS. The RECs retire as they are purchased to meet the requirements. The transactions of RECs are tracked through contract agreements to prevent double claims. This electronic tracking system enables RECs as a credible means to claim the environmental attributes of renewable electricity generation. In the U.S., 28 states and the District of Columbia have different levels (up to 40%) RPS requirements (Bird et.al., 2010). Currently, RECs are widely traded in Texas, Massachusetts, Connecticut, and Maine where these states comply with RPS. Private companies are also interested in purchasing the certificates. For example, Motorola increased their green power purchase to 119 million kilowatt-hours of RECs from a renewable energy company named NativeEnergy and increased the percentage of green electricity up to 32 %. As more and more states and corporations plan to meet RPS requirements, the demand for renewable energy and RECs will increase. Even though a major portion of green electricity is traded by using RECs, the major challenge facing the retailer is to convince the benefits in the local environment.

Energy Production and GHG Emission in North Dakota

North Dakota has extensive reserves of coal and petroleum. North Dakota has the largest deposit of lignite coal in the world and ranks fourth in oil production among the states (NDDC 2009; Austin 2009; MRP 2009). The economy and energy consumption is growing at a rate of 5% and 2.5% respectively. The reports on energy consumption states that in per capita energy consumption, the state ranks 4^{th} (648 million btu). Transportation contributes 22% of energy consumption and the state ranks 5^{th} and 14^{th} in the case of per capita gasoline and ethanol consumption respectively (EERE 2006). In 2007, the total sales of gasoline and diesel in North

Dakota were 326 million gallons and 466 million gallons respectively (NDDC 2009). The state produces more than 70.7 billion cubic feet of natural gas and is expected to reach 75 billion cubic feet by 2012 (NDDC 2009). It seems like a paradox: even after supporting an energy intensive economy, North Dakota ranks last (50th) in gross state product (EERE 2006).

North Dakota's annual electricity consumption grows at a rate of 2.9% (EERE 2006). Power is primarily generated by coal fired plants (93.8%) and the power companies are planning to increase the energy generation from coal by 24.6% (NWF 2010). The share of electricity produced from hydro-electric projects (4.8 %) and other renewable sources including wind constitute less than 1.1%. A North Dakota Public Service Commission (2010) news release mentioned that "North Dakotans pay the lowest electricity rates in the nation while enjoying the fruits of a dynamic energy economy and the high paying jobs it produces." According to the Public Service Commission, the state pays only 6.58 cents per kWh of electricity followed by South Dakota (7.63 cents per kWh), and Montana (8.46 cents per kWh). This could be achieved by utilizing the abundant natural reserve of coal and excluding all negative externalities associated with coal firing. North Dakota state profile of exposure to coal-fired power plant published by Clean Air Task Force (2010) reported that the total number of children exposed within 30 mile radius is 38,701 and children with asthma is 1,943. The total gasoline and diesel consumption is 300 million gallons and 158 million gallons respectively (EERE 2010).

Table 7. Summary Statistics on Green House Gas Emissions from Coal in North Dakota

Item	Value	U.S. Rank
Total GHG Emission		
Sulfur Dioxide (thousand MT)	124.0	20
Nitrogen Oxide (thousand MT)	63.0	24
Carbon Dioxide (thousand MT)	32,918.0	29
GHG Emission per unit of energy		
Sulfur Dioxide (lbs/MWh)	8.3	6
Nitrogen Oxide (lbs/MWh)	4.3	3
Carbon Dioxide (lbs/MWh)	2,217.0	1

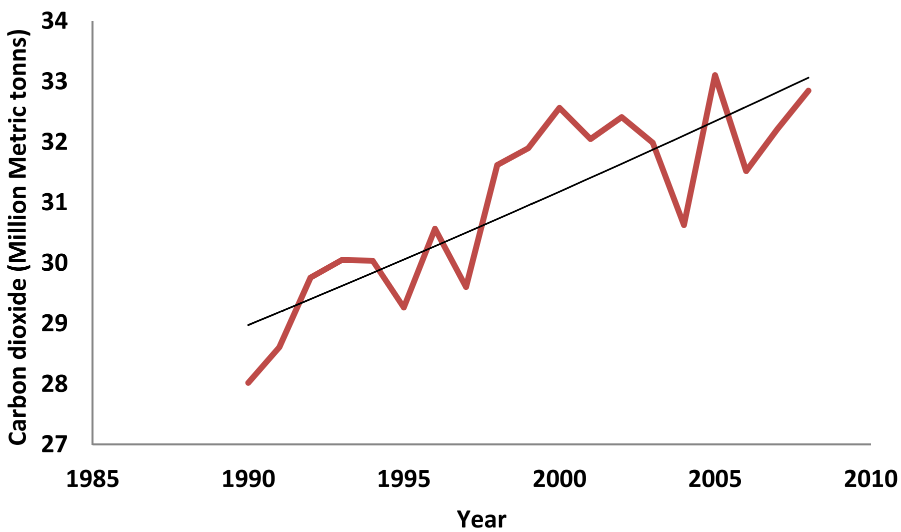
Source: United States Energy Information Administration (EIA).

The dependence on fossil fuels for energy production results in large amount of carbon emissions into the atmosphere. Even though North Dakota ranks 47 in the 2000 census population (USCB 2010), the state holds 20th, 24th and 29th ranks in sulfur dioxide, nitrogen oxide, and carbon dioxide emissions respectively (Table 7). This higher rate of emissions can be attributed mainly to two reasons. First, the per capita energy consumption in North Dakota is 34% higher than the U.S. average (NWF 2010) partially due to high heating demand in winter. The state also supports an energy-intensive economy that accounts for nearly 50% of the State's total energy consumption. Second, the GHG emission from coal per unit of energy is higher in North Dakota. The estimates of the DOE shows that coal that is widely used in North Dakota emits 2,217.0 lbs of carbon dioxide per MWh of energy produced. In other words, North Dakota ranks first in carbon dioxide emissions per unit of energy produced. The state also ranks 6th and 3rd in sulfur dioxide and nitrogen oxide emissions respectively. The Clean Air Act (CAA) enacted by EPA in 1970 authorized the establishment of national ambient air quality standards

(NAAQS) that envisions reducing pollutants that include sulfur dioxide, nitrogen dioxide, carbon monoxide, ozone, lead, and particulate matter (PM-10).

According to the DOE (EIA 2008), 29.78 million short tons of coal is sold at an average sales price of $12.92 per short ton from Mclean, Mercer, and Oliver counties of North Dakota. North Dakota produces the cheapest coal followed by Montana. The coal firing facilities of the state use mainly two types of coal: subbituminous and lignite. The large electric power producing plants are located in the Mercer, Mclean, and Oliver counties of North Dakota where lignite coal is abundant. Basin Electric Power (Leland Olds and Antelope Valley), Dakota Gasification Company, Great River Energy (coal creek and Stanton station), Minnkota Power, and Otter Power Trail Company situated close to the lignite coal mines consumes 93% of coal produced in North Dakota. In total, the state produces 32.73 million MWh of electricity and the share of electricity from coal constitutes 91% (29.67 million MWh). The benefit of producing cheap electricity (more than 60%) is not accrued to the residence or the industries of North Dakota. The net retail sales of electricity is only 12,416,074 MWh (38%) and the rest is sold outside North Dakota. In other words, the negative externalities associated with electricity production stays in the state which is not reflected in the lower price of electricity.

Fig 3. Carbon Dioxide Emission from Total Coal Consumed in Electric Power Industry



Source: EIA 2008b. Electric Power Annual 2008.

Fig 3 shows an increasing trend in the coal use and carbon dioxide emission in electric power industry in North Dakota from 1990 to 2008. During this period, coal consumption and carbon emissions increased by 6.3% and 6.9% respectively. The analysis shows that the sulfur dioxide and NOx emissions are decreasing. There are several negative effects associated with CO_2 emissions and increase in atmospheric temperature. The Intergovernmental Panel on Climate Change predicted that on an average, global warming will result in an increased temperature of 6.75 degrees Fahrenheit in North Dakota by the year 2100 (NWF 2009). This could result in earlier snowmelt, lower stream flows for lakes and rivers, lesser ground water quality, lesser recharge rates, and possess serious threats to the wetland ecosystem especially the

Prairie Pothole Region. According to the national wildlife foundation (2009) the rising temperature disturbs the diversity of wildlife that includes 318 birds, 85 mammals, 15 reptiles, 87 fish, and 12 amphibians. The report also mentioned that global warming decreases the state's annual agricultural production industry by $3 billion due to reduced soil moisture, increased irrigation, and fluctuating yields.

Table 8. List of Companies in North Dakota and their Coal Use in 2009 (Tons)

Company or Institution	Location	County	Sub-bituminous	Lignite
ADM Corn Processing	Walhalla	Pembina	38,141	
Alchem, Ltd.	Grafton	Walsh	0	
American Crystal Sugar - Drayton	Drayton	Pembina	142,594	
American Crystal Sugar - Hillsboro	Hillsboro	Trail	190,186	
Basin Electric Power - LeLand Olds	Stanton	Mercer	160,927	3,251,986
Basin Electric Power - Antelope Valley	Beulah	Mercer		5,785,554
Dakota Gasification Company	Beulah	Mercer		6,016,415
Developmental Center - Grafton	Grafton	Walsh	4,986	
Great River Energy - Coal Creek Sta.	Underwood	Mclean		8,037,581
Great River Energy - Stanton Station	Stanton	Mercer		
Minn-Dak Farmers Cooperative	Wahpeton	Richland	127,808	
Minnkota Power - MR Young Station	Center	Olive		4,014,425
Minot State University	Minot	Ward		0
Dakota College - Bottineau	Bottineau	Bottineau	807	
Montana-Dakota Utilities - Heskett Sta	Mandan	Morton		536,383
ND National Guard - Camp Grafton	Devils Lake	Ramsey	1,820	
ND School for the Deaf	Devils Lake	Ramsey	583	
North Dakota State College of Science	Wahpeton	Richland	3,743	
North Dakota State Hospital	Jamestown	Stutsman	7,325	
ND State Penitentiary	Bismarck	Burleigh		3,590
North Dakota State University	Fargo	Cass	33,100	
Otter Tail Power - Coyote Station	Beulah	Mercer		2,032,400
Red Trail Energy	Richardson	Stark	88,839	
University of North Dakota	Grand Forks	Grand Forks	53,007	
Valley City State University	Valley City	Bames		2,458
State institutions (sub total)			105,371	6048
Commercial /Industrial			587,568	6,016,415
Utility Electric Generation			824,361	23,658,329
Total			**1,517,300**	**29,680,792**

Source: North Dakota Department of Health
Note: Subbituminous to Lignite ration (1:19.6)

Meeting the RPS Requirements (Voluntary) in North Dakota

The RPS requirements of North Dakota are among the lowest (10% by 2015) in the United States. Along with four other states (South Dakota, Utah, Virginia, and Vermont), North Dakota set voluntary goals rather than binding targets. In 2007, North Dakota enacted H.B. 1506 legislation to establish a voluntary objective; 10% of the retail electricity be obtained from renewable and recycled energy by 2015. The state legislature also approved house bill 1462 and established an energy policy commission to enhance the overall energy policy (NDDC 2009). In addition, EmPower ND commission supports the '25X25 initiative' to derive at least 25% of energy from renewable sources. North Dakota Public Service Commission is responsible for administering RPS.

North Dakota has several programs to promote investments in renewable energy sector and reduce GHG emissions. The mission statement of North Dakota Industrial Commission's renewable energy program (REP) is "to promote the growth of North Dakota's renewable energy industries through research, development, marketing, and education" (NDIC 2010). The primary goals of the program is to; (1) develop and use renewable energy resources of the state, (2) create green collar jobs, (3) achieve economic stability, growth, and opportunity in the renewable energy industry, (4) encourage and promote new technologies, (5) promote public awareness on renewable energy industries, (6) increase in income for agricultural producers and land owners. The major responsibilities of REP are to provide financial assistance for developing renewable energy and promote related industries. In addition, several federal policies and incentives promote the development and production of renewable energy in North Dakota.

Table 9. Programs in North Dakota under American Recovery and Reinvestment Act

Projects	Amount Awarded($)
Expand and Extend Clean Coal Power Initiative Round III	0
Geologic Sequestration Training and Research Grant Program	598,949
Geothermal Demonstrations	3,467,728
Energy Efficiency Conservation Block Grant Program	12,818,000
Weatherization Assistance Program	25,266,330
State Energy Program	24,585,000
Energy Efficiency Appliance Rebate Programs	615,000
State Assistance on Electricity Policies	766,350
Enhancing State and Local Governments Energy Assurance	258,858
Workforce Training	728,060
North Dakota Total	**69,104,275**

Source: Recovery Act State Memos: North Dakota. 2010. Department of Energy. All numbers and projects listed as of June 1, 2010. Note: As ARRA is ongoing the amount awarded is subjected to change.

The list of projects that are financed under the Recovery Act is given in Table 9. For ten different projects, North Dakota has received $69.10 million ($69.5 million as per Recovery Act State Memos) for promoting energy efficiency measures and producing renewable energy. Expand and Extend Clean Coal Power Initiative Round III provided financial assistance to Antelope Valley Station Post-Combustion CO_2 capture project to demonstrate 90 % removal of

CO_2 from a lignite based boiler. The Geologic Sequestration Training and Research Grant Program is to develop a future generation of technical professionals for handling large volume geologic storage projects (Federal Grants Wire, 2010). In this project, the funds were allotted to North Dakota State University Fargo, ND to develop protective coatings for co-sequestration processes and pipelines ($298,949; Duration: 24 Months) and to the University of North Dakota Grant Forks, ND for efficient regeneration of physical and chemical solvents for CO_2 capture ($300,000; Duration: 36 Months) (UND 2009). In the Energy Efficiency Conservation Block Grant Program (EECBG), eighteen communities in North Dakota received $13.3 million (Recovery Act State Memos, 2010) to manage localized energy efficiency programs. The Weatherization Assistance Program (WAP) enables low-income families to reduce their expenditure on energy bills by modifying their homes. In the Recovery Act, the state aims to spend $25.3 million to weatherize nearly 3,300 homes. State Energy Program's mission is to provide education for farmers, ranchers, contractors and building tradesman to reduce energy use ($24.6 million). The Energy Efficiency Appliance Rebate Programs provide rebates for purchasing ENERGY STAR® appliances which saves energy and support local economies. State Assistance on Electricity Policies is awarded to the Public Service Commission to help electricity workload. The program for enhancing state and local government's energy assurance is awarded to North Dakota Department of Commerce to update and develop State Energy Assurance Plans that incorporate renewable energy portfolio.

To develop renewable energy resources and to increase domestic renewable manufacturing capacity, the state was awarded 5 projects with a sum of $40.7 million. In this program, Otter Tail Power Company in Steele County and Krieger Repair at Carwright received $30.2 million and $9,000 for wind projects respectively. The Schuff Steel Company received a manufacturing tax credit for $7.1 million to construct 300 wind towers per year (Recovery Act State Memos, 2010). Some among the other state supported renewable energy projects are; (1) feasibility study to evaluate the prospects of cofiring Great River Energy's coal-burning Spiritwood station near Jamestown ND, (2) front engineering study to determine technical and economic requirements for commercializing technology to produce biobased cellulosic nanowhiskers, (3) studies on F-T fuel production, (4) catalyst development/testing, (5) study on biomass-derived syngases, (6) project to evaluate the best practices of producing biomass including most productive grass species, (7) optimal harvest methods and best practices to maintain perennial grass.

The state also designed several policies and incentives to support renewable energy production (DSIRE). The Renewable Energy Tax Credit is applicable to commercial and industrial sectors. This policy provides corporate income tax credit at a rate of 3% for a period of 5 years (15%) effective on January 1, 2001 and expires on January 1, 2011for acquiring and installing renewable energy systems. To support wind power, the Large Wind Property Tax Reduction was enacted from January 1, 2001 to reduce the property taxes on centrally-assessed wind turbines of 100 kW or greater (70% to 85%). The state also offers a property tax exemption for some locally-assessed renewable energy systems. The Renewable Energy Property Tax Exemption is only enacted to support wind, geothermal, solar and storage technologies. Biomass related technologies are not included in the property tax exemption. The benefit includes a 100% exemption on property tax for a period of 5 years and biomass energy is not supported by this incentive. The Northern Plains Electric Cooperative offers a Residential and Commercial Energy

Efficiency Loan Program to support weatherization improvements. Under this program the customers can borrow $5000 for efficiency technologies and up to $10,000 for geothermal pumps. Geothermal Tax Credit offers an income tax credit (15%; 3% per year for 5 years) to individuals, estates and trusts for acquiring geothermal energy systems.

As per the official site for ARRA, ND ranks 45th in the amount of funding awarded to the state. The federal government has awarded 359 contracts, 1,262 grants, and 22 loans (Feb 17, 2009 –Jun 30, 2010). Most of these policies in the energy sector are designed to support energy efficiency, human development, and renewable energy production (wind energy). ARRA spending in North Dakota is mainly concentrated for weatherization assistance program (36.6%), state energy program (35.6%), and energy efficiency conservation block grant program (18.5%). More than 90% of the investments are for energy efficiency and training. Even though agriculture constitutes 10% of the North Dakota Economy, the investment in bioenergy production with the help of the farming community is not given importance till date.

Wind Energy in North Dakota

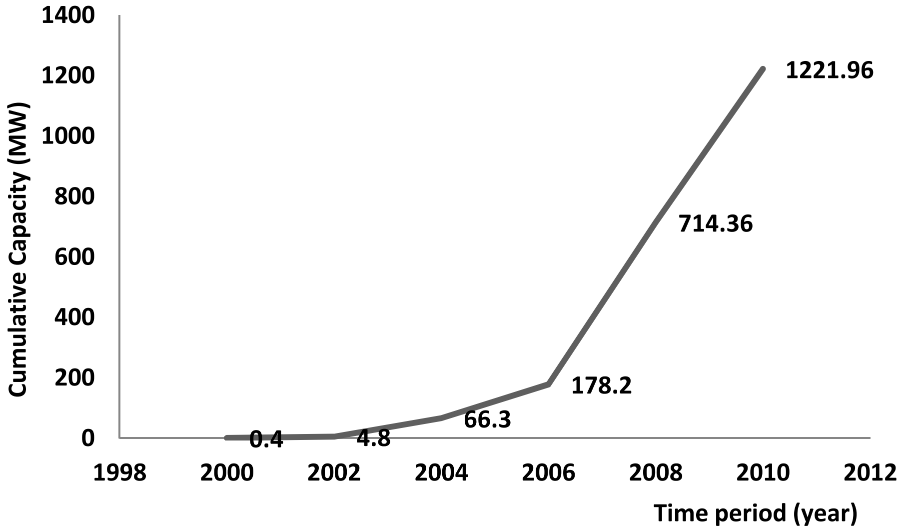
Wind developers are primarily attracted to North Dakota mainly because of its potential to produce wind power from the windiest spots of the state. Other than a good wind power production potential, the developers of wind power need a power purchase agreement, low-interest financing, and low transmission upgrade or construction cost (EERC, 2010). The wind energy sector in North Dakota has received considerable investment due to high potential in wind energy resources. The state hosts 790 wind towers with a production capacity of 1221.96 MW. The majority of wind turbines are manufactured by GE energy and is developed by NextEra Energy Resources. The largest wind farm in North Dakota is located at Rugby established by Iberdrola Renewables. The farm consists of 71 Suzlon turbines with a power capacity of 149.1 MW of wind energy. The installation of wind energy North Dakota has shown a remarkable increase since 2004. Within a period of 5 years the wind production capacity has increased more than 17 fold (Table 10).

Table 10. List of Active Wind Projects in North Dakota (2010)

Active Projects	**Capacity (MW)**	**Number of Turbines**	**Year online**
Fort Totten, Fort Totten	0.1	1	1997
Grafton Technical College, Grafton	0.07	1	1997
Richardton Abbey, Richardton	0.13	1	1997
Turtle Mountain Chippewa Tribe, Belcourt	0.1	1	1997
Turtle Mountain Chippewa Tribe, Valley City	0.9	1	2001
Turtle Mountain Chippewa Tribe, East Petersburg	0.9	1	2002
Prairie Winds, Minot	2.6	2	2002
North Dakota wind I, Edgeley	40.5	27	2003
North Dakota wind II, Kulm	21	14	2003
Wilton Wind Farm, Wilton	31.5	21	2005
Oliver Wind Energy Center, Oliver County	50.6	22	2006
Velva Wind Farm, Mc Henry County	11.8	18	2006
Wilton Wind Farm, Wilton	18	12	2006
Langdon Wind Project, Dickey County	118.5	79	2007
Oliver II, Oliver County	48	32	2007
Ashtabula-NextEra, Ashthabula	148.5	99	2008
Ashtabula-Otter Tail, Ashthabula	48	32	2008
Turtle Mountain Community College	0.66	1	2008
Langdon II FPL, Langdon	40.5	27	2008
Tatanka Wind Project, Dickey and McIntosh County	91.5	61	2008
Langdon II Otter Tail, Cavaliar County	40.5	27	2008
Asthabula II	67.5	45	2009
Luverne	49.5	33	2009
Prairie Winds 2, Minot	4.5	3	2009
Prairie Winds ND I	115.5	77	2009
Rugby	149.1	71	2009
Wilton Wind Energy Center II	49.5	33	2009
Ashtabula II	52.5	35	2009
Cedar Hills Wind Facility	19.5	13	2010
Total	**1221.96**	**790**	

Sources: Stevens (2010) and AWEA 2010

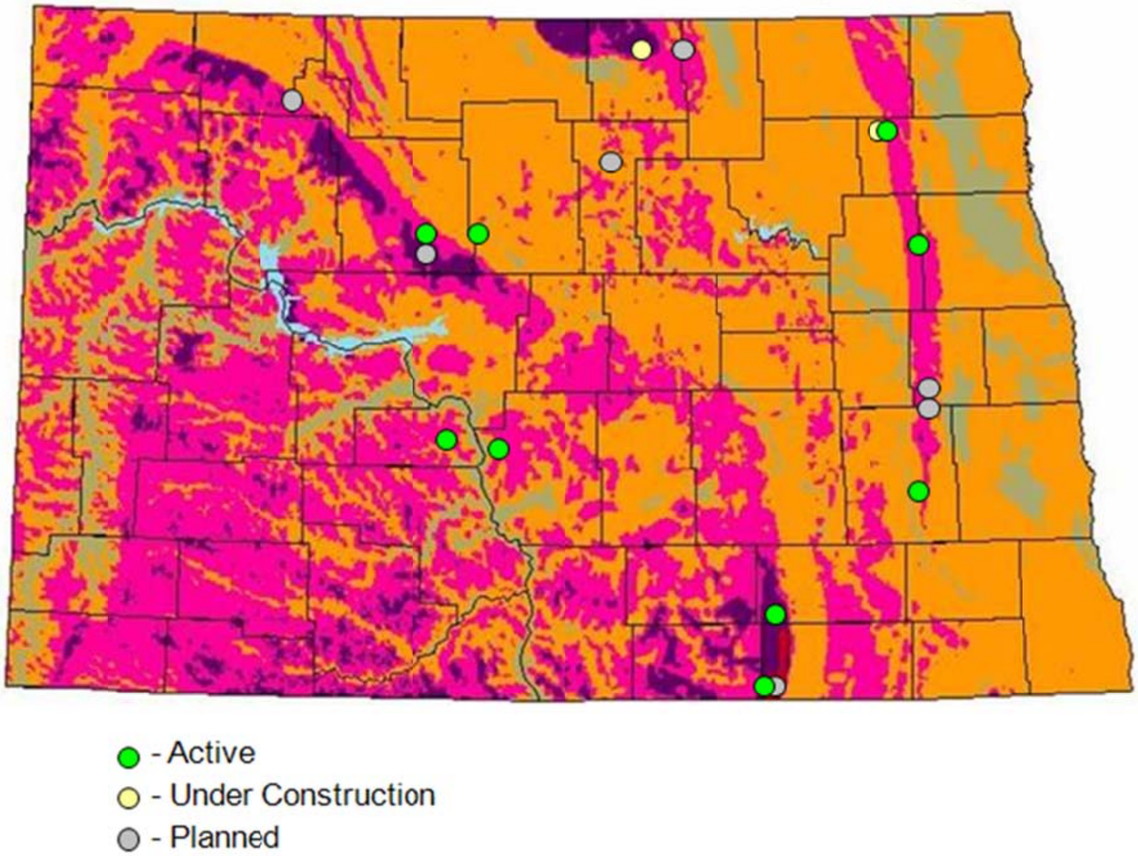
Fig 4. The Growth in Wind Power Capacity (MW) in North Dakota



Wind production in North Dakota is promising compared to other states. According to North Dakota Department of Commerce (2009), North Dakota provides adequate transmission system for meeting the current load and extends favorable regulatory environment and terrain for new transmission lines. The EmPower ND policies aim to increase the production of wind power from 1221.96 MW to 7,500 MW in 2020. With the current growth rate in the installation of new wind farms this target is achievable in the near future. Bison Wind 1A wind project is already under construction with a capacity of 36.8 MW. Several projects by energy companies that include Xcel Energy, Denali Energy, and M-Power at different sites with a total of 1632.0 MW are under different stages of implementation. North Dakota host's the National Center for Hydrogen Technology and also a joint project to convert wind energy to hydrogen. This project is implemented by Basin Electric Power Company and the DOE and focuses on new strategies to convert and store wind energy in those areas that are constraint with wind's intermittency and capacity variability in the electrical grid (CREBU, 2010).

Installation of wind farms creates employment opportunities in the rural communities. As per NextEra Energy, wind energy production results in an average annual landowner payment of $2,980 per MW. The state also receives a property tax of $2,230 per MW and installation of 13 turbines creates one highly paid permanent job (excluding the construction). Currently the state receives $3.64 million as land owner payment, $2.72 million as property tax revenues and 60 permanent jobs in the wind energy sector (this excludes the construction of wind turbines).

Fig 5. Location of Wind Farms on North Dakota with Average Wind Speed of 80 m



Ethanol Production in North Dakota

North Dakota produces a significant amount of corn-ethanol. The list of companies and the production is given in the Table 4. North Dakota consumes 120 million bushels of corn and produces 348 MGY of ethanol from six biorefineries EIA (2010). Empower ND Commission aims to produce 450 million gallons of ethanol by 2011and develop a geographically wide market for byproducts. According to North Dakota Department of Commerce, the state incentives for promoting ethanol production were started in 2002 as a part of senate bill 2222 to initiate an incentive program in North Dakota. As per century code 17-20, all ethanol plants that were in operation before July 1, 1995 are eligible for a production incentive of 40 cents per gallon of ethanol produced by the plant and supplied to a wholesaler or distributor. This biennium (2005-2007) production incentive for plants with production capacity of fewer than 15 million gallons was $0.9 million and for plants with more than 15 million gallons per year capacity were $0.45 million. Currently the Governor’s counter-cyclical ethanol production incentive supports the ethanol industry when ethanol prices are unusually low and/or corn prices are unusually high. The quarterly distributed ethanol production incentive depends on both the price of input (corn) and output (ethanol) market price. The payment under the 17-02-03 can be summarized in the following equation:

EPI = max [$1.6 million, {(CP – TPC) MFC + (TPE- RPE) MFE} QE]

Where,

EPI = Ethanol production incentive for a facility
CP = Average quarterly price of corn expressed in dollars per bushel established by North Dakota Agricultural Statistics
RPE = Rack price of ethanol expressed in dollars per gallon
TPC = Threshold price of corn ($1.80 per bushel)
TPE = Threshold price of ethanol ($1.30 per gallon)
QE = Quantity of ethanol produced in the quarter of year
MFC = Multiplier factor for corn (one tenth of a cent)
MFE = Multiplier factor for ethanol (two tenth of a cent)

In addition, the Office of Renewable Energy and Energy Efficiency may not make any payments that would result in a negative ethanol production incentive fund balance and in the case of insufficient funds, the disbursement will be on a pro rata basis (century code 17-20-03). The facility will not be eligible for receiving a cumulative state payment of $10 million in a period of 10 years. The state also provides biofuels blender pump program to retailers for alleviating the cost of blender pump installation by an amount of $5,000 per pump or $40,000 per retail location.

Table 11. Fuel Ethanol Facilities Capacity by State and Plant (Million Gallons per year)

Sl. No	Company	Location (County)	Name Plate Capacity	Operating Production
1	Alchem Ltd. LLP	Grafton (Walsh)	10.0	NA
2	Archer Daniels Midland	Walhalla (Pembina)	*28.0	*28.0
3	Blue Flint Ethanol	Underwood (Mclean)	50.0	50.0
4	Hankinson Renewable Energy, LLC	Hankinson (Richland)	110.0	110.0
5	Red Trail Energy, LLC	Richardton (Stark)	50.0	50.0
6	Tharaldson Ethanol	Casselton (Cass)	110.0	110.0
	North Dakota Total		**358.0**	**348.0**

* company's total capacity is divided among plants

Even though there is a strong demand for ethanol to meet the requirements, the ethanol industry faces several problems in North Dakota. The fluctuating corn price and increasing price of agricultural inputs decreases the profitability of ethanol production. The production is concentrated in the Mid-West region of U.S. and the demand is more in the urban areas. With existing facilities, the transportation of ethanol from the refinery to the blenders becomes expensive.

As one of the major crops of North Dakota, soybeans production could meet the demand for producing 5 MGY of biodiesel (Wechel, Gustafson, and Leistritz 2003). Even though these researchers stated that biodiesel production is relatively straightforward and requires low investment, the production was not found feasible in 2003 because of unfavorable low price for regular diesel and high cost per gallon of biodiesel. In their research paper, the cost of producing a gallon of biodiesel was $2.46 and the regular diesel price in the Fargo area during that period was $0.91 per gallon. There was no biodiesel production from soybeans in North Dakota even though there were several retailers for biodiesel. Recently, ADM, the largest biodiesel producer in North America started their production at Velva, ND using canola as feedstock (Hoon 2010).

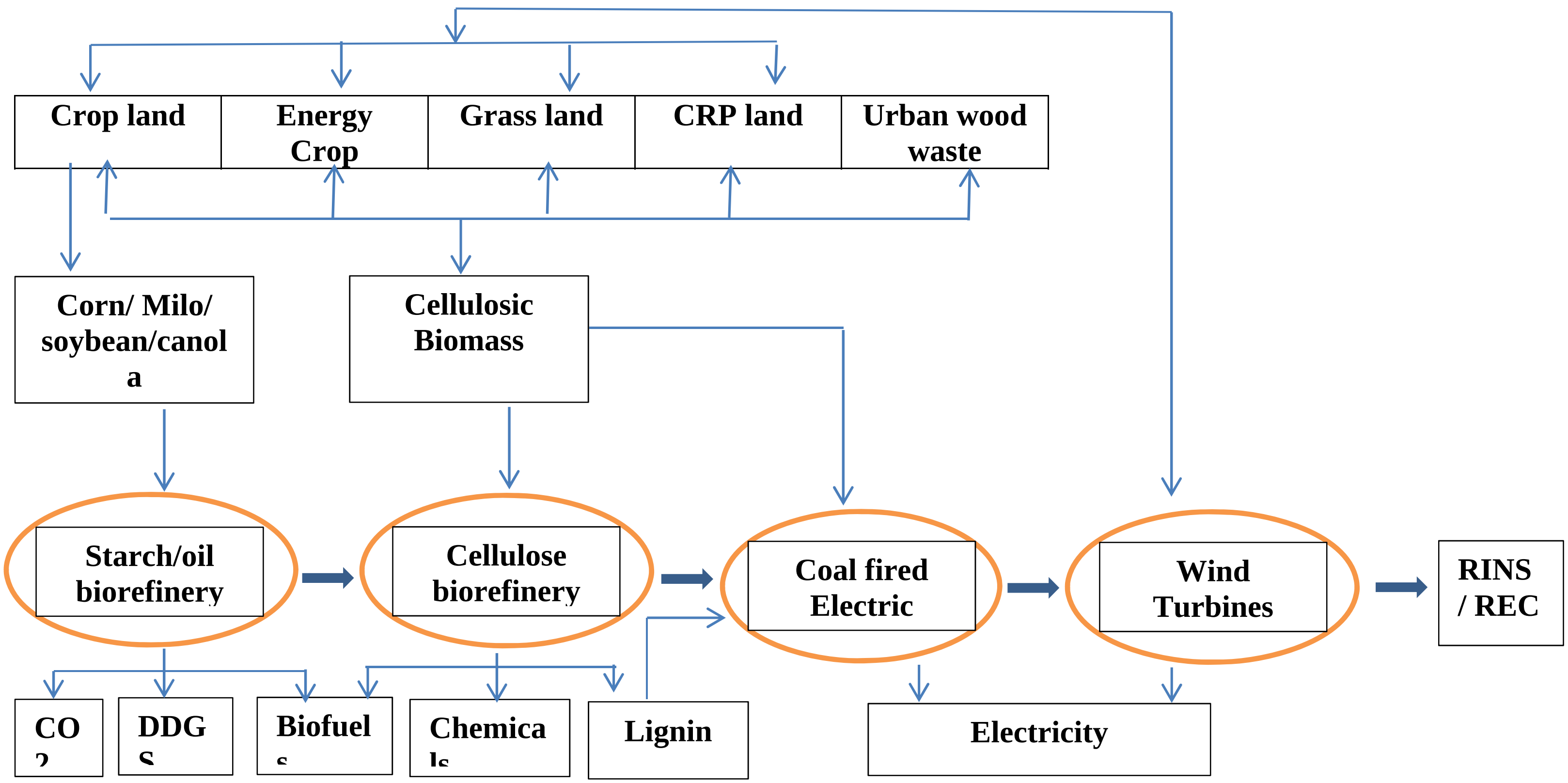
North Dakota state government provides tax credits (income tax incentives) for corporations for adapting or retrofitting an existing facility or to construct a new facility that produces or blends biodiesel. This incentive is also extended to facilities that crush soybeans and canola (NDTax 2010). With a maximum of $250,000, these corporations are eligible for income tax credit that is equal to 10% of their direct costs incurred (for more information see. Chapter 57-38 Income Tax). The state also extends the income tax credit that equals 5 cents per gallon to those who blend at least 5% biodiesel (NDTax 2010). With the current higher prices for regular diesel and the EISA mandate of 1 billion gallons of biodiesel, the feasibility of biodiesel production needs to be revisited. Even though EISA (2007) mandate for biodiesel (1 billion gallons) creates an increased demand, the biodiesel industry in North Dakota faces several challenges. Inadequate distribution and blending facilities, high soybean prices, underutilization of existing facilities, lack of market for meal co-products, and inconsistent quality of byproducts are some of the hurdles to increase the production of biodiesel in North Dakota (NDDC 2009).

Potential for Producing Cellulosic Ethanol, Chemicals, and Biopower in North Dakota

It is undoubtedly clear that North Dakota is blessed with wind and biomass resources. The state also utilizes a considerable amount of crops produced for renewable energy production. More than 10% of state GDP is derived from the agriculture sector. Several options to produce scalable amount of renewable energy could be sourced from farms throughout the state. Fig 6 provides a schematic representation of biomass and wind resource utilization in North Dakota and provides a clear picture on the role of agriculture in achieving energy security.

Crop lands could supply raw materials for cellulosic and non-cellulosic biorefineries. The cellulosic biomass from different sources can be converted into transportation fuels, chemicals and electricity. Cellulosic ethanol produces 4.4 to 6.1 times the energy used to produce and reduces greenhouse gas emission up to 86%. According to National Wildlife Federation, North Dakota has 21.0 million dry tons of biomass available per year. This equals 42,000 MW of

Fig 6. Schematic Representation of Biomass and Wind Resource Utilization in North Dakota



electricity per year or 1449 MGY of ethanol (conversion rate is assumed as 69 gallons per dry ton). Cellulosic biomass can be obtained from grasslands (26%), wheat (24%), soybeans (11%), CRP lands (8%), corn (5%) and other energy dedicated crops (Table 12). Even though soybean constitutes 11% of the area cropped, the crop residue degrades rapidly in the field and limits its use as a feedstock (Walsh et al. 2000; Kadam and McMillan 2003).

Table 12. Area under Various Crops in North Dakota

CROP	Area (Million Acres)	Percentage area
Total grass	8.98	26%
Total wheat	8.39	24%
Soybeans	3.81	11%
CRP	2.83	8%
Total Mixed Forage	2.41	7%
Total Corn	1.88	5%
Total Barley	1.10	3%
Total sunflowers	0.85	2%
Canola	0.71	2%
Fallow	0.67	2%
Total beans	0.59	2%
Total Peas	0.48	1%
Alfalfa	0.48	1%
GRAND TOTAL	34.48	

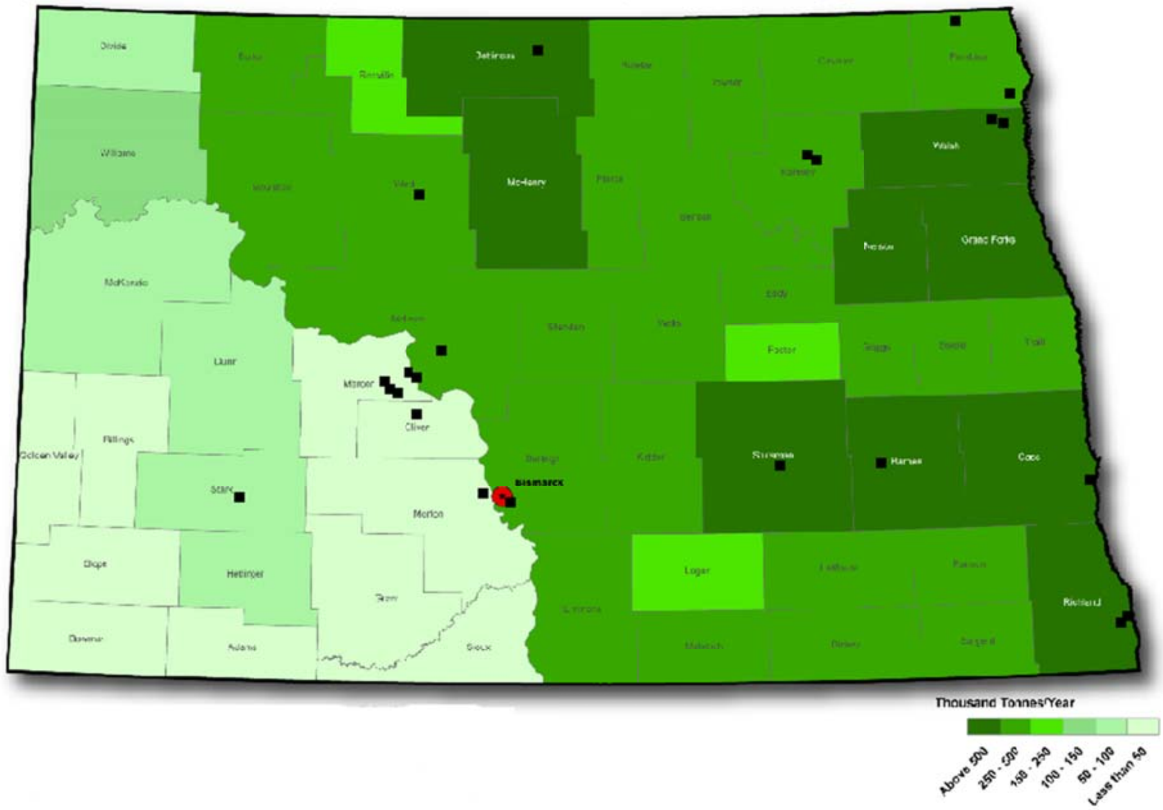
Source: Farm Service Agency. 2009 Reported Acreage summary

The counties of Richland, Cass, Barnes, Stutsman, Bottineau, Ward, Mclean, Wells, Trail, and Grand Forks have the potential to produce more than 500,000 dry tonnes of biomass per year. Two-thirds of biomass produced is obtained as crop residues (NREL 2009). All these counties can supply starch-based and oil-based feedstock for ethanol and biodiesel production depending on the cropping pattern. The farms will also receive a considerable amount of income by supplying the crop residues for biorefineries such as in Sprirtwood.

High intensity of biomass in the vicinity of a biorefinery decreases the cost of transporting biomass. The major source of biomass in the state is from the grasslands. More than 99% of grasslands are covered by native grasses followed by a small share of Brome and Sudan grass. The area under dedicated energy crops like switchgrass (306.34 acres), big bluestem (90.50 acres), and fescue tall (90.50 acres) are relatively small. This shows that biomass production for cellulosic feedstock is not fully utilized in these grasslands.

The average productivity of biomass from grassland and CRP lands are assumed to be around 3 tons per acre per year when harvested every other year (Taylor and Koo 2010). The OakRidge National Laboratory reported that in North Dakota, switchgrass and other species of dedicated energy crops could produce biomass as high as 4.39 tons per acre per year. The report also estimated a farm gate price of $38.42 per ton of biomass. North Dakota is ranked as the state with highest potential for producing biomass from dedicated energy crops.

Fig 7 Biomass Availability and Location of Major Coal Firing plants in North Dakota



Note: The black square dots represent the location of coal fired facilities in North Dakota

The CRP land occupies only 8% of the total arable land in North Dakota. Several studies have proposed using grasses obtained from CRP land to supply feedstock to produce biofuels. Urban tree trimming and construction wood waste, otherwise disposed in the landfills with a payment of tipping fee could be used as feedstock for biorefineries. Croplands produce both grains/crops and crop residues.

Currently, there are 6 corn-ethanol plants operating in North Dakota (Table 11). Cellulosic ethanol plants could be established as a part of existing corn-ethanol plants or separately. If the new plant is an extension of an already existing corn-ethanol plant, the cost of establishment can be reduced considerably. Once ethanol is produced, the procedures of distillation, purification, storage, transportation, and blending are the same. The plant could diversify the feedstock and use the existing facilities. In addition, the equivalent value associated with cellulosic ethanol is 2.5 times as that of corn-based ethanol. For example, Richland County has the largest harvested area of corn (236,000 acres) and has the potential to harvest more than 500,000 tonnes of biomass, out of which 300,000 tonnes of crop residues per year. The largest ethanol producing plant in capacity, Hankinson Renewable Energy, LLC is situated (Table 11) in Richland County of North Dakota. The adjacent counties such as Cass (ND), Traverse (MN), and Roberts (SD) also have high potential in biomass production. Tharaldson Ethanol plant situated at Casselton (Cass County, ND) has a similar opportunity in diversifying the plant to include cellulosic feedstock in ethanol production. The farming community, especially the corn growers, will be benefitted by supplying corn stover and other agricultural residues to the plant. This reduces the waiting period in establishing dedicated energy crops in the proposed regions. As

60% of corn in North Dakota is diverted to ethanol production, additional investment to increase the capacity and production will bear more risk in terms of the market price of corn.

Biomass procured from croplands and other categories of land can also be utilized for producing electricity. The majority of coal fired facilities in North Dakota (Fig 6 and Table 8) are located in counties that have abundant resources of biomass. The major cost components of cellulosic energy production are the costs of biomass feedstock and transportation. If the density of harvestable biomass per unit of land is high, the radius of collecting biomass decreases. As the transportation cost is proportional to distance, the cost of transporting biomass will be lesser if collected from a small geographical area. Income for landowner per unit of land increases with density of available biomass. The environmental impact due to the utilization of agricultural residuals with regard to carbon sequestration is negligible (Petrolia 2009). The researchers concluded that agricultural residual based fuels may reduce the use of fossil fuels.

Socioeconomic Aspects of North Dakota and Renewable Energy Development

The per capita gross state product and growth rate of the population are considered as major factors that adversely affect renewable energy generation in the state. North Dakota is one of the least populated states in the U.S. The demand for renewable electricity reduces with population.

There are two different views regarding the effect of renewable energy production on the gross state product. Policy makers suspect that renewable energy production increases the energy price and creates an adverse effect on the economic performance. But others consider renewables as a new investment opportunity that creates additional employment in energy and construction sectors of the economy. North Dakota supports renewable energy production from wind by providing incentives. Nevertheless, the policy implementation that includes enforcing RPS is only voluntary in nature, without any kind of penalties. North Dakota Ranks 50th in the gross state product. With an energy intensive economy, the stake holders believe that expensive renewable energy might dampen the economy.

Large economies can support the deployment of renewable energy in several ways. High economic growth acts as a buffer for energy price increase and is beneficial for the development of renewable energy (Chang, Huang, and Lee 2009). Higher investment in renewable energy production will result an increase in state gross product. Researchers found strong evidence of renewable energy technologies in the promotion of macroeconomic growth (Chang, Huang, and Lee 2009).

The demographic features of the state also play an important role in promoting renewable energy. The mandatory green power option (MGPO) that allows the customers to choose green power supplier or green energy provided by the utility, supported wind energy industry in several states (Menz and Vachon 2006). It was also found that generation disclosure and certification rules also affected green energy sales. Evidences show that US consumers are willing to pay a premium for renewable energy (Roe et.al. 2001). The effectiveness of these policies depends on the awareness of people regarding the environmental attributes of green energy. The educational level of population might increase the awareness and acceptability of green power.

Electricity price is a crucial factor that affects the development of renewable energy production. Higher electricity price reduce the deployment of renewable energy. At higher levels, energy prices make renewable energy production more competitive. The states with abundant resources of coal and natural gas, are less likely to promote clean energy. State legislators fear the loss of permanent jobs and income in the conventional energy sector. Because of lobbying, the states with higher contributions of petroleum and coal manufacturing to gross state product have less share of renewables in the energy portfolio (Sovacool 2009; Marques, Fuinhas, and Manso 2010). As North Dakota has the largest lignite coal deposit and has the cheapest electricity in the United States, the presence of fossil fuel deposits might be a factor that reduces the deployment of renewable energy.

Majority of states with high potential to produce renewable energy adopted state level portfolio standards. With high wind potential, North Dakota produces a considerable share of wind electricity. According to Caley (2010), the neighboring state's adoption stimulates the adoption of RPS to explore and develop markets for renewable energy. The neighboring states of North Dakota, Montana and South Dakota have only voluntary requirements.

CONCLUSION

Energy, agriculture, and GHG emissions are highly interrelated. Environment-friendly farming practices can reduce CO_2 in the atmosphere by carbon sequestration. Many agri-products are currently used as feedstock for biofuel production to replace fossil fuels. However, the agricultural sector is becoming more and more energy intensive and the cost of production increases with fuel prices. As the largest consumer of energy, the U.S. has taken several initiatives in reducing the use of fossil fuels, achieve energy security, and reduce GHG emissions. The industrial community in the U.S. invested heavily in biofuel and wind energy production. During the period of 2003-2007, biofuel and wind energy production increased by 147% and 196%, respectively.

United States ranks second in carbon emissions. Electricity production and transportation contribute the majority of CO_2 emissions in the U.S. In the near future, there will be significant changes in the energy portfolio of the U.S. It is predicted that less production cost, technological progress, domestic sources, and less carbon emissions compared to coal will increase the use of natural gas in the future. The drilling in the Gulf of Mexico and biofuel production will reduce the import of petroleum products from the OPEC nations.

EPA regulations on hazardous gas emissions are getting stringent. The federal and state governments have enacted mandates and encouraged investments with incentives to produce renewable energy. It is evident that mandate driven renewable energy production is more sustainable than incentive driven energy production. The ban of MTBE and EISA (2007) mandate of ethanol blending increased the ethanol production up to12.25 billion gallons (name plate capacity).

The new generation integrated biorefineries use multiple inputs and produce multiple outputs. The diversification reduces the risks associated with prices of inputs and outputs. Production of biofuels using domestically produced cellulosic and non-cellulosic resources helps to achieve energy security. Cellulosic biomass cofiring is 2.5 times more efficient than cellulosic ethanol in reducing GHG emissions. Biopower production demands less investment and modification in existing coal fired plants.

United States is the leading producer of wind energy. Even though wind energy demands large initial investment, per unit cost of energy production is less compared to other renewable energy sources. State level policies to support wind energy such as compliance with RPS requirement and financial incentives like PTC played a significant role in the growth of the wind energy sector. Inadequate transmission grids are the major constraint for the expansion of wind farms in remote areas. RECs help the wind energy industry to market the environmental attributes as a separate commodity. The energy certificates reduce the transportation of renewable energy to distant places as the firms can comply RPS requirements by purchasing RECs.

North Dakota supports an energy intensive economy. The emission of GHGs per unit of energy produced is higher in North Dakota. Among the states in the U.S., North Dakota supplies electricity at the lowest price to the customers. This was made possible by using the abundant resource of lignite coal. During 1990 to 2008, the coal consumption and carbon emissions increased by 6.3% and 6.9% respectively. A major share of electricity produced is not consumed within the state.

North Dakota ranks first in the potential to produce wind energy and biomass production from dedicated energy crops. Unfortunately, these resources are not utilized to its full potential. The state has increased the wind production capacity by almost 17 fold in the last six years. North Dakota ranks 10th in wind energy production with a name plate capacity of 1,225 MWh of energy. In North Dakota, the RPS requirements are lower and voluntary in nature. Even though Texas has comparatively lower wind energy potential, the production of wind power is more than seven times higher than that in North Dakota. This indicates that higher RPS requirements with compliance attract investments in the renewable energy sector.

North Dakota ranks 4th in per capita ethanol consumption. The governor’s counter cyclical payment program and production incentive programs are the monetary incentives to support corn-ethanol production in the state. The ban of MTBE, EISA (2007) mandates, and the state incentives motivated investors to establish ethanol refineries. The state produces 348 MGY of ethanol using 120 million bushels of corn. The state also hosts a biorefinery that produces biodiesel using canola.

North Dakota has several initiatives including ‘Renewable Energy Program’ to promote investments in renewable energy. The state has also designed tax credit incentives to support those projects. Most of the energy related projects funded under ARRA are designed to enhance human skills and to achieve energy efficiency. There was no significant investment in bioenergy production. The funds are mostly used as incentives for wind energy and related industries. Less state financial incentives for bioenergy production could be a major reason that ND is the least preferred place for the location of integrated biorefineries.

If the state of North Dakota has complied with the RPS of higher standards, the renewable energy industry would have been flourished. A higher growth rate in the renewable energy production could have been achieved by introducing appropriate incentives and rebates.

The mandates of RPS would have provided certainty in the demand and price for renewable energy products. If carbon emission legislation such as Waxman-Markey cap and trade bill (H.R. 2454) is enacted, the coal based industries in the state will have to purchase renewable energy by paying millions of dollars. This creates three negative impacts in the community: (1) if North Dakota has not produced enough green electricity to meet the demand, the premium paid by a consumer in North Dakota for green electricity will be channeled to other states that produces renewable energy (2) the consumer may not be able to avail the benefit of clean environment as the green energy is produced at some other places, and (3) the resources of the state will not be utilized to its full potential and reduces the possible income generation in the rural communities.

POLICY RECOMMENDATIONS

1. As mandates are more efficient and less expensive, it would be better to promote policy measures such as RPS with compliance, fuel generation disclosure rules, and mandatory green power options.

2. The state-level policies that include RPS percentage requirements, eligibility, types of renewables included, and the timetables need to be carefully designed and implemented.

3. Long-term policies and investments for developing infrastructure facilities such as transmission grids and base load generators are needed for higher growth rate.

4. Increasing the marketing efficiency of green energy by ensuring guaranteed grid access, long-term contracts, and establishment of purchase prices based on the cost and method of generation provide better return for investments.

5. Demonstrating strong commitment and reducing uncertainty regarding financial incentives play a crucial role in promoting renewable energy.

6. Financial benefits that include tax credits, grants, low- interest loans, subsidies, financing preferences, and funding for research and development need to be provided for a specified period of time.

7. Penalties and pollution taxes for violation and non-compliance need to be enforced.

8. Institutions for quantifying the externalities of conventional energy production that helps in the pricing of conventional fossil fuels need to be established.

9. Awareness regarding the benefits of green energy needs to be increased to improve market penetration and willingness to pay a premium for green electricity.

10. Per capita electricity consumption needs to be lowered by promoting energy efficiency measures. This reduces the impact of higher prices for renewable energy in the state economy.

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