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A Clean Energy Economy for North Dakota

Analysis of the Rural Economic Development Potential of Renewable Resources

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Executive Summary

Situated at the geographic center of North America, North Dakota rises from flat lowlands in the east toward the dry hills and plateaus of the western badlands. Its unique terrain is rich in natural resources and productive land. Ranking 47th among the states in population density, North Dakota has a strong and diverse economy based on agriculture, energy, minerals, and tourism. Because of the recent oil boom in the Bakken Shale area, North Dakota has the lowest unemployment rate in the United States. But the global economic downturn has been felt across the rest of the state, with the number of unemployed North Dakotans climbing by 40 percent in the past two years.[1]

To ensure continuing economic growth and a prosperous future, North Dakota has the opportunity to build a strong long-term economy on the solid foundation of its bountiful renewable resources. Vast areas of fertile land, the nation's strongest steady winds, and a stable and productive workforce combine to give North Dakota the potential to become a national leader in producing the clean energy that America needs. A national shift toward renewable energy development would create tens of thousands of new North Dakota jobs and give a big boost to rural communities across the state. Arguably the state with the greatest clean energy potential, North Dakota is in a prime position to become a key supplier of renewable energy and the tools to produce it—provided that national policies are enacted to put America on the path to a clean energy future.

The following chart summarizes the estimated potential of key North Dakota renewable resources with a national clean energy strategy in place:

Table ES1: North Dakota's Clean Energy Resource Potential, Energy Advantages, and Environmental Benefits

Energy Source	Potential Output Estimate	Effect on North Dakota Energy Production	Carbon Dioxide Emissions Reduction	Economic Benefit
Wind Power	25 new wind farms averaging 150 MW = 13.1 million MWh of electricity per year[2]	Wind energy worth $788 million could be produced each year	14 million metric tons[3]	775 permanent jobs, thousands of construction jobs, $80 million in local economic benefits, $10.5 million in property taxes[4]
Biofuels	470 million annual gallons potential from existing crop residues	Equivalent to 130% of North Dakota gasoline consumption	4.1 million metric tons[5], equivalent to removing 875,00 cars	10 cellulosic ethanol plants would create 2,260 jobs, $216 million in economic activity
Biopower	Replacing 10% of coal use with biomass would mean 2.9 million MWh[6]	Almost 9% of North Dakota's electricity consumption would be biopowered[7]	3.1 million metric tons[8]	1,060 net long-term jobs would be created
Biogas	4,000 metric tons of methane	14,000 MWh of electricity	Equivalent to 84,000 metric tons of CO_2[9]	$1 million worth of homegrown energy per year
Energy Efficiency	15% electricity savings and 10% natural gas savings by 2020[10]	Annual electricity savings of 1.1 million MWh, gas savings of 63 million therms[11]	1.2 million metric tons	402 net jobs created, $270 million in consumer energy savings

Fossil Fuel Costs Are a Drag on the North Dakota Economy

North Dakota's energy usage is substantially higher than average—the state ranks fourth in per capita energy consumption in the United States—but most of North Dakotans' energy dollars are literally going up in smoke.[12] Although the state has six ethanol plants (four of which are currently operational) and 20 wind power facilities, fossil fuels dominate the state's energy mix. Each year North Dakotans spend a total of $3.69 billion on gasoline and other petroleum fuels; natural gas for heating, power, and industrial use; and coal for electricity production.[13,14] That means every person in North Dakota spends an average of more than $5,700 annually on fossil fuels.

The true costs are substantially higher when the hidden costs of fossil fuels are included. In a report requested by the U.S. Congress, the National Research Council found the costs of health damage from the air pollution that results from burning fossil fuels alone to be $120 billion per year in this country, or about $400 per person.[15] The costs of our dependence on foreign oil and the long-term harm from global climate change associated with unchecked emissions of carbon dioxide make the real fossil fuel bill incalculable.

Without strong new national policies to propel clean energy development and reduce energy consumption, the upward trend in energy demand will compound the problem of overdependence on fossil fuels. The Energy Information Administration (EIA), a division of the U.S. Department of Energy, forecasts that a rebounding economy and growing population will drive an average increase in domestic electricity demand of 1 percent per year in the long run.[16] If North Dakota's generating capacity increased at this rate, 950 megawatts (MW) of new generating capacity would be built in the state over the next 15 years.[17,18] Meeting such increased electricity demand with today's mix, which is 91 percent coal-fired, would add more than 7 million metric tons of carbon dioxide to North Dakota's annual emissions by 2025—the pollution equivalent of adding more than 1.5 million gasoline-powered cars to the state's roads.[19,20]

Policies to Support Clean Energy Will Create Good Jobs in North Dakota

Consumers' energy dollars are put to work most productively when invested in clean energy technologies and energy efficiency, which are far more job-intensive than the fossil fuel supply chain. An abundance of local renewable resources means North Dakota's energy dollars can stay close to home, where the economic benefits of clean energy investments are multiplied—and the local jobs can't be exported. A study cosponsored by the Natural Resources Defense Council (NRDC) and conducted by the Political Economy Research Institute (PERI) of the University of Massachusetts found that investments in clean energy and energy efficiency create, on average, more than three times as many jobs as fossil-fuel energy. Those jobs generate relatively high wages and are spread across a wide range of skill and education levels. Instead of mining, drilling, and transportation, green jobs are primarily in manufacturing, construction, engineering, agriculture, and installation and operation of energy production facilities. Compared with fossil energy, the study found that clean energy investment creates 3.6 times more jobs for people without a college education and 2.6 times more jobs for people with college degrees.

Growth in clean energy jobs would be especially valuable to North Dakota, which ranks 29th in the nation in per capita income.[21] The PERI study found that clean energy employment in the United States expanded by more than 9 percent during the 10 years ending in 2007. North Dakota is one of the leaders in this national trend, with 31 percent growth in clean energy jobs during a decade in which overall North Dakota jobs grew by just 9 percent.[22] However, the total number of clean energy jobs in North Dakota grew to only 2,112 during that decade, a fraction of 1 percent of total state employment. New national policies to promote renewable resource development could provide an unusually big boost to North Dakota's economy, because the state is so rich in clean energy potential. Despite its sizable fossil fuel industry, North Dakota would be a prime beneficiary of a national commitment to clean energy growth.

A renewable energy standard (RES) directs utility companies to meet a growing portion of their customers' electricity needs with clean energy. While the United States still lacks a national RES, 32 states, including North Dakota, have enacted state standards and taken steps toward developing clean energy resources. North Dakota has set a goal for utilities voluntarily to meet 10 percent of their customers' electricity needs with renewable resources by 2015, a modest target for a state with such exceptional renewable energy potential. Many states have set their sights far higher and have made their RES mandatory for all utilities. A strong, longer-term national standard would put all states on an equal footing and provide North Dakota an opportunity to make clean energy one of its most valuable exports.

A national RES would create jobs, strengthen communities, and save money. A study by Navigant Consulting on behalf of a business coalition projects a net increase of 274,000 full-time U.S. jobs under a "25 percent by 2025" national RES, including at least 4,000 new North Dakota jobs related to the wind power industry.[23] This study also projects that without a national RES, the number of renewable electricity jobs in North Dakota will decline over the next 15 years. An analysis by the Union of Concerned Scientists found that a "25 × 25" mandate would create 297,000 U.S. jobs and save families and businesses $64 billion in energy costs, including $90 million in annual consumer savings in North Dakota.[24]

With supportive national policies in place, North Dakota could become a center not only of clean energy production but also of component manufacturing for clean energy production facilities. A study by the Renewable Energy Policy Project (REPP) found that a national commitment to build 185,000 MW of renewable electricity capacity (the estimated power needed to produce 25 percent of America's electricity from renewable sources) could result in the creation of 999 new manufacturing jobs in North Dakota.[25] Comparing the number of jobs resulting from wind and solar energy versus coal, REPP calculated from a common denominator of one million dollars invested over a period of 10 years that wind and solar energy generate nearly 1.5 times as many jobs as coal.[26]

A 2009 national study by the College of Natural Resources at the University of California found that adoption of a comprehensive national clean energy strategy designed to increase renewable energy production, support energy efficiency, and reduce carbon emissions would create up to 11,000 new jobs in North Dakota and increase the state's economic output by as much as 1.8 percent by 2020.[27]

Energy Efficiency Investment Creates Jobs, Saves Money, and Reduces Pollution

North Dakota ranks among the least energy efficient states, sitting at 49th place in the 2009 State Energy Efficiency Scorecard published by the American Council for an Energy Efficient Economy (ACEEE).[28]

According to a study cosponsored by a broad group of utilities, the Environmental Protection Agency (EPA), and NRDC, the United States could reduce its non-transportation energy usage by 23 percent through investment in cost-effective energy efficiency.[29] As EPA administrator Lisa P. Jackson stated upon release of the report, "The energy that most effectively cuts costs, protects us from climate change, and reduces our dependence on foreign oil is the energy that's never used in the first place."[30]

Greater energy efficiency can lead to lower energy bills, even as we make the investments needed for the long and necessary transition to clean power production. Energy efficiency investment also creates high-quality jobs in local communities while saving consumers money on their monthly utility bills. ACEEE studied the projected economic impacts of a proposed national goal of 15 percent electricity savings and 10 percent natural gas savings by 2020; it found that this would create 402 net new jobs within 10 years in North Dakota and $270 million in savings for the state's consumers. In addition, achieving these energy savings would reduce carbon dioxide emissions in North Dakota by 1.1 million tons[31], the equivalent of taking 210,000 cars off North Dakota roads.

NORTH DAKOTANS OVERWHELMINGLY SUPPORT RENEWABLE ENERGY AND ENERGY EFFICIENCY

North Dakota's remarkably robust and diverse set of renewable energy options positions it for strong growth in a clean energy economy. That's why North Dakotans overwhelmingly support renewable resource development and energy efficiency. A survey by the University of North Dakota found that:[32]

- 93 percent think renewable energy should be a legislative priority.
- 91 percent of North Dakotans are concerned about the United States' dependence on foreign sources of oil.
- 75 percent are concerned about the United States using up fossil fuel supplies.
- 70 percent are concerned about whether serious health or environmental problems may be caused by the burning of fossil fuels.
- 67 percent are concerned that fossil fuels may be causing global warming.
- 80 percent would like to see renewable energy or energy efficiency meet additional U.S. electricity demand.
- 95 percent think it's a good idea to grow crops to replace some petroleum usage.
- 80 percent support funding more research and incentives to produce energy from biomass.

Clean Energy Provides New Income Opportunities for North Dakota Farmers and Ranchers

Among the states, North Dakota has the seventh-largest amount of agricultural land, with 39.7 million acres of actively managed farms and ranches.[33] With 24 percent of its workforce employed in agriculture-related jobs, North Dakota has much to gain from national policies to curb greenhouse gas emissions and support renewable resource development.[34] Production of clean energy is an attractive business opportunity with multiple potential revenue streams for farm operators, including:

- wind power generation
- sale of bioenergy feedstocks
- sale of small-scale energy production to local utilities through net metering
- sale of renewable energy credits (RECs)
- sale of carbon offset credits
- sale of renewable energy by-products like organic fertilizer and animal processed fiber (APF)

This report examines the potential for renewable resource development in North Dakota and finds unprecedented opportunity for long-term economic growth in rural communities from an array of emerging clean energy technologies, including wind, biofuels, biopower, biogas, geothermal, and solar energy.

Wind Power

North Dakota ranks first among all states in commercial wind energy potential, according to the American Wind Energy Association.[35] Despite its enormous potential, however, North Dakota ranks only 10th in wind power development, with existing wind capacity of 1,203 MW and another 75 MW under construction (and 2,050 MW in projects under consideration).[36] If 25 more commercial-scale wind farms were built in North Dakota (adding 3,750 MW of wind power), the result would be not only tens of thousands of construction jobs, but also 775 permanent jobs, $10.5 million in annual property tax revenue, and $80 million per year in ongoing positive economic impact on local communities.

Biofuels

Cellulosic ethanol, made from organic waste materials, crop residue, and sustainably produced nonfood plants (instead of edible sugars and starches), and biodiesel made from sustainably produced oilseeds and algae, are the next generation of smart biofuels. North Dakota is well situated to become a center of next-generation biofuels production. If produced sustainably, existing usable North Dakota crop residues could be sufficient to produce as much as 470 million gallons of transportation fuels each year, equivalent to 130 percent of all the gasoline used in North Dakota. An average North Dakota wheat farm annually produces biomass residue with an energy value of more than $16,000, and an average corn farm annually produces $21,000 worth of stover. Ten cellulosic plants, each with a capacity of 50 million gallons per year, would create 2,260 long-term jobs, $216 million in annual economic activity, and $12.4 million in local property taxes.

Biopower

The same energy crops that can be converted into ethanol-based transportation fuels can also be used for direct production of heat and electricity when chopped, pelletized, or gasified and used as fuel in biomass-fired power plants. Sustainably produced biomass is a particularly valuable renewable feedstock because it can be converted into electricity whenever it's needed, making biopower an excellent complement to variable wind and solar output. With little capital investment, existing coal-fired power plants can be modified to burn part biomass fuel, and many areas of the state are close enough to an existing plant to cost-effectively supply biomass feedstock. New, 100 percent biopower plants may also be viable. If 10 percent of North Dakota's coal-fired power capacity were supplanted by biopower plants, more than 1,060 net new long-term jobs would be created, not including new agricultural jobs to produce and harvest the biomass fuel.

Biogas

Methane from decomposing manure is a powerful greenhouse gas, with 21 times the global warming effect of carbon dioxide. But burning methane curbs its harmful effect on the environment and creates valuable energy with many ancillary benefits. In addition to providing a potential source of revenue and energy for livestock operations, anaerobic digestion systems create high-quality fertilizer and other by-products while reducing odors, water pollution, and emissions. North Dakota is a significant livestock producer but has no operating biodigesters. AgSTAR, a joint program of the EPA, the U.S. Department of Agriculture (USDA), and the U.S. Department of Energy (DOE), provides information resources and financial support for biodigester installations, which could help North Dakota overcome deployment barriers and capture the benefits of biodigester technology. North Dakota also has several landfill sites that could produce significant amounts of useful energy from landfill gas.

Geothermal

North Dakota has good potential to capture energy from underground heat for use in many farm and home applications. North Dakota also has potential to generate enormous amounts of geothermal electricity in the future, using new technologies being researched at the University of North Dakota. Geothermal power is one of the few energy resources that can provide continuous clean energy with a very small land footprint and almost zero greenhouse gas emissions. However, environmental issues, such as potential effects on underground aquifers, must be closely examined. Government support of research and development of geothermal technology is crucial to opening the door to this almost limitless clean energy resource.

Solar

While North Dakota is not thought of as part of the Sunbelt, its relatively dry climate, particularly in the western part of the state, gives it more sunlight than any other state on the Canadian border, and its long summer days provide greater solar electricity potential than places like Jacksonville, Florida, and Houston, Texas. Because of their intensive energy needs and location in open areas, farms have great potential for using solar energy for such applications as water and space heating, grain drying, greenhouse heating, and small-scale electricity production, especially as the cost of solar installations continues to drop. Some areas of North Dakota also have good potential for larger-scale solar thermal electricity production.

Hydrogen

As an unlimited clean energy resource, hydrogen holds great promise, but the technology to produce, store, distribute, and commercialize it is in its infancy. North Dakota is home to the National Center for Hydrogen Technology (NCHT), which is engaged in important research focusing on the wide-ranging challenges of commercializing hydrogen fuel cell technology. However, it may take many decades to successfully do so at an acceptable cost. More mature technologies like wind, solar, and biomass can be the foundation of a clean energy economy for North Dakota, while NCHT continues its leadership in addressing the issues surrounding an eventual transition to a hydrogen-based energy future.

A National Clean Energy Strategy Is Needed Now

The full economic and environmental benefits of North Dakota's vast renewable resources can't be realized until we adopt a national clean energy strategy. If North Dakota developers and landowners were confident of access to interstate transmission lines and long-term clean energy demand, they would build new wind farms. If the state's farmers were confident in a vibrant market for energy crops, they would invest in planting them where appropriate. If American farm equipment manufacturers were confident of a market for new machinery to process energy crops, they would invest in producing it. And if power generators were confident of ample feedstock supply and long-term energy sales opportunities, they would build facilities to generate biopower. But without a set of national policies designed to move America decisively toward a clean energy future, nobody in the supply chain—and certainly not the banks and investors that are needed to underwrite the necessary investments—will take the necessary steps toward creating a viable national

clean energy market. The clean energy market is replete with chicken-or-egg dilemmas that can be effectively and immediately addressed only through federal policies that assure both long-term supply and demand for renewable energy.

Policy Recommendations to Cultivate Clean Energy in North Dakota and Across America

The U.S. Congress is considering legislation to begin the transition to a clean energy economy through a range of polices designed to enable renewable energy resources to compete on a level playing field, encourage more efficient energy use by businesses and individuals, and stabilize emissions of global warming pollution.

- A renewable energy standard (RES) that promotes truly clean and renewable resources
- Economy-wide "cap-and-trade" with strong targets for reducing global warming pollution
- Use of a portion of emission credits toward incentives for renewable energy technologies and efficiency measures

In addition, NRDC continues to advocate for the following policies to make clean energy supply and energy efficiency the twin engines of strong and stable economic growth for the entire nation:

- Full lifecycle carbon accounting that does not result in emissions increases outside the energy system
- Greatly improved vehicle emissions standards
- Transportation planning standards targeted at reducing total vehicle miles traveled by integrating public transit and expanded passenger and freight rail, land use, road congestion relief, and housing strategies
- A low-carbon fuels standard (LCFS)
- Expanded support for renewable energy research and development (R&D)
- Consistent and fair net metering and interconnection standards for utility-customer-generated renewable electricity
- Enhanced incentives for deployment of advanced energy efficiency technology
- Deployment of "Smart Grid" technology where cost effective to make the electricity system more efficient and to allow demand reductions to compete with electricity supply
- Compliance with the most recent building energy codes for newly constructed buildings and added resources for localities to enforce the codes
- Promotion of performance-based sustainable management practices to protect wildlife habitat, soil, and water resources, and improve the livelihood of local communities

North Dakota's energy path must lead in a new direction on both the supply and demand sides of the equation in order to build a healthy state-wide economy and to ensure that economic benefits flow to communities-rural and urban-all across the state.

CHAPTER 1

North Dakota's Wind Power Potential

Like other renewable energy sources, wind supply is inexhaustible, produces no waste and causes no pollution, and its costs are subject to neither market nor geopolitical volatility. Improvements in wind technology have brought its long-term costs down to a level that is becoming competitive with fossil-fueled power generation.[37]

Wind power continues to be the fastest-growing energy resource in the United States, accounting for 42 percent of all new electric generating capacity in 2008. With a push from the American Recovery and Reinvestment Act (ARRA, also known as the stimulus bill), a new record for wind power expansion was set the following year. Construction of almost 10,000 MW of new wind power facilities increased the total installed wind capacity by 39 percent in 2009.[38] However, in the absence of a long-term national clean energy strategy, this momentum cannot be sustained, and U.S. manufacturing of wind power components has already begun to fall. One factor is the global economic downturn, which has crimped investment but hasn't stopped countries like Germany, Spain, and China from forging ahead with development and deployment of new renewable technology while the U.S. begins to lag behind.[39] Of immediate concern is the looming expiration of federal tax credits for wind development, which will disappear at the end of 2010 unless extended by Congress.

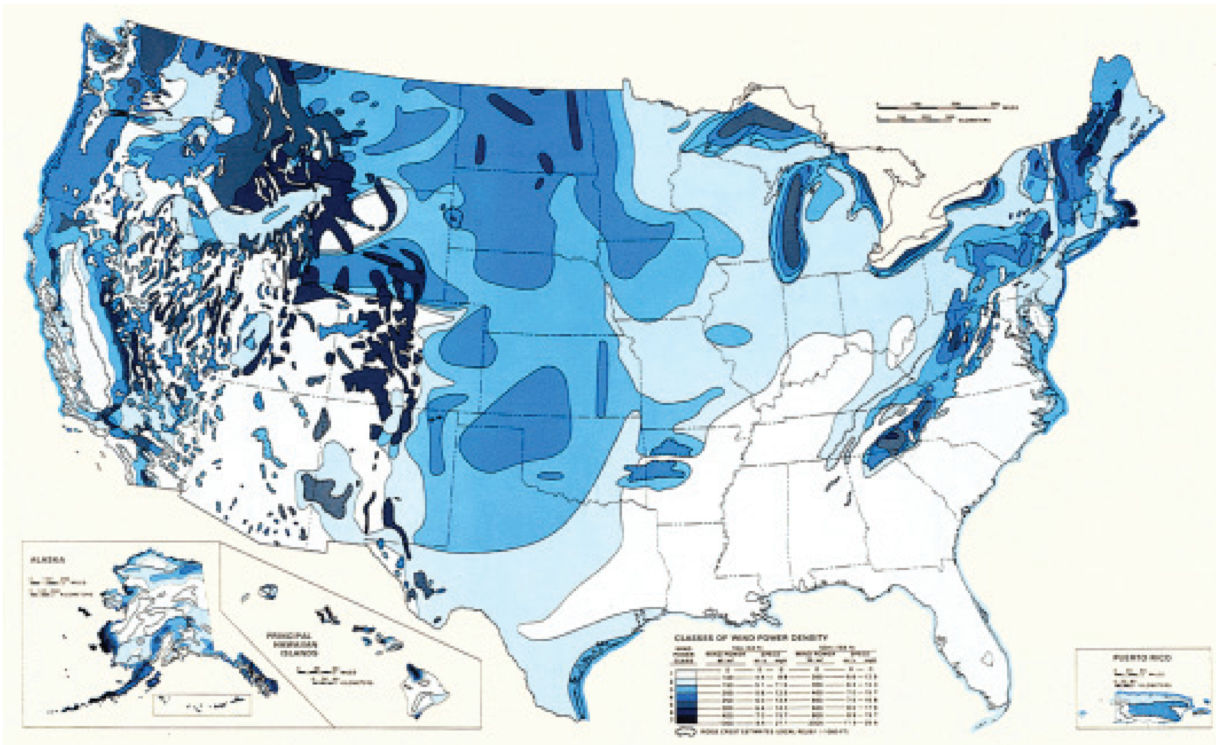
Total installed U.S. wind power capacity has grown to 35,000 MW, enough to supply the electricity needs of 9.7 million households, which is still a small fraction of its potential.[40] While less than 2 percent of total U.S. electricity supply comes from wind today (compared with 5 percent in Europe), a DOE report concluded that 20 percent of America's electric power could be wind generated within about 20 years. If the right policies are pursued, North Dakota would be a prime beneficiary of a national long-term wind power development strategy.[41]

North Dakota's Wind Resources Are Exceptional

North Dakota ranks first among all states in commercial wind energy potential, according to the American Wind Energy Association.[42] As the following National Renewable Energy Laboratory (NREL) map on page 4 shows, North Dakota has the largest areas of strong, steady winds east of the Rocky Mountains.

After subtracting land that is unsuitable for energy development, such as protected areas and parks, NREL found that 84 percent of North Dakota's remaining land area has good wind power potential, with theoretical potential totaling 770,000 MW[43]—more capacity than all fossil-fueled power plants in the United States combined.[44] Of course, only a tiny fraction of that should or would ever be developed, but every county in North Dakota has some areas suitable for commercial production of wind energy. Currently only eight counties have wind developments in place.

Figure 1: United States Annual Average Wind Power



North Dakota ranks 10th in wind power development, with existing wind capacity of 1,203 MW, producing only about one-eighth as much wind power as Texas, the nation's leader. However, the state's extraordinary wind development opportunity is evidenced by Google's recent decision to make North Dakota wind farms the target of its first large investment in commercial-scale clean energy.[45]

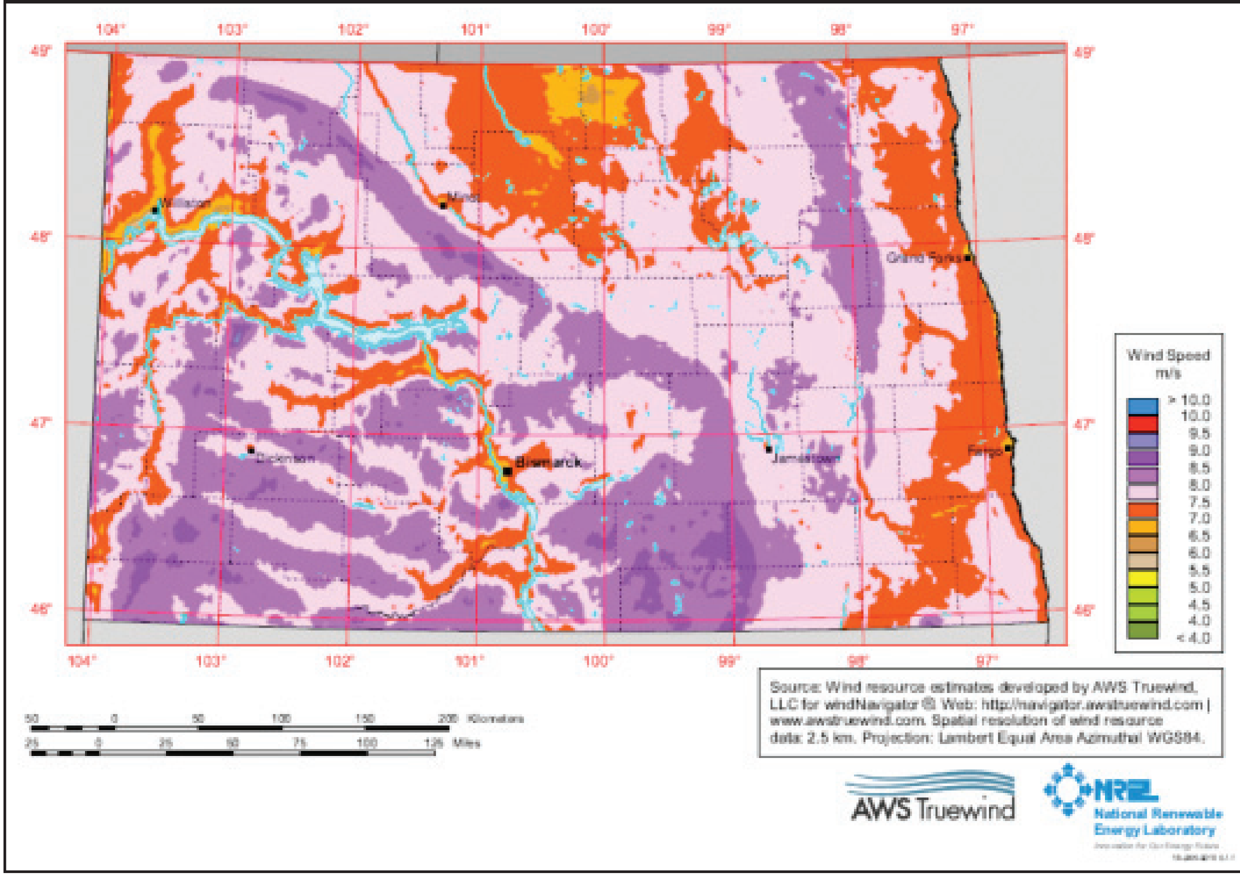
North Dakota wind power is beginning to scale up, but it will take a national commitment to clean energy for the enormous potential of this resource to be realized. Wind "density," a measure of how strongly and steadily the wind blows in a given area, is the standard used to assess the quality of wind for electricity production. Wind density is classified on a scale from 1 to 7, with class 3 and higher of sufficient strength for wind power development. The following detailed map (top of page 5) of North Dakota wind speeds 80 meters above the ground shows that almost the entire state exceeds the 6.5-meter-per-second threshold for commercially viable wind density at that height. The prime wind resources of class 4 and above are colored in shades of purple on this map.

As shown in the following chart (top of page 6), North Dakota's wind resources are of exceptionally high quality, with most areas having steady, strong winds the majority of the time, instead of the more variable wind strength common to most other areas. That means North Dakota wind can produce more power when it is most needed to meet electricity demand.

While wind power doesn't pollute the air or damage the earth like fossil fuel power, it still raises environmental concerns that must be addressed. Modern wind turbines turn relatively slowly but remain a hazard to birds and bats. Constructing wind turbines and associated roads and transmission infrastructure can also impact wildlife habitat in trees and on the ground. Doing a thorough and complete environmental impact analysis in advance of wind project siting is necessary to mitigate wildlife and natural resource impacts, including bird and bat interactions, and to ensure that local residents are not adversely affected.

Noise from wind turbines was a problem with early designs, but today's equipment is "no noisier than the reading room of a library" from 300 meters, an industry association reports.[46] The concern that wind farm development might reduce the value of surrounding property was recently addressed in a detailed study by Lawrence Berkeley National

Figure 2: Average Annual Wind Speed of North Dakota at 80 Meters



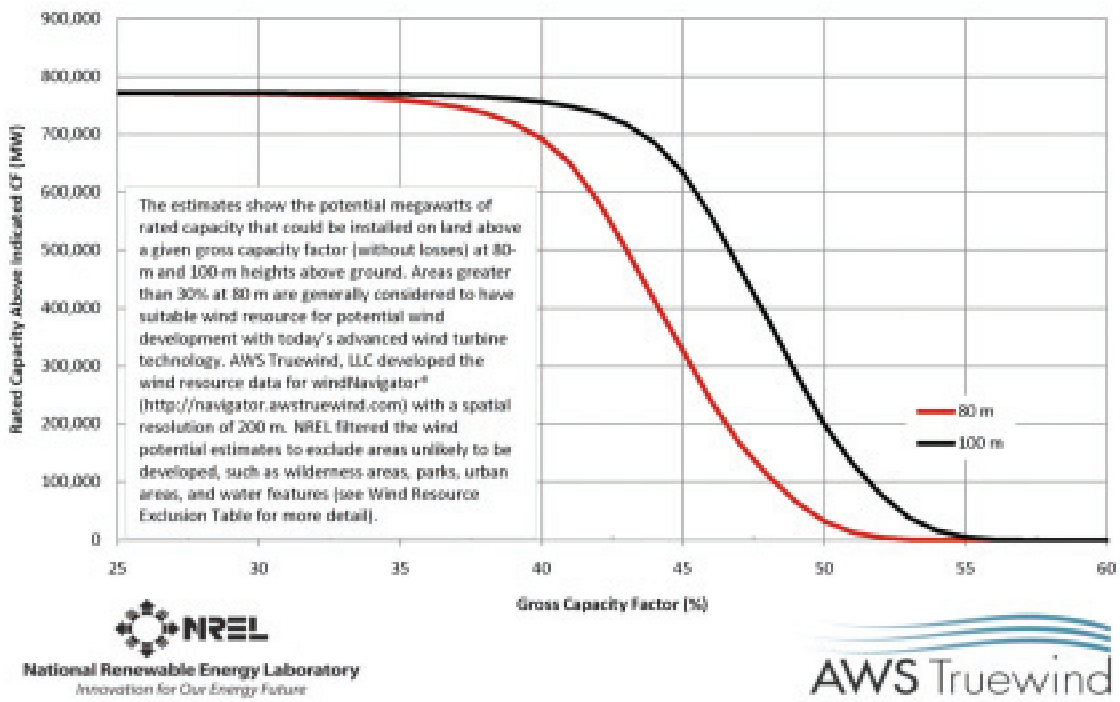
Laboratory. It found no statistical evidence that local property sale prices decrease after construction of a wind facility, concluding that "neither the view of the wind facilities nor the distance of the home to those facilities is found to have any consistent, measurable, and statistically significant effect on home sales prices."[47] From an agricultural perspective, the presence of wind facilities may actually help maintain the value of nearby farms by demonstrating the commercial viability of local wind resources and the potential income for local property owners from additional wind development.

Wind Power Pumps Up Local Economies

Development of just a tiny fraction of North Dakota's wind power potential would create enormous local economic benefits. DOE has developed a Jobs and Economic Development Impact (JEDI) model to estimate the local economic impact of different types of energy projects. This tool calculates the direct and indirect ripple effects on overall economic activity resulting from the construction and operation of wind facilities, using state-specific data. On page 7, Table 2, excerpted from JEDI, details the predicted economic impact of a 150 MW North Dakota wind facility.

According to this DOE analysis, a 150 MW wind project in North Dakota would produce 831 jobs and $83.7 million in local economic activity during its construction phase. Operating the plant would generate 31 full-time-equivalent local jobs, $422,000 in property taxes, and $3.2 million in economic benefit to the local economy each year. If 25 such wind facilities were built in North Dakota (for 3,750 MW of new wind power, an achievable goal[48]) the result would be not only tens of thousands of construction jobs, but also 775 permanent jobs, $10.5 million in annual property tax revenue, $80 million per year in ongoing positive economic impact on local communities, and 13.14 million MWh of clean electricity.[49] At a wind power market price of $60/MWh, these projects would generate $788 million in annual power sales.[50]

Figure 3: North Dakota Wind Resource Potential Cumulative Rated Capacity vs. Gross Capacity Factor (CF)



The emergence of a large domestic wind power industry would be a boon to many rural communities in North Dakota. It would also mean a new market for manufacturers of the components that go into wind turbines and towers. The REPP study referenced earlier in this report identified 67 existing firms in North Dakota with capability to manufacture components of clean energy facilities.[51] North Dakota is already on its way to becoming a leader in manufacturing wind power components. One such facility, DMI Industries, a turbine tower manufacturer employing 500 people, has a plant in West Fargo. Another company, LM Glasfiber, produces turbine blades in Grand Forks. And Schuff Steel Co., with the support of ARRA tax incentives, is planning to build a new wind tower facility in Bismarck. Because of its location in the heart of the "wind belt" and its reliable workforce, North Dakota is well situated to see more of such job creation if national policies to support wind power are put in place.

Wind Power Creates Opportunities for Farmers and Communities

The average size of a private landholding in North Dakota that is actively managed (e.g., farms and ranches) is 1,249 acres. Almost 12,000 of these parcels are larger than 1,000 acres, and 6,500 exceed 2,000 acres.[52] A typical wind project would involve scores of turbines erected on a group of adjacent farms. Today's large turbines typically have capacities of 1.5 to 2.5 MW.[53] There are many factors determining how many wind turbines can be built in a particular location, but the rule of thumb is about 1 MW per 50 acres. The wind towers and the roads to reach them have a footprint of only about one-half acre per turbine—the rest of the land can be farmed or grazed—but the towers need to be spaced apart to take maximum advantage of the wind and avoid interfering with each other. A 2,000-acre farm could accommodate 16 to 25 wind turbines totaling 40 MW—and could receive $120,000 in guaranteed annual income from land-lease payments—without significantly reducing its crop or livestock production. A 150 MW wind project would have 60 to 100 turbines spread across three or four typical North Dakota farms.

Table 2: Predicted Economic Impact of a 150-MW North Dakota Wind Facility

Wind Farm—Project Data Summary Based On Model Default Values	
Project Location	NORTH DAKOTA
Year of Construction	2010
Total Project Size—Nameplate Capacity (MW)	150
Number of Projects (included in total)	1
Turbine Size (kW)	1,500
Number of Turbines	100
Installed Project Cost ($/kW)	$2,015
Annual Direct Operations and Management Cost ($/kW)	$19.58
Money Value (Dollar Year)	2008
Installed Project Cost	$302,261,283
Local Spending	$53,213,009
Total Annual Operational Expenses	$49,269,147
Direct Operating and Maintenance Costs	$2,937,100
Local Spending	$935,396
Other Annual Costs	$46,332,047
Local Spending	$871,950
Debt and Equity Payments	$0
Property Taxes	$421,950
Land Lease	$450,000

Local Economic Impacts—Summary Results			
	Jobs	**Earnings**	**Output**
During Construction Period			
Project Development and On-site Labor Impacts	89	$4.90	$6.10
Construction and Interconnection Labor	78	$4.40	
Construction-Related Services	12	$0.50	
Turbine and Supply Chain Impacts	540	$17.30	$60.20
Induced Impacts	201	$5.40	$17.40
Total Impacts	**831**	**$27.70**	**$83.70**
During Operating Years (Annual)			
Onsite Labor Impacts	9	$0.50	$0.50
Local Revenue and Supply Chain Impacts	14	$0.40	$2.00
Induced Impacts	9	$0.20	$0.70
Total Impacts	**31**	**$1.20**	**$3.20**

NOTE: Earnings and output values are millions of dollars in year 2008 dollars. Construction and operating jobs are full-time equivalent for a period of one year (1 FTE = 2,080 hours). Wind farm workers includes field technicians, administration, and management. Economic impacts "During Operating Years" represent impacts that occur from wind farm operations/expenditures.The analysis does not include impacts associated with spending of wind farm profits and assumes no tax abatement unless noted. Totals may not add up due to independent rounding. Results are based on model default values.

Under the most common model for wind power development, a private project developer raises the capital, arranges for construction, leases the necessary land from farmers, contracts for the sale of the energy output, and owns and operates the facility. However, a promising option known as community wind can provide greater local benefits than does wind development by a distant third party. Several states, led by Minnesota, have successfully implemented policies to promote ownership of wind facilities by individual farmers, groups of adjacent farmers, and local communities. Some of these are large, commercial-scale facilities, but it has been demonstrated that facilities with a small number of turbines—sometimes even just one—can produce power cost-effectively. A study by Lawrence Berkeley National Laboratory found that wind project development costs did "not show strong evidence of economies of scale."[54] One advantage of small-scale projects producing power for local consumption is that they don't need direct connections to interstate transmission lines.

Financing a wind facility of any size remains a significant hurdle, particularly under current economic conditions. The 2009 federal economic stimulus package contains new support for renewable energy projects, including the option of up-front grants instead of long-term tax credits, making it easier to finance new facilities in the current economic downturn. The Government Accountability Office reports that farmers could "double or triple" their wind power income through ownership rather than land-lease arrangements.[55]

Wind power development also holds tremendous economic potential for North Dakota's Indian tribes, who inhabit areas of the state that have very poor economies but are rich in wind resources. New federal policies are needed to support tribal wind development, such as legislation proposed by Senator Byron Dorgan (D-ND) to streamline the issuance of permits on Indian land and allow tribal ownership of wind facilities, while transferring federal tax credits to outside partners.

A National Transmission Strategy Is Critical, but Must Be Coupled with Constraints on Carbon Dioxide Emissions

Producing wind power almost equal to 10 percent of its total electricity consumption today, North Dakota is making progress toward fulfilling the potential of wind power to meet in-state electricity needs.[56] But if cleaner energy becomes a national priority, North Dakota can take full advantage of its extraordinary wind resources to become a cost-effective source of energy for other states, provided the electricity transmission grid can accommodate it.

Transmission capacity takes longer to build than new wind power capacity and has proved to be more controversial and difficult to site. In 2005 the North Dakota Legislative Assembly created the North Dakota Transmission Authority to facilitate the development of transmission infrastructure and to finance and construct transmission lines where they are needed, if private developers don't step forward. Several new transmission lines connecting North Dakota to other states are under private development. However, piecemeal transmission initiatives will not result in a sound long-term solution to the problem. North Dakota has no jurisdiction outside its borders, and its wind development may be stymied by lack of a national transmission strategy. Such a strategy will not be easy to craft because critical and difficult issues of jurisdiction, siting, and cost allocation must be addressed at the state, regional, and federal levels. The crucial effort to expand interstate transmission capacity to meet the nation's clean energy needs is the subject of intense study and policy analysis by DOE, the Federal Energy Regulatory Commission, the North American Electric Reliability Corp., and its regional councils like the Midwest Reliability Organization, which includes North Dakota.

Environmental considerations are a crucial part of sound transmission strategy. Every transmission line has some negative effect on the landscape and the local ecosystem, so it is essential to use existing corridors and rights-of-way where possible. The relative costs and benefits of different transmission policy options must be weighed in the context of achieving overall clean energy goals. A transmission expansion policy should be coupled with caps on carbon dioxide emissions in order to realize the potential of wind and other renewable energy resources without increasing global warming pollution from fossil-based generators.

CHAPTER 2

North Dakota's Biomass Potential: Biofuels, Biopower, and Biogas

The term "biomass energy" refers to a wide range of fuels derived from crops, wood, and waste. The energy in plants starts out as solar energy, which is absorbed through photosynthesis and can later be converted to other forms of energy, either by burning biomass as a solid, fermenting it into a liquid, or decomposing it into gases. In solid, dry form, energy crops and crop residues can be used to replace coal and natural gas as fuel for biopower electricity. Biochemical and thermal processes are employed to turn biomass into liquids such as ethanol and biodiesel, known as biofuels, which can replace or be blended with gasoline and diesel for cars and trucks. Biogas produced from animal waste and other organic waste materials can be used to generate heat and electricity.

Biomass recently surpassed hydropower as the largest source of renewable energy in the United States, but it still accounts for just 3 percent of all domestic energy consumption. Using biomass energy rather than fossil fuels can result in far less global warming pollution, if the release of carbon dioxide when plants are grown and converted into energy is balanced by the absorption of carbon dioxide from the air when new plants are raised. Understanding the carbon balance of different biomass resources requires a thorough accounting of direct impacts to the soil, the energy and emissions involved in cultivation, and indirect land-use impacts. Some sources of biomass are carbon sinks over time, while others can actually end up causing the release of more carbon than fossil fuels. Equally important to achieving a positive environmental outcome is ensuring that biomass resources are managed and produced sustainably. This requires the adoption of practices to prevent negative impacts to resources such as soil, water, and wildlife habitat and to avoid indirect land-use impacts that can negate the benefits of bioenergy.

Sustainably Produced Biofuels Can Reap Economic and Environmental Benefits

National policies to support growth of a sustainable biomass energy industry would open big new markets for North Dakota's agricultural products. According to studies by the National Research Council and the Union of Concerned

Scientists, the United States could produce between 370 and 550 million tons of biomass for energy use by 2020 from sustainably sourced lands and feedstocks.[57] Such resources would provide real climate benefits and be protective of wildlife and soil and water quality. But the market will move away from conventional food-based bioenergy to these low-carbon sources only if our policies account for the carbon correctly.

Energy crops can be grown-in fact are already grown-across much of North Dakota. The state ranks first among all states in the production of wheat, a crop with emerging potential to be used to create valuable energy from sustainably collecting residues without any sacrifice in food production. North Dakota is also the nation's top producer of 13 other agricultural commodities, many of which have residues with clean energy potential.[58]

Most gasoline in the United States already comes blended with 10 percent ethanol, a biofuel produced today primarily from corn. Wheat can also be fermented to produce ethanol. However, producing ethanol and biodiesel from food crops can drive up food prices (as well as biofuel prices) and cause undesirable land-use changes. That's why crucial new technology is being developed to make ethanol from crop residues and nonfood plants and to make oil-based biofuels from nonfood crops like camelina and algae.

North Dakota is the nation's number-one producer of canola, a cool-season crop that has been used to make biodiesel. In 2007 Archer Daniels Midland built a biodiesel plant in Velva, North Dakota, that can produce 85 million gallons of biodiesel per year using 750,000 metric tons of canola oil or other oilseed crops.[59] Canola is an edible oil, and therefore its use as a fuel source should be closely examined for any effects on food prices and land use, but North Dakota could be a prime area for production of high-density, dedicated energy oils.

The Energy and Environmental Research Center (EERC) at the University of North Dakota in Grand Forks has successfully produced high-quality, 100 percent renewable jet fuel from oil crops.[60] Under a new contract, EERC is researching production of jet fuel from algae. Algae can produce up to 15,000 gallons of fuel per acre, as compared with 50 gallons from an acre of soybeans.[61]

Instead of using edible plant sugars and starches, next-generation ethanol is made by breaking down the fibrous material that makes up the nonedible cellulose structure of plants. This cellulosic biofuel can be made from almost any kind of plant or wood waste, including wheat straw, corn stover, forest residue, mill waste, and high-density energy crops such as switchgrass and poplar. Eventually, North Dakota's three operating corn ethanol plants, with 335 million gallons of annual capacity, could be converted or collocated with new cellulosic facilities.[62]

Cellulosic biofuels have a relatively high energy balance, creating four to ten times as much energy output as the amount of energy used to grow the crops and produce the fuel.[63] In contrast, ethanol produced from corn today provides only about 25 percent more energy than the amount that goes into it. Another advantage of cellulosic ethanol is that the yield using dedicated energy crops is potentially far greater than the 400 gallons per acre achieved by the most efficient corn ethanol production process.[64] The by-products of cellulosic ethanol production include protein for animal feed and enough solid matter to fuel electricity generation to run the production plant, with some excess power and renewable energy certificates left over to sell on the market.[65]

Just as growing crops can have significant impacts on soil, water, and wildlife, so can all the potential sources of biomass. Whatever feedstock is used to produce bioenergy, it is essential that its production be managed in a way that protects soil fertility, water quality, and wildlife habitat.

Cellulosic Ethanol Is on the Verge of Commercialization

The Energy Independence and Security Act of 2007 contains a Renewable Fuel Standard mandating that at least 36 billion gallons of biofuels per year be blended into gasoline and diesel fuel by 2022. It includes a cap on corn ethanol of 15 billion gallons. That means at least 21 billion gallons of "advanced biofuels" such as cellulosic ethanol and biodiesel must be produced annually 12 years from now. At least 1 billion gallons is anticipated by 2013. The race is on to bring cellulosic ethanol production to commercial viability. Scores of U.S. companies have invested in developing the specialized enzymes and processes needed to bring production to industrial scale, and more than a dozen pilot plants are at different stages of design, construction, and operation. A cellulosic ethanol plant capable of producing 20 million gallons per year has been proposed by the electric cooperative Great River Energy for Spiritwood, North Dakota. This innovative project of would use 480,000 tons of crop residue to produce advanced biofuels, with its by-products co-fired

with coal to generate electricity at an adjacent power plant. Steam from the power plant would then be used to power the biofuels plant.[66]

North Dakota Already Has Feedstock for Biomass Energy

North Dakota has a small population but the largest acreage of cropland in the United States, with ample resources for large-scale biomass energy production.[67] And the initial feedstocks needed to launch a biopower industry are literally lying on the ground. Taking into consideration only those feedstocks that would be available for energy production (after leaving a portion of crop residue in the field to maintain soil productivity, and after subtracting wood waste that is already productively used), NREL has calculated that North Dakota annually produces 6.6 million dry tons of crop residues, plus 100,000 tons of usable wood residues.[68]

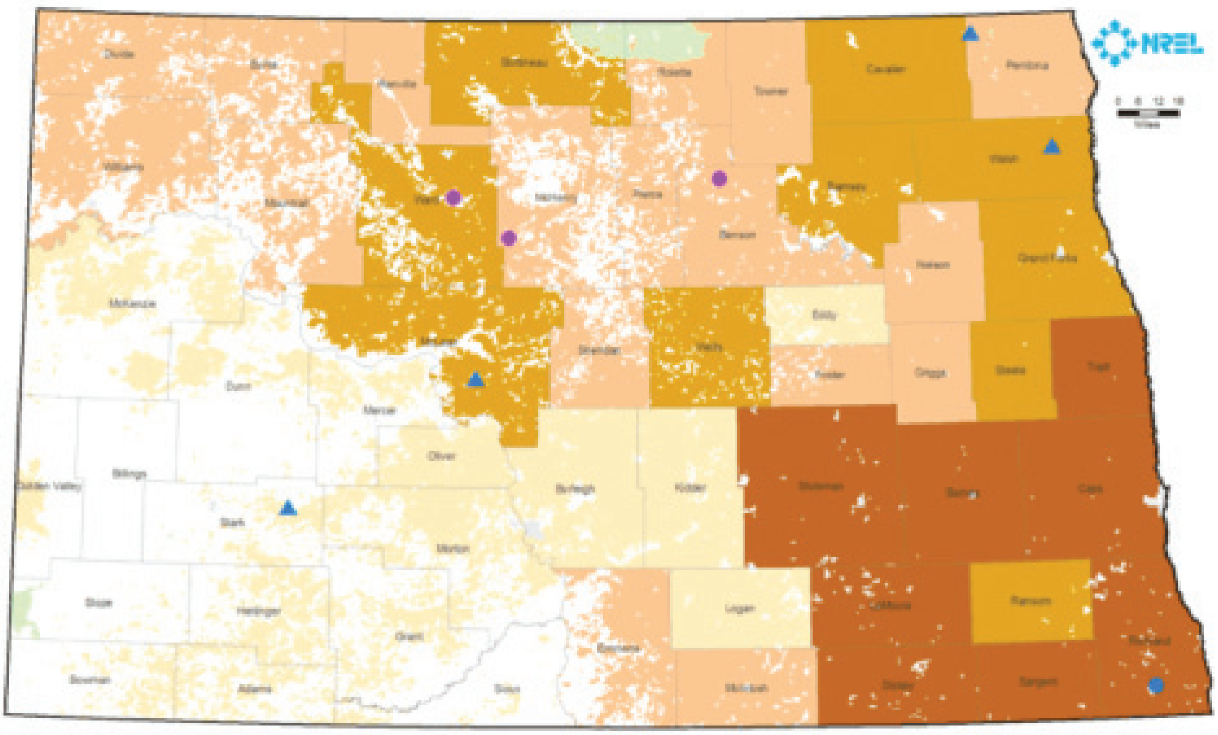
Altogether, the usable existing biomass feedstock in North Dakota amounts to 6.7 million tons each year, without including any new dedicated energy crops. What can be done with 6.7 million tons of biomass? If all of it were devoted to producing cellulosic ethanol, it would produce 470 million gallons of biofuel each year,[69] equivalent to 130 percent of all the gasoline used in North Dakota.[70] Burned in power plants, it would generate more than 5 million MWh of electricity, which is one-sixth of North Dakota's annual electricity production.[71] Replacing that much fossil fuel with clean energy would reduce carbon dioxide emissions by more than 4.1 million tons, equivalent to removing 875,000 cars from North Dakota's roads.[72]

Sustainably harvesting that farm and forest residue as biomass feedstock could also produce significant revenue. Current estimates for the future value of crop residue biomass are about $30 to $50 per ton,[73] so the gross revenue to be derived from the agricultural waste materials could be as much as $335 million. Assuming a price of $40 per ton and a usable yield of at least 0.6 dry ton of usable residue per acre, this comes to more than $16,000 in potential annual gross revenue for the crop residue from an average North Dakota wheat farm of 685 acres.[74] The typical North Dakota corn farm is somewhat smaller, averaging 405 acres. But with a usable yield of about 1.3 tons of stover per acre, it could generate gross revenue of more than $21,000.[75] Net income for the farmer would depend on the cost to collect, store, and transport the biomass. Transporting it more than about 50 to 100 miles would likely be uneconomical. Research is needed on methods and machinery to minimize both the processing costs and the energy used to turn crop residues into bioenergy sources. A clear, long-term national strategy to support bioenergy production would spark the innovation necessary to create an economically viable biomass market.

Initial steps to support biomass development were included in the 2008 Farm Act, including the Biomass Crop Assistance Program (BCAP), which will provide support for production, transportation, and processing of biomass. One company in North Dakota, Northern Sun, a division of ADM in Enderlin, is a qualified biomass conversion facility under the BCAP program.[76]

The following map (on page 12) of potential crop and forest residue biomass in North Dakota was created by NREL.

Figure 4: Map of Potential Crop and Forest Residue Biomass in North Dakota Counties



Biomass (Thousand Tons/year/county)	0	1–100	100–250	250–500	> 500
Crops and Crop Residues					
Forest and Primary Mill Residues					
Urban Wood and Secondary Mill Residues					

Facilities	Active	Under Construction
Ethanol Biorefinery	▲	●
Biodiesel Production Facility	▲	●

States
Counties
Urban Areas

NOTE: The map is color-coded: dark brown are counties with potential to produce more than 500,000 tons of crop-based biomass annually, medium brown = 250–500,000 tons, light brown = 100–250; dark green = 100–250,000 tons of forest and primary mill residue, lighter green = less than 100,000 tons; gray areas can produce 100–500,000 tons of urban wood residues. Only the uncolored areas on the map lack significant biomass potential.

Biofuels Boost Rural Economic Development

Biofuel production could provide enormous benefits to rural communities in North Dakota. The U.S. Department of Energy (DOE) has developed a "Jobs and Economic Development Impact" model (JEDI) to project the local economic impact of building energy facilities. This tool estimates the direct and indirect ripple effects on overall economic activity resulting from the construction and operation of cellulosic ethanol production plants, using state-specific data. Table 3, excerpted from JEDI, details the predicted economic impact of a 50 million gallon-per-year biochemical cellulosic ethanol plant in North Dakota.

Table 3: Predicted Economic Impact of a North Dakota Cellulosic Ethanol Plant

Cellulosic Ethanol Plant—Project Data Summary	
Project Location	NORTH DAKOTA
Year Construction Starts	2012
Conversion Process	Biochemical
Project Size—Production Capacity (Mil. Gal./Year)	50
Construction Period (Years)	3
Plant Construction Cost ($/Gal. Fuel Produced)	$2.93
Plant O&M Cost ($/Gal. Fuel Produced)	$0.72
Feedstock (Type)	Ag Residue
Cost of Dry Feedstock ($/Ton)	$34.74
Produced Locally	100%
New Production	25%
Feedstock Supplier	
Farmer	100%
Wholesaler	0%
Fixed Operations and Maintenance Cost ($/Gal.)	$0.11
Non-Fuel Variable Operations and Maintenance Cost ($/Gal.)	$0.22
Money Value—Current or Constant (Dollar Year)	2005
Project Construction Cost	$146,349,526
Local Spending	$69,269,045
Total Annual Operational Expenses	$55,577,256
Direct Operating and Maintenance Costs	$35,893,245
Local Spending	$12,370,499
Other Annual Costs	$19,684,011
Local Spending	$1,243,971
Debt and Equity Payments	$0
Property Taxes	$1,243,971

Local Economic Impacts—Summary Results			
	Jobs	**Earnings**	**Output**
During Construction Period			
Project Development and On-site Labor Impacts	490	$38.43	$55.79
Construction Labor	406	$34.83	
Construction-Related Services	84	$3.59	
Equipment and Supply Chain Impacts	356	$9.68	$30.19
Induced Impacts	309	$7.63	$24.63
Total Impacts (Direct, Indirect, Induced)	**1,155**	**$55.73**	**$110.61**
During Operating Years (Annual)			
On-site Labor Impacts	57	$2.07	$2.07
Local Revenue and Supply Chain Impacts	113	$2.88	
Agricultural Sector Only	14	$0.31	
Other Industries	98	$2.56	
Induced Impacts	57	$1.40	$4.53
Total Impacts (Direct, Indirect, Induced)	**226**	**$6.35**	**$21.56**

NOTE: Earnings and output values are millions of dollars in year 2005 dollars. Construction-period-related jobs are full-time equivalent for the 3-year construction period. Plant workers includes operators, maintenance, administration, and management. Economic impacts "During Operating Years" represent impacts that occur from plant operations/ expenditures. The analysis does not include impacts associated with spending of plant profits and assumes no tax abatement unless noted. Totals may not add up due to independent rounding.

According to this DOE analysis, a cellulosic ethanol plant producing 50 million gallons per year would generate 385 full-time jobs for the duration of its three-year construction phase and $110 million in local economic activity. Operation of the plant would create 226 long-term jobs and a total of almost $22 million annually in direct and indirect economic impact, plus $1.24 million in annual property taxes. Ten ethanol plants of that size, an achievable goal for North Dakota (if dedicated energy crops and/or forest residues are used as feedstock in addition to crop residue), would produce 2,260 jobs, $216 million in annual economic activity, and $12.4 million in total local property taxes.

Biopower Works Around the Clock

The same energy crops and crop residues that can be converted into liquid transportation fuels can also be used for direct production of heat and electricity when shredded, gasified, or pelletized and burned as fuel in biomass-fired power plants. Sustainably produced biomass energy feedstock can be stored to generate biopower when it is needed, making it a perfect clean energy complement to the variable output of wind turbines.

Today there are 120 biomass-fired electric power plants in the United States and 48 facilities that co-fire biomass with coal; none are located in North Dakota.[77] The largest biopower facility in the country, a 100 MW plant fueled by wood residue, is under construction in Texas.[78] However, the development of biopower has been impeded by the fact that power systems using "open-loop" biomass, such as agricultural residue, receive only half the production tax credit provided to "closed loop" renewable resources such as wind and geothermal.[79]

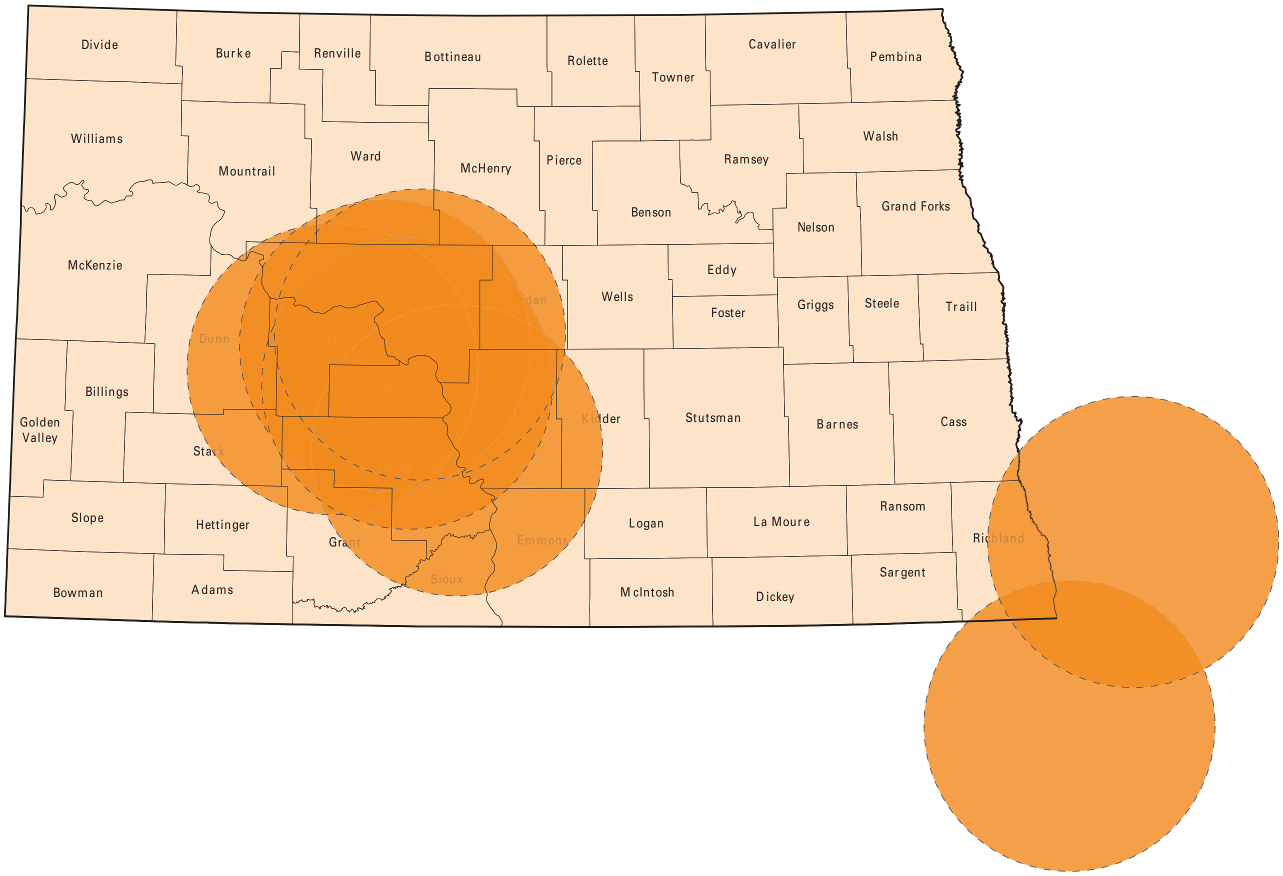
Because biomass can be substituted for a portion of the coal used in existing utility-scale power plants without massive investment in new facilities, it is a relatively low-cost and quick way to ramp up renewable electricity generation in the near term.[80] A study for NREL found a median estimate of $200 to $400 in capital costs per kilowatt of capacity to retrofit a coal plant to co-fire with biomass. The retrofit costs are a small fraction of the costs for a new coal or biomass plant, which are estimated at $2,550 to $5,350 per kilowatt, depending on the technology employed.[81] Biomass can provide 15 percent of the total energy in a coal-fired boiler without any changes beyond adjusting the fuel intake system and modifying the burners.[82] Although building a new power plant that would burn any coal at all cannot be justified on economic or environmental grounds, in some locations it may be cost-effective to build a separate biomass boiler next to an existing coal-fired plant to feed steam into a common turbine.

In Ohio, a sizable coal plant that was putting out so much pollution that the EPA ordered it closed is instead being converted to run on 100 percent biomass, at a retrofit cost of less than $650 per kilowatt.[83] Another utility coal plant in Georgia is being converted to run entirely on wood waste and is expected to have lower fuel and operating costs than when it was coal-fired.[84] A new study about the viability of the proposed facility in Spiritwood, North Dakota (referenced earlier), has shown that using biomass to supplant coal in North Dakota is cost effective at a carbon dioxide price of $25 per metric ton.[85]

Transporting large quantities of solid fuel for long distances is costly, but energy crops and residues in North Dakota could be harvested from areas close to existing coal-fired power plants. Following is a North Dakota map with circles showing the areas within 50 miles of each coal-fired plant, to highlight the regions that could conveniently provide feedstock if the plant were converted to co-fire with biomass.[86] Many of these areas, in the western part of the state, do not have intensive food-crop cultivation and could be suitable for energy crops. However, to avert any undesirable environmental impacts, consideration must be given to the appropriateness of the land and crop for cultivation, the need to avoid displacement of food crops, and the adoption of practices that enhance soil fertility, protect water quality, and preserve wildlife habitat.

The following map on page 15 illustrates the geographic potential of cost-effective biomass production for co-firing in North Dakota—an area of more than 15,000 square miles.

Figure 5: Map of Potential Biomass Resources for Co-firing Using Existing North Dakota Coal Plants



Growing Biomass Can Cultivate Jobs

If 10 percent of the coal that North Dakota currently burns to generate electricity were replaced by biomass, it would create annual demand for about 5.2 million tons of energy crops and residues to produce 2.9 million MWh of electricity.[87] Biopower plants would also create jobs. There are multiple ways to project the employment effects of building and operating new biopower plants. A report commissioned by NREL estimates that each megawatt of biopower capacity creates almost five jobs, with roughly two of them being direct production jobs.[88] Developers of a 50 MW biomass plant in Florida forecast 2.5 direct jobs per megawatt.[89] Assuming three new direct and indirect jobs per megawatt of biopower capacity, if 10 percent of North Dakota's coal-fired capacity were replaced with biopower, more than 1,060 net new long-term jobs would be created (after accounting for the effect on coal employment).[90]

Dedicated Energy Crops Could Fire Up North Dakota's Bioenergy Output

The potential for biomass production from North Dakota's crops can be supplemented by dedicated energy crops grown sustainably on marginal or degraded lands. In addition to oil crops such as camelina, many other fast-growing plants can be cultivated in North Dakota's climate as feedstock for biofuels or biopower. Perennial plants like switchgrass, a tall-growing native prairie grass that does well in much of eastern North Dakota, giant miscanthus, a hybrid grass being grown for energy production in Asia, and fast-growing hybrid poplars and willow trees can be cultivated without much fertilizer on marginal land that is not suitable for row crops. These high-density energy plants have shown yields from

10 to 20 dry tons per acre, far more than the biomass yield of corn or soybeans, and will regenerate without replanting, some for decades.[91] Just as corn yields have increased fourfold in the past 30 years, biomass yields will grow as energy crop hybrids are developed, and certain plants will emerge as best suited for particular growing conditions and different types of energy production.

The Bismarck Plant Materials Center of the USDA ran a five-year test in Upham, North Dakota, of different varieties of bluestem, a common prairie grass, and observed yields as high as 4 dry tons per acre without fertilizer or irrigation.[92] North Dakota is estimated to have almost 20 million acres capable of production of warm-season perennial grasses.[93]

While many potential energy crops are native to the Great Plains, in evaluating the potential for any new energy crop it will be important to conduct a full assessment of the crop's potential invasiveness within the local context prior to commercial production to avoid introducing a plant that could threaten native biodiversity. In addition, if cultivation of bioenergy crops displaces food or fiber crops, the impact on land use from that displaced demand should be taken into account. Diverse native habitat, such as natural forests, wetlands, and native grasslands, should not be converted to bioenergy production. However, if energy crops are grown on degraded or abandoned agricultural land, they may be able to significantly improve both soil quality and wildlife habitat.

The energy content of biomass varies, but it takes about 400 to 700 acres of dedicated biomass crops to fuel 1 megawatt of electric generating capacity for a year, producing enough electricity to power 600 to 900 homes.[94] While the amount of land needed for substantial electricity production from dedicated energy crops is not insignificant, and while many areas are inappropriate for energy crops, sustainable cultivation of energy crops on a very small portion of North Dakota's 44 million acres would be sufficient for extensive biopower production. Because one-time planting costs for most energy crops are relatively high and it takes two to four years to reach maximum yield, growing energy crops is a long-term investment.

A National Strategy Is Needed to Address Biopower's Chicken-or-Egg Dilemma

Why are dedicated energy crops being cultivated in Europe and Asia but not the United States? The answer lies in our failure to adopt a national energy strategy. If North Dakota farmers were confident of selling energy crops, they would invest in planting it where appropriate to do so. If American farm equipment manufacturers were confident of a market for new machinery to process energy crops, they would invest in producing it. And if power generators were confident of ample feedstock supply and long-term energy sales opportunities, they would build facilities to generate biopower. But without a set of national policies designed to move America toward a clean energy economy, nobody in the supply chain—and certainly not the banks and investors that are needed to underwrite it—will take the necessary first step toward creating a viable biopower market.

The clean energy market is replete with similar chicken-or-egg dilemmas that can be effectively addressed only through federal policies that assure both long-term supply and demand for renewable energy.

Biogas Has Multiple Benefits

When animal manure or other organic matter decomposes in the absence of oxygen, it produces a gas containing 60 to 70 percent methane. If released into the atmosphere, methane is a powerful greenhouse gas, with 21 times the global warming effect of carbon dioxide.[95] But burning methane curbs its harmful effect on the climate and releases large amounts of useful energy. Methane, a relatively clean fuel, is the main component of the natural gas and propane used to heat homes; to fire stoves, ovens, and hot water heaters; and to generate electricity. By capturing methane, 496 landfills across the country turn decomposing garbage into a valuable energy resource.[96]

North Dakota's only operating landfill gas facility is in Fargo, where the gas powers an oilseed processing plant run by Cargill.[97] The EPA has identified a closed landfill owned by the city of Grand Forks as a prime candidate for a landfill gas energy (LFGE) plant. Landfills in Minot, Gwinner, and Sawyer are also potential LFGE sites.[98]

For decades, a growing number of large swine and dairy operations in the United States have been managing the immense amounts of manure they produce by using anaerobic digesters to make methane biogas, which is then used to power generators and to create thermal energy. Several anaerobic digester technologies are in use, the most common of

which is a heated "plug flow" tank system. Other biodigester types include covered manure lagoons, from which biogas is piped to a generator, and "complete mix" systems, which are primarily used in dairy operations. Some systems are capable of co-digestion, which allows other kinds of organic wastes to be processed along with manure.

Whatever technology is employed, a biodigester system is a waste management solution with many benefits, including:

- energy production (electricity and heat)
- substantially reduced odor from animal facilities
- reduced potential for groundwater and surface water contamination
- production of high-quality fertilizer and other by-products

Sizable biodigesters and related equipment require an investment of $300,000 to $900,000 or more, with many site-specific cost variables.[99] Although some support is available in the form of state and federal grants and tax credits, the technology is currently used only at 135 large-scale concentrated animal feeding operations (CAFOs) in the United States (compared with about 3,000 farm-scale biodigesters operating in Europe).[100] The federal AgSTAR program estimates that there are 7,000 dairy and swine operations in this country that are good candidates for profitable biodigester systems, having more than 500 head of dairy cows or 2,000 swine.[101]

North Dakota is a sizable livestock producer, ranking 16th in the United States in cattle and 24th in swine.[102] According to NREL, North Dakota has manure management systems producing more than 4,000 tons of methane per year, but this methane is not being captured and used.[103] If all these emissions were converted into energy, livestock manure could generate about 14,000 MWh of energy annually.[104] At the average commercial retail electricity rate in North Dakota of 6.79 cents per kWh, this would yield more than $1 million worth of homegrown power each year, assuming biogas production were eligible for net metering treatment.[105] Additional future revenue could be derived from renewable energy certificates and the potential value of carbon emission credits for burning 4,000 tons of methane, if federal policies to limit greenhouse gas emissions were enacted.[106] While not all manure-based methane can be captured for energy use, North Dakota has potential for biogas production.

The statewide livestock inventory includes 182,000 hogs and pigs, with 18 swine operations of more than 2,000 head and 10 with more than 5,000 head.[107] Some of these may not be ideal for biodigester technology because of the design of their manure systems, but many are likely to be feasible sites. North Dakota is home to just 7 dairy farms with more than 500 cows. However, smaller operations could also benefit from biogas production because centralized systems can allow farms—such as some of the 13 North Dakota dairies with 200 to 500 cows—to (literally) pool their manure resources to create scale economies, as is presently done at several locations in other states.

Following on page 18 is a North Dakota map showing 17 counties with livestock operations potentially large enough to benefit from farm biogas systems.[108]

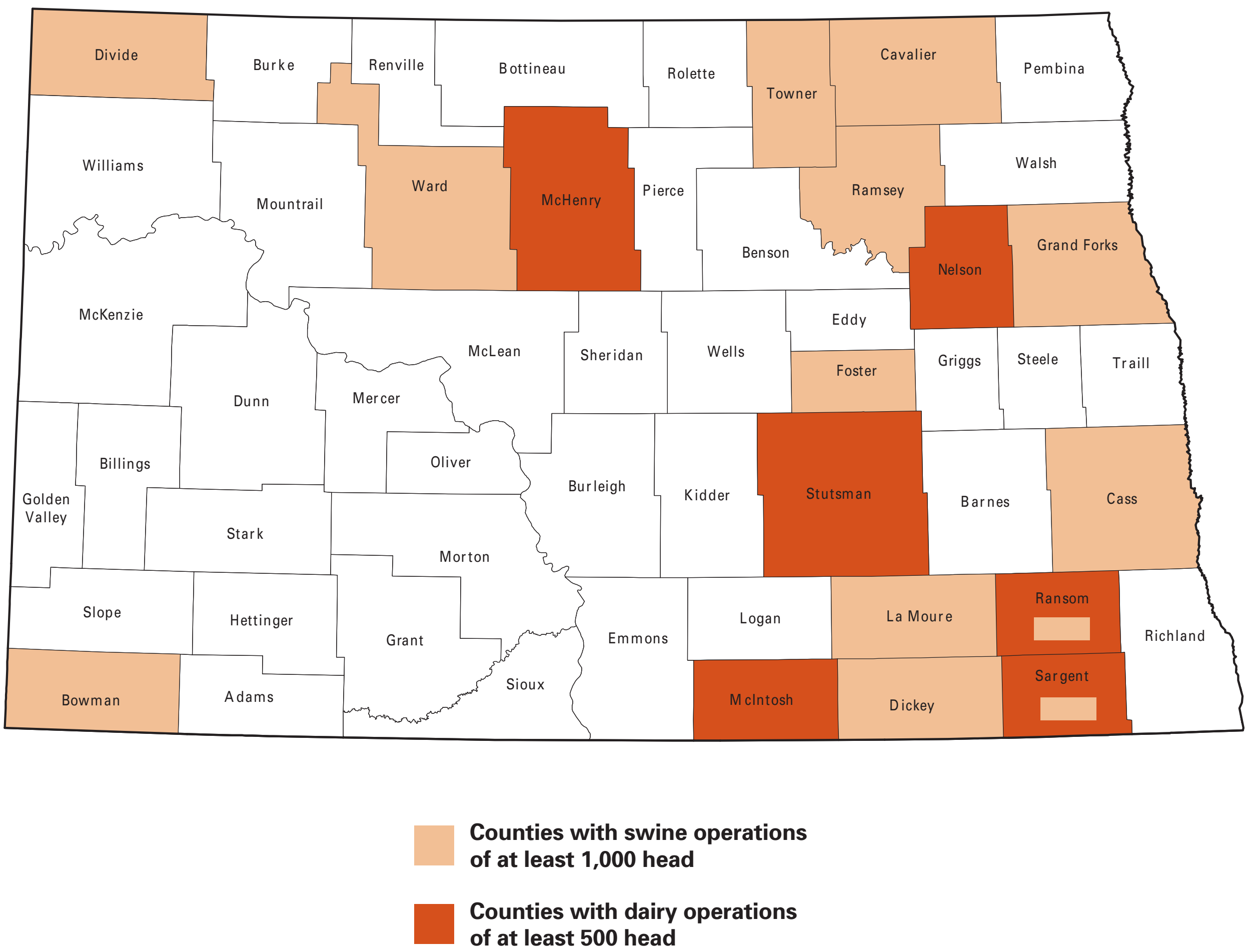
North Dakota has barely begun to take advantage of its animal-based bioenergy potential. But with the right set of supportive government policies in place, the benefits of these technologies to North Dakota's livestock operators and its environment could be realized within just a few years.

North Dakota Farmers Have Many Ways to Benefit From Bioenergy Production

If curbing greenhouse gas emissions becomes national policy, production of bioenergy can become an important farm business opportunity, with multiple potential revenue streams in addition to the sale of energy crops and residues. These include:

- The sale of energy to local utility companies. Producing renewable electricity on the farm can reduce or eliminate monthly electric bills through net metering. North Dakota is among 44 states with a net metering statute that allows small-scale renewable electricity generators to connect to the grid and requires utility companies to buy their electricity output at the retail utility price, up to the amount of usage by the customer.[109] In effect, production of renewable power makes the customer's electric meter "run backward" to reduce the net monthly electricity bill.[110] However, net metering is not available to customers of municipal utilities or electric cooperatives in North Dakota, which serve more than half the state's load. In a national assessment by the Network for New Energy Choices, North Dakota received a grade of D for its restrictive net metering policies, which cap eligible

Figure 6: North Dakota Counties with Livestock Operations Able to Support Methane Biodigester Systems



systems at 100 kilowatts and allow utilities to buy extra renewable electricity generation above the customer's usage for a price equal only to the "avoided cost" of fossil fuel.[111] New federal and state laws are needed to make sure all customers are eligible for net metering and to standardize interconnection policies to make it easy to "plug in" clean energy.

- The sale of renewable energy certificates (RECs). Each MWh of renewable electricity is given an REC (sometimes called a green tag), which is proof of its clean origin. These RECs can be bought and sold in trading markets. Buyers include utilities that are required to purchase green power, plus corporations and individuals who do so voluntarily to support renewable energy development. National clean energy policy directives would add to the long-term value of RECs and stimulate bioenergy production.
- The sale of carbon offset credits. Under a national carbon reduction strategy that includes offsets (which the U.S. Senate is considering in several bills), when a project in a sector not covered by the emissions cap verifiably reduces greenhouse gas emissions or removes carbon from the atmosphere, each ton of reduction generates a carbon credit that can be used to offset emissions elsewhere. These carbon credits could become a valuable new source of revenue for North Dakota farmers and ranchers.[112]

In addition to reducing direct greenhouse gas emissions—for example, by capturing livestock methane through biodigesters or reducing the use of nitrogen fertilizers—another opportunity for farmers to generate carbon offset credits is by enhancing the process by which carbon dioxide is absorbed from the air and stored in the soil. Certain soil management practices, such as no-till or low-till farming, can retain organic materials and carbon in the soil that would be otherwise released into the atmosphere using conventional plowing methods. Other examples of carbon sequestering practices include cover cropping, planting trees on marginal lands, and maintaining riparian buffers. Any assessment of soil carbon sequestration must be subject to site-specific review of soil capacity and farming practices. Future innovations in farm-level enhancement of carbon sequestration methods may provide new options for generating offset credits.

Any carbon offset program must include strict measurement and verification standards to ensure that any claims of direct emission reduction and/or carbon sequestration are demonstrably over and above what would have happened under a business-as-usual scenario in the absence of the offset credit. In 2015, North Dakota will have the potential to produce carbon offsets totaling 1.2 million metric tons of carbon dioxide equivalent ($MMtCO_2e$) from projects in agriculture, landfill gas, and forestry, bringing in revenue of $9 million. In 2030, this potential will increase to 3.9 $MMtCO_2e$ and revenue of $41.3 million.[113]

- The sale of fertilizer: The value of digested solids may be greater than the value of electricity produced by an anaerobic biodigester system. The chemical process of biodigestion converts the organic nitrogen in manure into ammonium, the primary component of commercial fertilizer. Biodigesters create high-quality organic fertilizer that is biologically stable and largely sterilized, with far fewer pathogens and weed seeds and posing less risk of water pollution than standard chemical fertilizers do.
- Sale of animal processed fiber (APF): Some biodigester residues contain reclaimable fiber that can be used for horticulture products and building materials such as fiberboard and plant containers.[114]

CHAPTER 3

Other Clean Energy Opportunities for North Dakota

Geothermal energy production puts the earth's natural heat to work. By circulating water through buried pipes, geothermal heat pump systems can take advantage of the constant 55-degree temperature just a few feet underground to cool a building in the summer and heat it in the winter, dramatically reducing utility bills. According to the EPA, geothermal heat pump systems are the most clean and cost-effective way to maintain building temperatures. And they are well suited for farms and rural areas, where buildings are not densely situated and digging and installation are less expensive.

North Dakota's Geothermal Potential

Although the entire United States is suitable for geothermal heat pumps, there are greater geothermal opportunities in North Dakota than in most states because North Dakota has energy-rich hot water relatively close to the surface. Many parts of the state have geothermal energy at various levels underground that could be accessed for direct hydrothermal applications such as heating buildings, industrial processing, biofuel refining, and agricultural uses such as crop drying and greenhouse heating. New technology being developed for low-temperature geothermal electricity generation may greatly increase the potential for cost-effective small-scale distributed power production from this vast resource.[115] Because of the environmental issues associated with geothermal energy development, a permit from the North Dakota Geological Survey is required for any nonresidential project.[116]

While North Dakota has no operating geothermal energy facilities, the University of North Dakota has received DOE funding for R&D projects studying the feasibility of power generation using hot water encountered when drilling for oil.[117]

The biggest advancement in geothermal technology is EGS, or enhanced geothermal systems, which is based on improved deep-drilling techniques that are beginning to provide access to the massive energy of hot rocks at depths of 1 to 5 miles underground. A comprehensive study conducted by MIT found that a total investment of $1 billion over the next 15 years in EGS research and development—far less than the cost of a single "clean coal" power plant—would bring about the commercialization of this technology.[118]

Geothermal power is one of the few energy resources that can provide continuous clean energy with a very small land-surface footprint and almost zero carbon emissions. However, because EGS requires drilling into deep bedrock and may have effects on underground aquifers, it is vitally important to study the potential water quality impacts and seismicity risks of potential geothermal projects. Increased government support for research, development, and environmentally responsible deployment of geothermal technology is the crucial next step to opening the door to this almost limitless clean energy resource.[119]

North Dakota's Solar Potential

Solar energy is a rapidly growing U.S. energy source, with more than 81,000 solar installations in place at the end of 2008.[120] Photovoltaic capacity installed in 2008 grew by 63 percent compared with 2007 and was triple the amount of capacity installed in 2005.[121] While North Dakota is not thought of as part of the Sunbelt, its relatively dry climate, particularly in the western part of the state, gives it more sunlight than any other state on the Canadian border, and its long summer days provide greater solar electricity potential than places like Jacksonville, Florida, and Houston, Texas.[122] Most of North Dakota has an average solar energy density of 5 to 6 kWh per square meter per day, enough sunlight to derive significant amounts of energy. However, there are currently very few solar installations in North Dakota, with the EIA reporting shipments of photovoltaic cells to North Dakota totaling only 36 kilowatts in 2007 and 2008, and 1,686 square feet of solar thermal collectors in the same period.[123]

In the past, solar electricity has been relatively expensive, but today its price is dropping rapidly. Farm-scale solar electricity production is eligible for sale to utilities under North Dakota's net metering law (described earlier), making photovoltaic solar installations a potentially cost-effective long-term investment. Because of their high energy needs and location in open areas, farms have great potential for solar energy applications using thermal collectors for water and space heating, grain drying, and greenhouse heating, and small-scale photovoltaic electricity production for running irrigation pumps and other farm and home applications.[124]

As its price continues to shrink, solar technology continues to expand. Recently developed flexible thin-film solar cells are far less expensive than rigid polycrystalline photovoltaic panels and have many more potential applications because they can be put on the sides of buildings, on roof shingles, and on windows. Photovoltaic electricity can already be a valuable distributed energy resource, but parts of North Dakota also have good potential for larger-scale solar thermal electricity production. Using mirrors to create concentrated solar power (CSP), this process could provide cost-effective clean energy in coming decades as the technology improves and its costs decline.

North Dakota's Hydrogen Potential

The most abundant clean energy resource is hydrogen, but the technology to produce, store, distribute, and commercialize it is in its infancy. North Dakota is home to the National Center for Hydrogen Technology (NCHT), part of the Energy and Environmental Research Center at the University of North Dakota. NCHT has received more than $60 million in funding for ongoing projects with more than 85 partners engaged in research on hydrogen production and fuel cell technology.

Hydrogen fuel cells create electricity without combustion or moving parts. Instead, they directly convert chemical energy into electricity by combining hydrogen with oxygen, leaving H_2O—water—as the only by-product. Eventual conversion to a "hydrogen economy" is likely, and commercial hydrogen fuel cells are already available for certain applications. But it may take many decades to successfully address the wide-ranging challenges posed by hydrogen energy and to bring the costs of this technology to an acceptable level. In the meantime, the more mature technologies of wind, solar, and biomass can be the foundation of a clean energy economy for North Dakota, while NCHT continues its leadership in shaping the transition to a hydrogen-based energy future.

CHAPTER 4

Reaching the Clean Energy Future: Getting From Here to There

North Dakota can be at the heart of a new clean energy future for America if the right policies are put in place, starting with a national commitment to reduce emissions of global warming pollution, support energy efficiency, and advance development of homegrown renewable energy.

National Policies Needed to Realize North Dakota's Clean Energy Potential

While federal and state programs are playing a critical role in supporting the budding renewable energy industry, they are insufficient to the long-term task of transforming our energy economy, which requires a set of innovative energy policies in addition to program funding.

The most promising comprehensive approach is a "cap-and-trade" framework, under which overall annual limits on global warming pollutants are set, and emitting companies must comply by either reducing their emissions or obtaining "emission allowances" or offsets. The price of allowances would be established in a competitive market, providing incentive for businesses to find the least costly ways to reduce emissions. Generating fossil-fueled power would require allowances while generating carbon-free energy would not, thus leveling the playing field for renewable energy, making it an attractive investment, and spurring innovation in clean energy technologies. The American Clean Energy and Security Act (ACES, H.R. 2454), passed by the House of Representatives in June 2009, proposes this kind of framework and includes strong targets: 17 percent reduction below 2005 levels by 2020; 42 percent reduction below 2005 levels by 2030; 83 percent reduction below 2005 levels by 2050. A cap-and-trade system was employed in the 1990s to reduce "acid rain" caused by power plants, and it led to so much innovation that compliance costs turned out to be 75 percent lower than initial projections.[125] If allowances are fully or partially auctioned under a federal program, part of the money generated could be used to invest in energy efficiency and renewable technologies, so that net costs to energy consumers are minimized.

A strong Renewable Energy Standard achieving 25 percent of U.S. electricity from renewable sources by 2025 would drive economies of scale for maturing technologies in the renewables industry. Such a national commitment to sustainable energy production would:

- Reduce our dependence on foreign oil and improve our energy security
- Create tens of thousands of new Montana jobs and revitalize rural communities
- Support the growth and prosperity of Montana farms
- Ensure a healthy and sustainable environment for future generations

Our national energy strategy also needs to include a low-carbon fuels standard (LCFS) to gradually reduce the overall carbon level of the pool of transportation fuels, when measured on a full-fuel-cycle basis. As a performance standard, LCFS would work hand-in-hand with the emissions cap to ensure that vehicle fuels gradually shift to cleaner alternatives.

Sustainable biomass energy must account for real climate and environmental benefits. For this to happen, three critical and related provisions should be included in national-level clean energy and climate legislation now before the Senate:

1. **Accurate accounting for biomass emissions from sources covered by the cap.** Not all renewable biomass produces zero-carbon energy. But current legislation lacks a way to differentiate low-carbon biomass from high-carbon biomass.
2. **Accurate accounting for emissions from land-use change in the Renewable Fuel Standard.** The 2007 RFS requires a science-based, full-life-cycle analysis that includes the global ripple effect of increased biofuels production, also known as indirect land-use change. The latest research confirms that whether biofuels create or reduce global warming pollution hinges on where and how the feedstocks are produced.
3. **A sound definition of "renewable biomass."** An appropriate definition helps protect sensitive wildlife habitat and natural ecosystems while making a wide diversity of feedstocks available for compliance with the renewable electricity and fuel standards. Biomass sourcing guidelines should provide safeguards for native grasslands, sensitive wildlife habitat, old growth, wilderness, roadless areas, and other especially sensitive components of our federal lands. At the same time, it should include sustainability measures that protect wildlife habitat, soil productivity, and biodiversity in working forests and discourage the conversion of natural forests to less diverse planted forests or energy crops. Loss of forests is one of the greatest threats to biodiversity worldwide and a major contributor to global warming.[126]

Solving the long-term energy crisis will take intensive focus on both the supply and the demand sides of the energy equation. A portfolio of demand-side policies is essential to reducing energy usage, including:

- new vehicle emissions requirements
- stronger national appliance standards
- a national energy-efficient building code
- expanded energy-efficiency investment incentives, loans, and tax credits

Improved energy efficiency is the quickest and most cost-effective way to reduce consumption of fossil fuels. A national Energy Efficiency Resource Standard (EERS) requiring utility companies to phase in programs to save 15 percent of electricity and 10 percent of natural gas by 2020 would cut $170 billion from energy bills and create more than 220,000 jobs, including 402 jobs in North Dakota and more than $270 million in annual savings for North Dakota consumers. Such a commitment to energy efficiency would also eliminate the need to build 390 new power plants and avoid emissions of pollution equivalent to the output of 48 million automobiles.[127]

The small additional cost to make home appliances more energy efficient is far outweighed by the savings consumers achieve when using them. That is why strengthened national energy efficiency standards for home appliances are a critical part of a long-term energy strategy.[128] Similarly, a national energy-efficiency building code for new construction would immediately begin to save occupants money on energy bills and help the environment, while reducing electricity demand and improving system reliability.

Any serious effort to reduce our dependence on fossil fuels also must include vastly increased support for renewable energy research, development, and deployment (RD&D), which continues to lag far behind government funding for fossil fuels and nuclear power.[129] In their developing phases, the nuclear, coal, and oil industries received subsidies an order of magnitude larger than the amount renewable technologies have received. A recent study by the Environmental Law Institute found that a clear disparity continues, with fossil fuels garnering 2.5 times more government support, including all subsidies and tax breaks, than renewable resources from 2002 through 2008.[130] Clean energy RD&D has fallen since the 1970s and is now a small portion of overall government RD&D spending. In order to jump-start clean energy development at this critical juncture, the level of clean energy RD&D must be increased dramatically.

No single deployment support mechanism is optimal for all stages of innovation. Investment tax credits, for example, can be effective in providing up-front capital incentives to expensive, high-risk new technologies. Credits are preferable for more mature technologies to ensure that installed systems deliver the energy they promise. Net metering and interconnection rules enable simple access and price certainty for small distributed installations. To date, legislation under consideration by Congress aims to balance these needs to research, develop and deploy the innovations and technological breakthroughs required to meet the climate challenge, including significant funds for energy efficiency and renewable energy technologies and carbon-capture-and-sequestration (CCS) technology.

Going forward, Congress must craft clean energy deployment policies that effectively address challenges specific to each phase of technology development, while providing needed long-term confidence, security, and stability to drive capital investment.

Prosperity, security, and a healthy planet cannot be achieved in the long run unless we transform the way we produce and use energy. The nascent transition from fossil fuels to renewable resources will be neither easy nor quick, but it presents an unprecedented set of opportunities for a state with the natural resources of North Dakota.

APPENDIX I

Federal Programs and Funding for Clean Energy Development in North Dakota

The federal government offers a number of programs to support renewable energy investors, developers, and property owners. The $786 billion American Recovery and Reinvestment Act of 2009 contains about $50 billion in energy program funding, including extension of clean energy production tax credits and support for transmission infrastructure, "smart grid" investment, low-income housing weatherization, plug-in hybrid electric vehicles, CCS technology development, state and local energy efficiency programs, and loan guarantees for renewable energy projects.

Among the existing, new, or expanded programs are:

- USDA Rural Energy for America Program (REAP) grants[131]
- USDA Rural Energy for America Program (REAP) loan guarantees[132]
- Business Energy Investment Tax Credit (ITC)[133]
- Renewable Electricity Production Tax Credit (PTC)[134]
- Modified Accelerated Cost-Recovery System (MACRS)[135]
- U.S. Department of Treasury Renewable Energy Grants[136]
- Residential Renewable Energy Tax Credit[137]
- Clean Renewable Energy Bonds (CREBs) for municipalities[138]
- DOE loan guarantees for electric transmission infrastructure (section 1705)[139]
- USDA business and industry loan guarantees for economic growth in rural communities[140]
- AgSTAR program to support biodigester installations[141]
- Biomass Research and Development funding[142]

APPENDIX II

State-Level Programs and Funding for Clean Energy in North Dakota

The North Dakota Office of Renewable Energy & Energy Efficiency (OREE) and other state agencies operate programs that support energy efficiency and renewable energy. These include:

- Renewable Energy Program grants[143]
- Renewable energy 3 percent annual tax credit[144]
- Sales tax exemption for non-coal generating facilities equipment
- Large Wind Property Tax Reduction of 70 to 85 percent[145]
- Wind monitoring grants to economic development authorities[146]
- Landfill Gas Feasibility Studies[147]
- Renewable Energy Property Tax Exemption[148]
- Ethanol Production Incentive[149]
- State Facility Energy Improvement Grants[150]
- Residential Efficient Refrigerator Rebate Program[151]
- Low-Income Weatherization Assistance Program[152]
- Energy Efficiency and Conservation Block Grant (EECBG)[153]
- Utility-specific rebate and loan programs[154]
- North Dakota Biofuels Blender Pump grant program[155]

It is becoming clear that North Dakota's economic future is inextricably linked to its energy future. With a commitment to energy efficiency and renewable resource development at the core of a state and national energy strategy, clean energy could become a key homegrown component of a healthy North Dakota environment and a robust North Dakota economy.

Endnotes

1 Bureau of Labor Statistics, Local Area Unemployment Statistics Database, North Dakota http://data.bls.gov/PDQ/servlet/SurveyOutputServlet?series_id=LASST38000004&data_tool=XGtable. Unemployment increased from 11,352 in December 2007 to 15,967 in December 2009.

2 Based on a projected 40 percent average wind “capacity factor”; generators annually produce an amount of energy equal to their rated capacity × capacity factor × 8,760 (number of hours in a year).

3 Calculation based on new wind supplanting coal; North Dakota lignite coal averages 219 pounds of carbon dioxide emissions per million BTU, the highest of any U.S. coal, because it has relatively low energy content of 14.7 million BTU/metric ton (see: www.eia.doe.gov/cneaf/coal/quarterly/co2_article/co2.html). In 2008, North Dakota used about 25 million short tons of coal to produce 29,672,230 MWh of coal-fired electricity, which released 32,848,000 metric tons of CO2, resulting in an average carbon emissions rate of approximately 1.07 metric tons per MWh; 13.1 million MWh of avoided coal emissions = 14 million tons.

4 Calculations for economic and other effects are detailed in the body of the report.

5 19.4 pounds carbon per average gallon of gasoline; 470 M gallons / 2,205 pounds/metric ton = 4,135,147 metric tons

6 According to EIA data at www.eia.doe.gov/cneaf/electricity/st_profiles/sep2008.pdf, the total power production of coal plants in North Dakota in 2008 was 29,551,647 MWh.

7 2.9M MWh out of 32.7MWh total.

8 1.07 metric tons per MWh.

9 Not including the reduction in carbon dioxide emissions from replacing other energy sources.

10 Energy efficiency savings estimates based on ACEEE, “State Benefits From a Federal EERS,” http://aceee.org/pubs/e091.pdf?CFID=3643806&CFTOKEN=11807860.

11 Based on 10 percent of total state consumption of approximately 630 million therms.

12 http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=MT

13 http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=nd.

14 Estimate extrapolated from EIA data showing coal costs of $597 million, petroleum costs of $2.8 billion, and $311 million of natural gas, using estimated 2009 population of 646,844.

15 www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=12794.

16 www.eia.doe.gov/oiaf/aeo/electricity.html.

17 A megawatt (MW) is a measure of electricity production equal to 1,000 kilowatts (kW), or 1,000,000 watts. Therefore, one megawatt is enough power for 10,000 lightbulbs of 100 watts each. A megawatt-hour (MWh) is the amount of power that would be consumed by those bulbs if they were all left on for one hour.

18 Based on 5,484 MW of existing generating capacity and a 1 percent annual demand increase, as forecast by the EIA; additional capacity estimate does not count any replacement of existing power plants.

19 www.eia.doe.gov/cneaf/electricity/st_profiles/sep2008.pdf, p. 205.

20 Calculation based on 91 percent of new capacity being coal, producing 1.07 metric tons/MWh = 2,359 lbs./MWh; 950 MW × 0.91 × 90 percent capacity factor × 8,760 hours = 6.82 million MWh = 7.3 million tons; assuming average car driven 12,000 miles/year @ 22.4 mpg (as per Dept. of Transportation data), emitting 19.4 lbs. carbon/gal. = 10,400 lbs./year per car = 4.72 tons per car. See www.eia.doe.gov/oiaf/aeo/overview.html#trends, also http://epa.gov/otaq/climate/420f05001.htm#carbon.

21 www.census.gov/statab/ranks/rank29.html.

22 www.pewcenteronthestates.org/uploadedFiles/Clean_Economy_Report_Web.pdf.

23 www.res-alliance.org/public/RESAllianceNavigantJobsStudy.pdf.

24 www.ucsusa.org/assets/documents/clean_energy/Clean-Power-Green-Jobs-25-RES.pdf.

25 www.repp.org/articles/BGA_Repp.pdf.

26 www.repp.org/articles/static/1/binaries/LABOR_FINAL_REV.pdf.

27 http://are.berkeley.edu/~dwrh/CERES_Web/Docs/ES_DRHFK091025.pdf.

28 See: http://aceee.org/pubs/e097.pdf?CFID=3643806&CFTOKEN=11807860.

29 www.mckinsey.com/clientservice/electricpowernaturalgas/downloads/US_energy_efficiency_full_report.pdf.

30 http://yosemite.epa.gov/opa/admpress.nsf/0/5B2E6D9AA8D257758525760200686356.
31 http://aceee.org/pubs/e091.pdf?CFID=3643806&CFTOKEN=11807860, see p.19.
32 http://ndare.org/UND percent20Survey.pdf.
33 This consists of 27.5 million acres of cropland, 233,000 acres of woodland, 10.5 million acres of pasture, and 1.5 million acres of ponds, roads, and homes, plus about 3.5 million acres in conservation or wetlands programs. See: www.ers.usda.gov/StateFacts/ND.HTM.
34 See: www.agdepartment.com/PDFFiles/agbrochure2009.pdf.
35 www.awea.org/faq/wwt_potential.html#How percent20much percent20energy.
36 www.awea.org/Projects/ProjectsNew.ASPx?s=North Dakota.
37 See: www.windpoweringamerica.gov/pdfs/2007_annual_wind_market_report.pdf, pp. 17 – 20.
38 www.reuters.com/article/idUSTRE60P36020100126.
39 See: www.americanprogress.org/issues/2010/03/out_of_running.html
40 Source: American Wind Energy Association (AWEA), www.awea.org/newsroom/releases/04-08-10-U.S._Wind_Industry_Annual_Market_Report.html. Household-equivalent number per MW is smaller than average because of the variable output of wind facilities.
41 www.20percentwind.org/report/Chapter1_Executive_Summary_and_Overview.pdf.
42 www.awea.org/faq/wwt_potential.html#How percent20much percent20energy.
43 See table linked to www.windpoweringamerica.gov/wind_resource_maps.asp?stateab=mt&print.
44 www.eia.doe.gov/emeu/aer/pdf/pages/sec8_42.pdf.
45 www.google.com/hostednews/ap/article/ALeqM5g47AnhGbRuj2_mETWwlmUUzeGWPgD9FI6SPG0.
46 See: www.awea.org/faq/wwt_environment.html#Noise.
47 http://eetd.lbl.gov/ea/emp/reports/lbnl-2829e.pdf. An earlier study actually found an increase in property values compared with comparable local property. See: www.repp.org/articles/static/1/binaries/wind_online_final.pdf.
48 This projection is consistent with the goal set by the Empower N.D. Commission: increasing North Dakota's installed wind capacity to 5,000 MW by 2020.
49 These numbers are consistent with a report by Wind Powering America on the benefits of 1000 MW of wind development in North Dakota; see: www.windpoweringamerica.gov/windandhydro/windpoweringamerica/econ_project_detail.asp?id=16.
50 Based on an average capacity factor for new wind facilities of 40 percent; the Wind Resource Potential chart above shows a significant portion of North Dakota wind with potential capacity factors of 50 percent or higher.
51 See: www.repp.org/articles/BGA_Repp.pdf.
52 www.ers.usda.gov/Statefacts/ND.HTM
53 See: www.awea.org/faq/wwt_basics.html#How %20many %20turbines %20does %20it %20take %20to %20make %20one %20megawatt %20. New GE wind turbines slated for operation in 2012 will have capacity of 4 MW, with rotor diameters of 360 feet.
54 www1.eere.energy.gov/windandhydro/pdfs/43025.pdf, p. 21.
55 www.gao.gov/new.items/d04756.pdf.
56 www.greentechmedia.com/articles/read/wind-industry-reports-growth-in-2009/. In 2008 electricity production, including exports, totaled 32,734,579 MWh, and wind accounted for 1,693,458 MWh. See "Net Generation by State by Type of Producer by Energy Source" (EIA) at www.eia.doe.gov/cneaf/electricity/epa/epa_sprdshts.html.
57 According to the National Research Council study, 384 million dry tons is available from agricultural and forestry residues and municipal solid waste. Early studies suggest that today cover crops could produce between 2 and 3.6 tons per acre of biomass when harvested and up to 5 tons with good weather and fertile soil. If 10 percent of the nation's 220 million acres of field-crop land were cover-cropped and the biomass harvested, this would produce between 44 million and 110 million tons per year. If incentives boosted cover-crop adoption rates to 30 percent, 66 million acres of land would be planted in cover crops, yielding between 132 million and 330 million tons per year of biomass. Because cover crops are best managed as a system with agricultural residues, these numbers may not be entirely additive to the NRC's 130 million tons of residues. Thus, combining innovative farm practices, such as double cropping winter cover crops with potential dedicated energy crops on marginal or abandoned land, an additional 40 million to 330 million dry tons could be available. These estimates do not include the potential of biofuel production from algae.
58 www.communityservices.nd.gov/uploads/resources/626/empower-nd-policy-03.17.09.pdf; www.nass.usda.gov/Statistics_by_State/North_Dakota/Publications/Top_Commodities/pub/rank10.pdf. [These leading North Dakota crops include barley, navy beans, pinto beans, canola, flaxseed, honey, lentils, peas, sunflowers, and wheat. North Dakota is also a major producer of oats, sugar beets, corn, and hay.]

59 See: www.farmandranchguide.com/articles/2007/10/26/ag_news/regional_news/news11.txt.
60 www.undeerc.org/news/newsitem.aspx?id=356.
61 www.undeerc.org/news/newsitem.aspx?id=346.
62 See: http://thefraserdomain.typepad.com/energy/2006/11/broin_companies.html; www.ethanoltoday.com/index.php?option=com_content&task=view&id=5&fid=17&Itemid=6.
63 Worldwatch Institute, "Smart Choices for Biofuels," p. 8, www.worldwatch.org/files/pdf/biofuels.pdf.
64 See: www.ers.usda.gov/AmberWaves/April06/Features/Ethanol.htm.
65 www.newrules.org/de/energyselfreliantstates.pdf.
66 www.biomassmagazine.com/article.jsp?article_id=3639.
67 www.statemaster.com/state/ND-north-dakota/geo-geography. North Dakota has 28.277 million acres of cropland, almost 65 percent of its total area.
68 For calculations of actual usable portion of crop residues, see: www.afdc.energy.gov/afdc/pdfs/39181.pdf.
69 Various studies have estimated cellulosic ethanol yields of up to 110 gal./dry ton; the number used here assumes no increase in the current yield of about 70 gal./ton.
70 Based on Federal Highway Administration statistics; see: www.fhwa.dot.gov/policy/ohim/hs06/htm/mf21.htm.
71 Estimate based on 6.7 million tons of biomass at a conservative 4,300 Btu/lb., or about 2/3 the energy by weight of lignite; see http://bioenergy.ornl.gov/papers/misc/energy_conv.html. North Dakota's electricity generation in 2008 = 32,734,579 MWh; see: www.eia.doe.gov/cneaf/solar.renewables/page/state_profiles/north_dakota.html.
72 Assuming 19.4 pounds of carbon per gallon (see: http://epa.gov/otaq/climate/420f05001.htm#carbon) and typical average gas usage of 536 gallons per vehicle per year.
73 This value will depend on many variables. See reports of the multiagency Biomass Research and Development Initiative (BRDI), www.brdisolutions.com/default.aspx; also www.greatriverenergy.com/makingelectricity/biomass_feasibility_rpt.pdf. Also see: www.usda.gov/oce/reports/energy/AER819.pdf.
74 0.6 ton/acre x $40/ton x 685 acres (8.43 million acres of wheat/12,300 farms in 2007) = $16,440.
75 1.3 tons/acre x $40/ton x 405 acres (2.35 million acres of corn/5,800 farms in 2007) = $21,060.
76 www.fsa.usda.gov/Internet/FSA_File/bcapfacilitieslist.pdf.
77 See http://cta.ornl.gov/bedb/biopower/Current_Biomass_Power_Plants.xls.
78 www.amrenewables.com/our-projects/nacogdoches-power.php.
79 Closed loop systems use inputs dedicated to energy production, while open loop systems use inputs with primary purposes other than energy.
80 Biomass can also be liquefied through a process of pyrolysis, or gasified, and then used as power plant fuel; as the technologies develop, these processes may eventually be more efficient than solid biomass for electricity generation.
81 Lazard, "Levelized Cost of Energy Comparison, " http://www.narucmeetings.org/Presentations/2008%20EMP%20Levelized%20Cost%20of%20Energy%20-%20Master%20June%202008%20(2).pdf
82 www.nrel.gov/docs/fy00osti/28009.pdf.
83 See: http://news.prnewswire.com/DisplayReleaseContent.aspx?ACCT=104&STORY=/www/story/08-11-2009/0005075796&EDATE, also www.powermag.com/renewables/waste_to_energy/1874.html.
84 http://mydocs.epri.com/docs/CorporateDocuments/Generation/Southern_Company_Biomass_Studies.pdf.
85 www.greatriverenergy.com/makingelectricity/biomass_feasibility_rpt.pdf.
86 The EIA uses 50 miles as a feasible distance for economic transportation of energy crops; see http://tonto.eia.doe.gov/FTPROOT/modeldoc/m069(2008).pdf. Also included on the map are areas of North Dakota that are within 50 miles of a coal-fired plant in an adjacent state.
87 Calculated by converting 10 percent of the 24.7 million tons of coal used in North Dakota each year (as per EIA data at www.eia.doe.gov/cneaf/coal/page/coaldistrib/2007/d_07state.pdf) and assuming 9,000 btu/lb. for coal and 4,300 btu/lb. for biomass. Some biomass crops such as switchgrass and miscanthus have energy densities as high as 7,500 btu/lb.
88 http://nrel.gov/docs/fy00osti/27541.pdf.
89 http://us.arevablog.com/2009/05/27/adage-announces-proposed-site-of-first-us-biopower-facility/
90 Estimate based on: 10 percent of North Dakota coal power capacity = 425 MW = 1275 new jobs, reduced by a proportional share of coal O&M and fuel procurement (total of 764 North Dakota jobs in coal O&M, 947 in mining), www.sourcewatch.org/index.php?title=Coal_and_jobs
91 BRDI, "Increasing Production for Biofuels," p.23; also see http://farmindustrynews.com/biofuels/0501-popular-trees-study/
92 www.plant-materials.nrcs.usda.gov/pubs/ndpmcpu7933.pdf
93 http://agbiopubs.sdstate.edu/articles/SGINC2-07.pdf

94 See also Oak Ridge National Lab report at http://bioenergy.ornl.gov/main.aspx#
95 IPCC Fourth Assessment Report (2007) Working Group I Report "The Physical Science Basis" http://www.ipcc.ch/ipccreports/ar4-wg1.htm.
96 www.epa.gov/lmop/docs/map.pdf.
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99 AgSTAR estimates the cost at $150 to $400 per 1,000 lbs. livestock weight. See: www.epa.gov/agstar/pdf/manage.pdf.
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101 "Market Opportunities for Biogas Recovery Systems," U.S. EPA/AgSTAR, 2006 http://www.epa.gov/agstar/pdf/biogas%20recovery%20systems_screenres.pdf
102 www.agcensus.usda.gov/Publications/2007/Online_Highlights/County_Profiles/North_Dakota/cp99038.pdf.
103 See: www.afdc.energy.gov/afdc/pdfs/39181.pdf, p. 17.
104 Extrapolated from www.epa.gov/agstar/pdf/biogas percent20recovery percent20systems_screenres.pdf.
105 See: www.eia.doe.gov/cneaf/electricity/epm/table5_6_b.html
106 The market value of renewable energy certificates and carbon credits depends on the specific policies adopted. Today, RECs cost from about $7 to $35/MWh.
107 *2007 Census of Agriculture*, U.S. Department of Agriculture.
108 See http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_County_Level/North_Dakota/st38_2_012_012.pdf and http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_1_State_Level/North_Dakota/st38_1_017_019.pdf. Available county level swine data does not detail the farms above 1,000 head. State level data shows 18 farms with more than 2,000 swine, located in the 10 counties with more than 1,000 head.
109 In North Dakota, net metering applies to a maximum 100 kW capacity for residential, commercial, and industrial systems.
110 For North Dakota net metering rules, see: www.legis.nd.gov/information/acdata/pdf/69-09-07.pdf.
111 www.newenergychoices.org/uploads/FreeingTheGrid2008_report.pdf.
112 The National Carbon Offset Coalition (NCOC) is working with rural economic interests throughout North America to expand the market of tradable and verifiable carbon offset credits. See: www.ncoc.us/.
113 Based on University of Illinois, Yale University, and University of California EAGLE analysis, USDA farm output data at www.ers.usda.gov/Data/AgProductivity/, forestry potential from www.statemaster.com/graph/geo_lan_acr_tot_for_lan-geography-land-acreage-total-forest, and new landfill gas potential from www.epa.gov/lmop/basic-info/index.html#03.
114 AgSTAR Powerpoint presentation by Chris Voell. http://www.harvestcleanenergy.org/conference/HCE8/Presentations/Voell.pdf
115 See: www.technologyreview.com/read_article.aspx?id=17524.
116 See: www.energy.wsu.edu/documents/renewables/NorthDakota.pdf.
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124 For a detailed description of agricultural solar applications, see: www.nyserda.org/programs/pdfs/agguide.pdf.
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126 Intergovernmental Panel on Climate Change, *Climate Change 2007: Synthesis Report Summary for Policymakers*, p. 5. Available at www.ipcc.ch/pdf/assessment_report/ar4/syr/ar4_syr_spm.pdf.
127 http://aceee.org/pubs/e091.pdf?CFID=3643806&CFTOKEN=11807860; see p. 19 for state savings table.
128 See: www.nrdc.org/air/energy/fappl.asp and www.nrdc.org/globalWarming/cap2.0/files/kick.pdf.
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