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A Clean Energy Economy for Missouri

Analysis of the Rural Economic Development Potential of Renewable Resources

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Executive Summary

In this time of global economic adversity, the state of Missouri is facing an unprecedented set of economic and energy challenges. Missouri, however, is also one of the most fertile states for the production of clean energy. Within its borders, dispersed across the state, are vast resources of wind, land, and water—all the ingredients needed for Missouri to become a national leader in new energy development, creating tens of thousands of good jobs and substantial new sources of income for farmers.

Because of the inextricable link between our energy future and economic future, the U.S. Congress is considering policies to support the development of a new domestic energy industry based on renewable resources. As part of the 2009 economic stimulus package, Congress extended existing support for renewable electricity sources like wind and solar energy, but that is just the start of what needs to be done.

This paper examines the potential for renewable energy resource development in Missouri and its benefits to rural communities.

Rising Energy Costs Are Draining Missouri's Economy

Today Missourians spend more than \$18 billion every year on natural gas for heating, fuel for cars and trucks, and electricity to power homes and businesses.¹ With a population of about 6 million, that amounts to \$3,000 in energy costs for every person in Missouri—and most of those dollars leave the state, never to return. Eighty-four percent of Missouri electricity is generated using coal—almost all of it shipped from distant Wyoming.² If nothing is done to reduce the growing demand for electricity and Missouri continues its dependence on coal, in coming years consumers may see big hikes in electric rates to pay for new power plants—and an increase in global warming pollution equivalent to adding 2.2 million cars to Missouri roads.³

If energy consumption continues to grow at the current rate, imports of fossil fuels into Missouri—and outflow of Missourian's energy dollars—will triple by the middle of this century.⁴ To avoid such losses, commitments to dramatically improve energy efficiency as well as develop renewable resources must become the twin engines of Missouri's energy future.

Renewable Resource Development Can Prime Economic Growth in Missouri

The Missouri economy lost more than 50,000 manufacturing jobs in recent years (even before the current economic downturn began in fall 2008). But Missouri's enormous untapped capacity for renewable energy production creates an unprecedented set of opportunities for long-term economic growth. The areas most ripe for commercial development today are the wind, biomass, and biogas sectors. Missouri also has potential to benefit from ongoing innovation in an array of emerging clean energy technologies suitable for development in the state.

“Within Missouri's own agricultural capacity lies a possible solution to our nation's energy crisis.”

—Missouri Governor Jay Nixon

Wind

Missouri has more than 2,500 square miles of land with commercial-grade wind resources, a power potential equal to 63 percent of the state's electricity use. Development of just a small fraction of this wind power would create thousands of new jobs to build and operate wind facilities and potentially many thousands more manufacturing jobs to supply wind turbine components. Wind power would provide a major source of new income for many Missouri farmers, and its taxes and economic multiplier effects would support rural communities. Federal government statistics show that the operation of 25 moderate-scale wind facilities (an achievable state goal) would provide thousands of construction jobs, 550 permanent jobs, \$15 million in property tax, and \$75 million in ongoing positive local economic impact in Missouri. And instead of importing energy from across the globe, Missouri could become an exporter of homegrown energy to parts of the country to its south and east that do not have the state's wind capacity.

Biofuels

Cellulosic ethanol, which is made from crop waste and nonfood plants instead of edible plant sugars and starches, is the future of smart biofuels; Missouri is perfectly situated to become a center of its production. Missouri produces usable crop residues sufficient to produce 500 million gallons of transportation fuel each year and has enormous potential to grow dedicated energy crops on marginal or unused land. Biofuel produced from existing waste biomass alone could create thousands of jobs, hundreds of millions of dollars of economic activity, and \$13,000 annually in gross income for the average Missouri corn farmer.

Solid Biomass (Biopower)

Electric power generation that combines solid biomass (from dedicated nonfood energy crops and crop residues) with coal at existing plants would be a relatively low-cost way to ramp up renewable resource development across the state and displace coal usage. Retrofitting existing plants to use biomass instead of coal would avoid massive investment in new facilities while cutting back on coal consumption. Unlike wind and solar, solid biomass (combusted alone or co-fired with coal) has the advantage of being "dispatchable": a resource that can be used for around-the-clock electric capacity. Replacing even a small percentage of Missouri's coal usage with locally grown biomass would create thousands of jobs.

Biogas

Methane from decomposing manure is a powerful greenhouse gas with 21 times the heat-trapping effect of carbon dioxide (CO₂) when released into the atmosphere. It is also a relatively clean and efficient fuel when burned for energy.

MISSOURI'S CITIZENS SUPPORT CLEAN ENERGY

In November 2008, Missouri citizens recognized the importance of moving toward a new energy economy when they voted decisively (66 percent) in favor of "Proposition C," a referendum to require utilities to generate or purchase at least 15 percent of their electricity from renewable sources by 2021. Missouri has now joined 26 other states in establishing a "Renewable Energy Standard,"^a which mandates that an escalating percentage of a jurisdiction's electricity be generated from renewable energy sources by certain dates.



Meeting the Missouri standard will eventually require more than 2000 megawatts (MW)^b of new renewable electricity generation. But the potential benefit to Missouri's economy and its people is far greater if national policies in support of renewable energy and energy efficiency are enacted. In fact, Missouri is one of the best-positioned states to produce a wide range of clean energy products and to compete for the multi-billion dollar annual investments that would result from a national commitment to "green power." As Governor Jay Nixon said in his 2009 State of the State address, "Within Missouri's own agricultural capacity lies a possible solution to our nation's energy crisis."

^a Also known as a "Renewable Portfolio Standard" (RPS).

^b A megawatt is a measure of electricity output equal to 1000 kilowatts or a million watts. One megawatt equals the power demand of about 600 to 900 homes.

The operation of 25 moderate-scale wind facilities (an achievable state goal) would provide thousands of construction jobs, 550 permanent jobs, \$15 million in property tax, and \$75 million in ongoing positive local economic impact in Missouri.

In addition to providing new farm income from energy and carbon credits, anaerobic digestion systems create high-quality fertilizer and other valuable byproducts, while reducing odors, water pollution, and emissions. Biogas production would be profitable at more than 200 large-scale livestock operations in 60 Missouri counties.

Other Renewables

- **Solar:** Although the cost of photovoltaic installations is already dropping, further state incentives include a 20 to 25 percent reduction in the cost of farm-placed arrays and a net-metering law that enables small producers to sell electricity back to the grid. Because of their intensive energy needs and location in open areas, farms have great potential for using solar energy applications such as water and space heating, grain drying, greenhouse heating, and electricity production.
- **Geothermal:** The clean and cost-effective geothermal system of summer cooling and winter heating circulates fluid through pipes in the constant-temperature stratum a few feet underground and then through the structure. This is especially suitable for rural areas where buildings are not densely situated and digging and installation are less expensive.
- **Aquatic Biomass:** Aquatic plants such as duckweed and water hyacinth thrive in the climate of southern Missouri, and can have productivity rates higher than soil-based crops. These can provide biomass feedstock for electrical generation and transportation fuels.
- **Soil Carbon Sequestration:** By implementing “no till” or “low till” farming methods, one acre of corn field may be able to retain half a ton of carbon dioxide that would otherwise be released using conventional tilling means. Restoring wetlands and planting trees not only sequesters carbon, but also may generate credits that could be traded or used for carbon offset under certain carbon reduction strategies.

National Policy Recommendations for Advancing Clean Energy in Missouri and Across the Country

Missouri has taken important initial steps to implement clean energy policies, but those actions must go arm-in-arm with national policies that will move America toward a revitalized energy economy. The U.S. Congress is considering legislation to begin the transition to a clean energy economy through a range of policies 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
- 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

With the right policies in place, Missouri can be at the heart of a new energy future for America. The development of homegrown renewable energy is the keystone of such policy.

CHAPTER 1

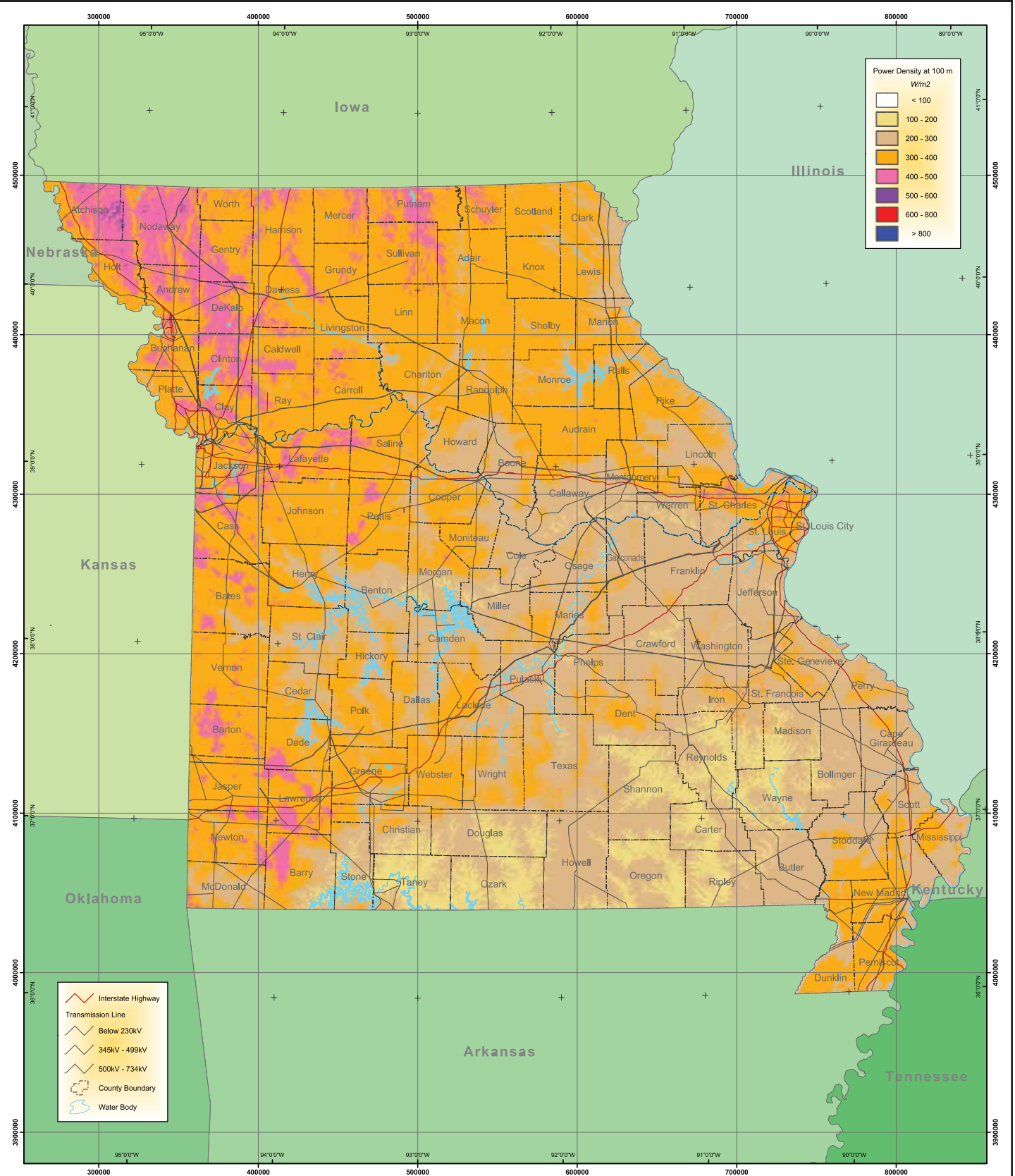
Missouri's Wind Potential

Over the last decade, wind power has become among the most cost-effective of renewable electricity technologies. The supply of wind power in the United States jumped by 50 percent in 2008, bringing the total installed capacity to more than 25,000 MW—enough electricity to supply the needs of 7 million households.⁵ Despite the state's abundant wind resources, only about half of 1 percent of the nation's wind power is presently located in Missouri, even though Missouri ranks in the top 20 states for wind energy potential,⁶ with an annual potential commercial production of 52 million megawatt-hours (MWh)⁷—equivalent to 63 percent of all the electricity used in the state today. Development of just a small fraction of this potential wind power would have enormous economic benefits for rural Missouri. Instead of importing energy from across the globe, Missouri could export this homegrown energy to other states.

Improvements in wind technology have brought its costs down to a level that is becoming competitive with fossil-fueled generation.⁸ Like other renewable power sources, wind supply is inexhaustible, produces no waste, causes no pollution, and its costs are not subject to volatility nor to geopolitical conditions. While just 1 percent of total U.S. electricity supply comes from wind today, a report by the U.S. Department of Energy (DOE) concluded that 20 percent of America's electric power could be wind generated within about 20 years if the right set of policies is pursued.⁹

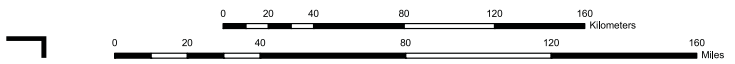
Compared to fossil-fueled generation, wind is a benign source of power. Modern wind turbines turn relatively slowly, although occasional bird and bat collisions occur. A recent study showed that the bird mortality rate for existing wind turbines is only about two bird deaths per turbine each year, which is a minuscule number when compared with other human sources of avian hazards (e.g., power lines, cell towers, and reflective glass on buildings).¹⁰ While noise from wind turbines was a problem with early designs, today's wind turbines are “no noisier than the reading room of a library” at 300 meters away.¹¹ And despite concerns that wind development would reduce the values of surrounding property, a detailed study by the Renewable Energy Policy Project (REPP) has found no negative effects.¹²

Figure 1: Mean Wind Power Density of Missouri at 100 Meters

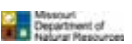


Interstate Highway
 Transmission Line
 Below 230kV
 345kV - 499kV
 500kV - 734kV
 County Boundary
 Water Body

Projection: Transverse Mercator, Zone 15
 Spatial Resolution of Wind Resource Data: 200m
 This map was created by AWS Truewind using the MesoMap system and historical weather data. Although it is believed to represent an accurate overall picture of the wind energy resource, estimates at any location should be confirmed by measurement.
 The transmission line information was obtained by AWS Truewind from the Platts POWERmap Transmission Line Layer. AWS does not warrant the accuracy of the transmission line information.
 Sources: POWERmap, powermap.platts.com
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Prepared for the Missouri Department of Natural Resources with financial assistance from U.S. DOE's Wind Powering America program.



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Location and Wind Density

Like any other power plants, wind turbines must be connected to the electricity transmission system to be able to send electricity where it is needed. Because wind development is often in remote locations, new transmission lines must often be built, which adds to the cost of the “grid” but makes it more robust and less prone to power outages. However, the proximity of Missouri’s wind projects to load centers such as Kansas City and St. Louis should serve to minimize transmission construction costs because of the relatively short distances to be traversed and the potential to use existing lines. While the wind is gustier in places like North Dakota, Missouri’s advantageous location may make its wind power more cost-effective to develop.

Wind “density,” a measure of how hard and steady the wind blows in a given area, is the standard used to assess the quality of wind for electricity production. The latest big wind turbines, reaching heights of 300 feet or more, can capture these good wind resources. Western Missouri, for example, has many areas with commercially viable wind resources (see Table 1).

The counties with significant areas of commercial-grade wind density are listed below along with their estimated highest quality wind areas (in square miles):

Table 1: Missouri Counties with Significant Areas of Commercial-Grade Wind Density

County	Square Miles of Wind-Dense Areas	County	Square Miles of Wind-Dense Areas
Andrew	125	Harrison	50
Atchison	200	Holt	150
Barry	100	Jackson	50
Barton	100	Lafayette	125
Bates	50	Lawrence	125
Buchanan	50	Mercer	50
Caldwell	50	Newton	50
Cass	100	Nodaway	250
Clay	50	Pettis	50
Clinton	175	Platte	50
Dade	50	Putnam	175
Daviess	50	Ray	50
DeKalb	150	Sullivan	50
Gentry	125		

NOTE: The areas estimated in Table 1 total more than 2,500 square miles. These numbers are general estimates based on available wind density maps and are not precise measurements.

The average farm in Missouri is 269 acres.¹³ While there are many factors determining how many wind turbines can be placed in a particular location, the rule of thumb is that about 60 to 90 acres of land are needed for each large turbine. The wind towers and the roads to get to them have a “footprint” of only about one-half acre per turbine—the rest of the acreage can be farmed—but the towers need to be spaced apart to take maximum advantage of the wind and avoid interfering with each other. An average farm could therefore have about three or four wind turbines, and receive about \$18–24,000 in annual income from land-lease payments.¹⁴ A 100-MW wind project would have about 50 large towers spread across the equivalent of 15 average-size Missouri farms.

The Economic Boon of Wind Power

The U.S. Department of Energy (DOE) has developed a “Jobs and Economic Development Impact” model (JEDI) 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. Table 2, excerpted from JEDI, details the predicted economic impact of a 100-MW Missouri wind facility.

Table 2: Predicted Economic Impact of a 100-MW Missouri Wind Facility

Missouri Wind Farm - Project Data Summary	
Project Location	MISSOURI
Year of Construction	2011
Total Project Size - Nameplate Capacity (MW)	100
Number of Projects (included in total)	1
Turbine Size (kW)	2000
Number of Turbines	50
Installed Project Cost (\$/kW)	\$2,031
Annual O&M Cost (\$/kW)	\$19.80
Money Value (Dollar Year)	2008
Installed Project Cost	\$203,101,647
Local Spending	\$36,253,783
Total Annual Operational Expenses	\$33,401,922
Direct Operating and Maintenance Costs	\$1,979,981
Local Spending	\$677,507
Other Annual Costs	\$31,421,942
Local Spending	\$875,454
Debt and Equity Payments	\$0
Property Taxes	\$575,454
Land Lease	\$300,000

Local Economic Impacts - Summary Results			
Earnings and output values are millions of dollars in year 2008 dollars			
	Jobs	Earnings	Output
During Construction Period			
Direct Impacts	66	\$4.1	\$4.7
Onsite Construction and Interconnection Labor	60	\$3.6	
Onsite Construction Related Services	6	\$0.5	
Indirect Impacts	353	\$12.9	\$41.6
Induced Impacts	155	\$5.0	\$16.2
Total Impacts (Direct, Indirect, Induced)	575	\$22.0	\$62.6
During Operating Years (Annual)			
Direct Impacts			
Onsite Wind Farm Labor Only	6	\$0.4	\$0.4
Indirect Impacts	9	\$0.3	\$1.7
Induced Impacts	9	\$0.3	\$0.9
Total Impacts (Direct, Indirect, Induced)	23	\$1.0	\$3.0

NOTE: Construction and operating jobs are full-time equivalent for a period of one year (1 FTE = 2,080 hours). Wind farm workers include field technicians, administration and management. Economic impacts "During operating years" represent impacts that occur from wind farm operations/expenditures. "Other Annual Costs" are costs of debt and equity, which are included as parts of Total Annual Operational Expenses. 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 values.

Source: U.S. Department of Energy JEDI model.

According to this DOE analysis, a 100-MW wind project in Missouri would produce 575 jobs and \$62.6 million in local economic activity during its construction phase. Operating the plant would generate 22 full-time-equivalent local jobs, \$575,000 in property taxes, and \$3 million in economic benefit to the local economy each year. If 25 such wind facilities were built in Missouri (an achievable goal) the result would be not only many thousands of construction jobs but 550 permanent jobs, almost \$15 million in annual property tax revenue, and \$75 million per year in ongoing positive economic impact on local communities.

A promising option with potential to provide far greater local benefits than wind development by distant third parties is known as “community wind.” Several states, led by Minnesota, have successfully implemented policies to promote ownership of wind facilities by individual farmers, groups of adjacent farms, and local communities. Because the economies of scale for wind power are primarily driven by the size and height of a turbine, not the number of turbines in a project, facilities with a small number of large turbines—or even just one—can produce power at costs similar to big corporate wind developments. A study at Lawrence Berkeley National Laboratory found that wind project development costs in 2007 did “not show strong evidence of economies of scale.”¹⁵ Financing of any size wind facility remains a significant hurdle, particularly in the current economic environment. However, the 2009 federal economic stimulus package contains new support for renewable energy projects, including the option of upfront financial grants instead of long-term tax credits, making it easier to finance smaller facilities. The General Accounting Office (GAO) reported in 2004 that farmers could “double or triple” their wind income through ownership rather than land-lease arrangements.¹⁶

The emergence of a large domestic wind power industry would be a boon to the economy of many parts of rural Missouri, and it would also mean a huge new market for domestic manufacturers of the components that go into wind turbines, towers, and other renewable facilities. The Renewable Energy Policy Project recently completed a detailed state-by-state study of the potential for existing companies to supply parts for renewable energy facilities.¹⁷ This new market could help revitalize Missouri’s economy, which, as the report points out, lost more than 50,000 manufacturing jobs in recent years (even before the 2008–2009 economic downturn). REPP identified 785 firms in Missouri with the capability to manufacture components of renewable power plants, ranking the state thirteenth among all states in the amount of manufacturing activity that would be created by burgeoning demand for renewable energy.¹⁸

REPP also reports that wind energy generates 5.7 person-years of employment per million dollars in investment over ten years, whereas coal industry spending generates only 4.0 person-years of employment over the same period.¹⁹

Missouri has a budding wind power industry but lags behind other states that also have good wind resources. Today there are three utility scale wind projects in the northwest corner of Missouri,²⁰ with a combined 163 MW of power generating capacity. Together they can produce about 500,000 MWh of electricity each year, amounting to about six tenths of 1 percent of retail sales of electricity in Missouri. In neighboring Iowa, which now leads the nation in wind power, there are nine wind farms with a total capacity of 2790 MW,²¹ while Illinois has 915 MW of operating wind power facilities.²² There’s a great distance to go for Missouri to fulfill the promise of its wind resources. But under new national renewable energy policies, Missouri’s substantial wind potential may be realized—and its economic benefits attained.

CHAPTER 2

Missouri's Biomass Potential: Liquid Biofuels, Solid Biomass, 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 it 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 fuel for cars and trucks. “Biogas” produced from animal waste and other organic waste materials can be used to generate heat and electricity.

Biomass has recently surpassed hydropower as the largest source of renewable energy in the U.S., but still accounts for just 3% of all domestic energy consumption. Using biomass energy can result in far less global warming pollution than fossil fuels, 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 grow. To fully understand the carbon balance of different biomass resources, we have to thoroughly account for direct impacts to the soil, the energy and emissions involved in cultivation, as well as indirect land use impacts. Some sources of biomass are actually carbon sinks over time, while others can actually end up releasing 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 an assessment of, and the adoption of practices to avoid, direct impacts to resources such as soil, water and wildlife habitat, as well as indirect land use impacts.

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

Why are dedicated energy crops being cultivated in Europe and Asia and not the U.S.? The answer lies in our failure to adopt a national energy strategy. If Missouri farmers were confident of a long-term market for energy crops, they would invest in planting it. 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 and immediately addressed only through federal policies that assure both long-term supply and demand for renewable energy.

Biofuels Must Be Done Right to Reap Environmental Benefits

Most gasoline already comes blended with 10 percent ethanol, a biofuel produced today primarily from corn. Missouri has five facilities making corn ethanol, with capacity to make about 200 million gallons per year, or 2.5 percent of the 9 billion gallons produced nationwide.²³ Neighboring Iowa is the nation's ethanol leader, with 38 refineries capable of producing more than 3 billion gallons per year.

But producing ethanol from crops like corn can drive up food prices (as well as ethanol prices) and cause undesirable land use changes, which is why new technology is being developed to make ethanol from crop waste and nonfood plants. Instead of using edible plant sugars and starches, this new type of ethanol is made by breaking down the fibrous material that makes up the non-edible cellulose structure of plants. "Cellulosic" ethanol can be made from almost any kind of plant or wood waste, including corn stover, cotton gin waste, wood trimmings, and high-density energy crops such as switchgrass and miscanthus. Cellulosic ethanol produces far more energy than corn ethanol—from four to ten times as much energy relative to the amount of energy required to grow the crops and produce the fuel.²⁴ A pilot facility capable of making 1.5 million gallons per year of cellulosic ethanol from corn stover, sorghum, and switchgrass has been built in St. Joseph, Missouri, one of a dozen such plants around the country expected to be operational in 2009.²⁵

Just as growing corn can have significant impacts on soil, water, and wildlife, so can all the different potential sources of cellulosic biomass. Whatever feedstock is used to produce energy, biomass resources must be managed in a way that protects soil fertility, water quality and wildlife habitat. Overall, even though Missouri is not part of the corn belt, it is well equipped to benefit from a move beyond food crops as a source of bioenergy, which would be driven by careful bioenergy policies that fully account for the carbon and management practices from different types of biomass.

The Energy Independence and Security Act of 2007 contains a Renewable Fuel Standard (RFS) mandating that at least 36 billion gallons of biofuels per year be blended into gasoline and diesel fuel by 2022, but 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 must be produced annually 13 years from now, beginning with a goal of almost 1 billion gallons in 2010.

Cellulosic ethanol is clearly the future of biofuels, and Missouri is perfectly situated to become a center of production. The University of Missouri and the Missouri Department of Natural Resources commissioned a study of the potential biomass "feedstocks" available in Missouri.²⁶ The researchers found that Missouri has approximately:

- 2.5 million acres of corn producing over 8 million tons of dry crop residue per year
- 1 million acres of winter wheat producing 2.2 million tons of dry residue
- 5 million acres of soybeans producing 5 million tons of dry residue
- 340,000 acres of grain sorghum producing 800,000 tons of dry residue
- Waste from 30 cotton gins and 400,000 acres of cotton totaling almost 600,000 tons
- Almost 1 million tons of timber harvest residue per year, and 2 million tons of mill residues²⁷

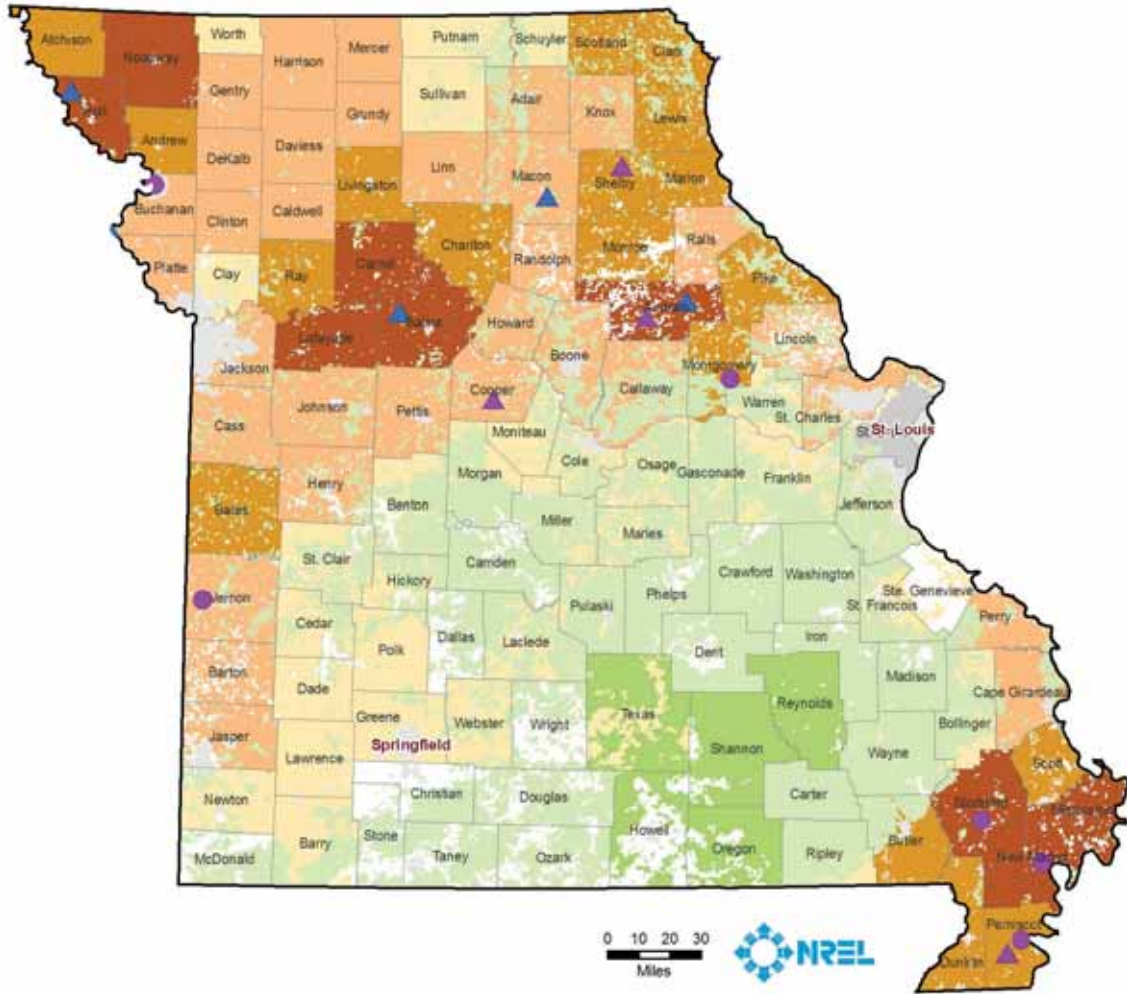
Of course, not all of the biomass feedstock can be captured, and a portion of the crop residues should be left in the field to prevent soil erosion and maintain its productivity. But the potential biomass feedstock in Missouri, including just 25 percent of the total residue for existing crops, amounts to seven million tons each year—without including any new production of energy crops.

The Carbon Offset and Economic Benefits of Biomass

What can be done with seven million tons of biomass? If it were all devoted to producing cellulosic ethanol, it would produce enough feedstock to produce 500 million gallons of fuel,²⁸ equivalent to about 15 percent of all the gasoline used in Missouri each year. Burned in power plants, that is enough biomass energy to generate 6 million MWh of electricity, or the equivalent of 10 percent of Missouri's annual electricity usage. Replacing that much fossil fuel with clean renewable energy would reduce carbon dioxide emissions by about 5 million tons, having the same effect as removing more than one million cars from Missouri roads.

What would that biomass be worth to farmers? Of course that depends on the price they can get for it and the cost of collecting it. Current estimates for the value of crop residue biomass at the "farmgate" is about \$40 to 50/ton,²⁹ so the immediate additional gross farm revenue to be derived from these waste materials would be about \$280 to 350 million. For a corn grower, at a usable yield of at least one ton of stover per acre, this equates to about \$13,000 in potential revenue for the

Figure 2: Map of Existing Residue Biomass in Missouri Counties



Biomass (Thousand Tons/year/county)		0	1-100	100-250	250-500	> 500
Crops and Crop Residues		[White]	[Light Yellow]	[Light Orange]	[Medium Orange]	[Dark Orange]
Forest and Primary Mill Residues		[White]	[Light Green]	[Medium Green]	[Dark Green]	[Very Dark Green]
Urban Wood and Secondary Mill Residues		[White]	[Light Gray]	[Medium Gray]	[Dark Gray]	[Very Dark Gray]
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 (mainly around St. Louis and Kansas City) can produce 100-500,000 tons of urban wood residues. Only the uncolored areas on the map lack significant biomass potential.

Source: National Renewable Energy Lab (NREL), <http://www.afdc.energy.gov/afdc/sabre/sabre.php?state=missouri>.

average Missouri corn farm. Net income would be reduced by costs to harvest, handle, and store the material. A study cited by DOE's National Renewable Energy Laboratory (NREL) found that a corn stover collection process in Iowa provided profit to farmers of between \$9 and \$38 per acre, depending on amount harvested and delivery distance (see Figure 2).³⁰

The potential for biomass production from Missouri crops is far larger if dedicated energy crops are included, instead of only crop residues and waste. Perennial plants such as switchgrass, a tall-growing native prairie grass, can be grown on marginal land with little moisture that is not suitable for row crops. With yields as high as 10 dry tons per acre,³¹ these plants will regenerate without replanting for ten years or more.

A portion of winter cover crops could also be sustainably harvested as an additional source of many millions of tons of biomass. A study by the Institute for Local Self-Reliance found that Missouri has the potential to produce an amount of ethanol equivalent to 78 percent of its current demand for gasoline.³²

The potential economic benefit to Missouri from biofuels production is enormous. While commercial cellulosic ethanol production does not yet have sufficient scale to demonstrate specific economic development effects, they are likely to be similar to corn ethanol. The Department of Energy's JEDI model (referenced earlier in the wind section of this report) calculates that a 50 million gallon-per-year corn ethanol plant in Missouri produces 105 total jobs during its nine-month construction phase. Operation of the plant creates 153 long-term jobs and a total of almost \$19 million in direct and indirect employment each year, plus \$556,000 in annual property taxes. Ten ethanol plants of that size would produce \$190 million in total annual employment activity and \$5.6 million in total local property taxes.

Biopower Potential: Burning Solid Biomass for Electricity

The same energy crops that can be converted to liquid ethanol for transportation fuel can also be used for direct production of electricity by burning them as fuel in biomass power plants. Unlike wind and solar, biopower is a dispatchable resource that can be used for around-the-clock electric capacity. The energy content of biomass varies, but it takes about 400 to 700 acres of dedicated biomass crops to fuel one megawatt of electricity capacity for a year, producing enough electricity to power about 600 to 900 homes.³³

The Department of Energy reports that there are 120 biomass-fired power plants in the U.S. and 48 facilities that "co-fire" biomass with coal, nine of which are commercial power plants (and none of which are located in Missouri.)³⁴ Because biomass can be substituted for a portion of coal used in existing power plants without massive investment in new facilities, it is a relatively low-cost way to ramp up renewable electricity generation in the near term. AmerenUE, the largest Missouri utility company, estimated in its 2007 "Integrated Resource Plan" that retrofitting a coal plant to accommodate co-firing biomass would cost about \$500 per kilowatt. Other estimates are lower, with a study for the National Renewable Energy Lab showing a median estimate of about \$200/kW. In any case, 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/kW, depending on technology employed.³⁵ Biomass has been co-fired with coal in power plant boilers in proportions as high as 40 percent. Although building a new plant that would burn any coal at all cannot be justified on economic nor environmental grounds, in some locations it may be cost-effective to build a separate 100 percent biomass boiler next to an existing coal-fired plant to feed steam into a common turbine.

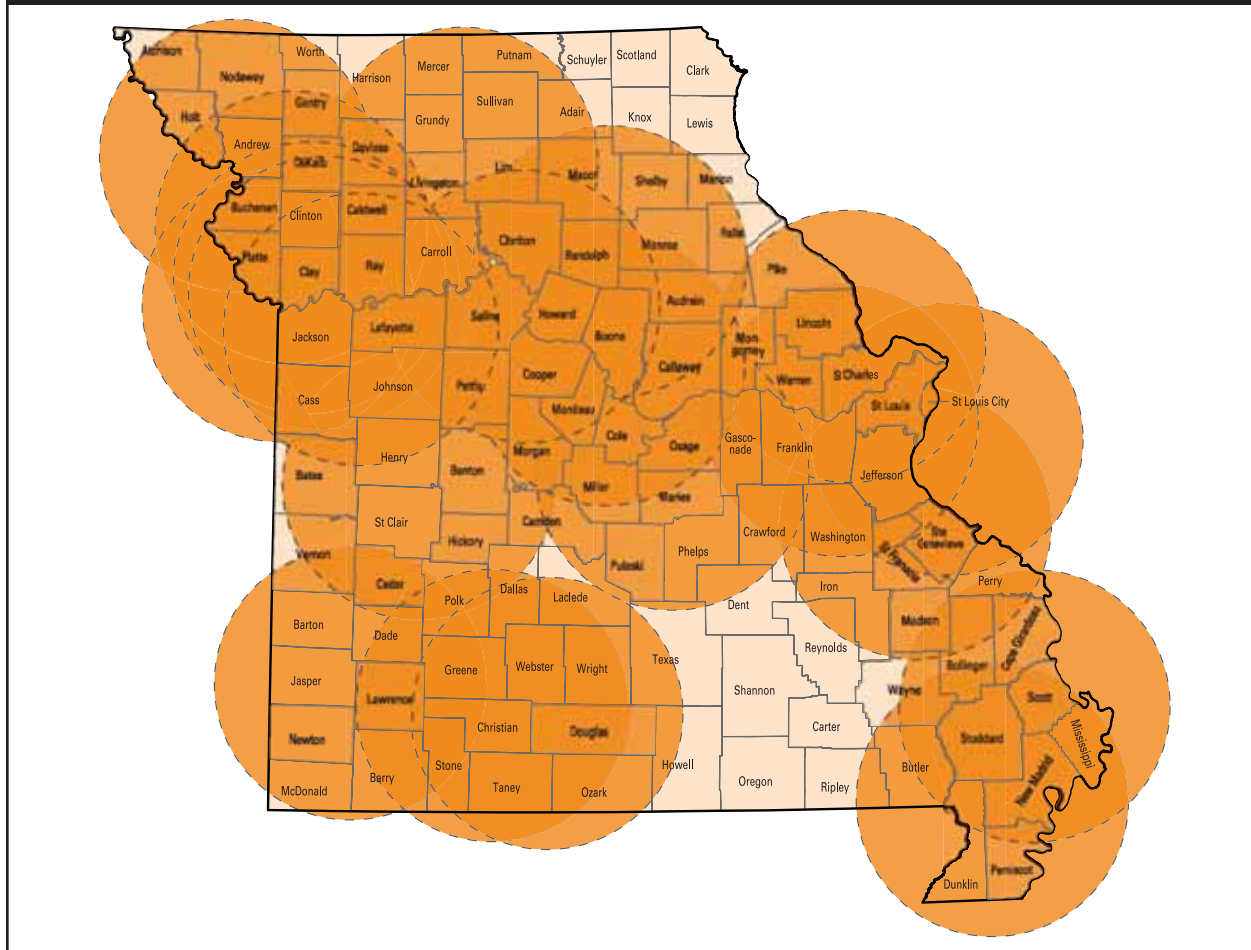
Because biomass crops are heavy and bulky, transporting them for long distances is neither economical nor energy efficient, so biomass-burning facilities should be close to where the crops are grown. The twelfth biggest coal-using state, Missouri has 20 existing large coal-fired generating stations, with a median size of about 250 MW. Figure 3 is a Missouri county map showing each coal plant with a 50-mile radius circle drawn around it to show the areas that could conveniently provide feedstock if it were converted to co-fire with part biomass.³⁶

While of course not all these power plants are likely to be converted to run on a biomass-coal mixture, this map illustrates the wide geographic potential for cost-effective biomass production for co-firing in Missouri.

Harvesting Biomass To Create New Jobs in Missouri

If Missouri replaced just 10 percent of its existing 45 million tons of annual coal usage with biomass, it would create annual demand for about 7 to 10 million tons of energy crops and residues.³⁷ Based on an estimate by the National Renewable Energy Lab (NREL) that each megawatt of biopower capacity creates 4.9 jobs, displacing even a small portion of coal with biomass would create many thousands of new jobs in rural Missouri.³⁸

Figure 3: Map of Potential Biomass Resources for Co-firing Using Existing Missouri Coal Plants



Biogas Potential

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 heat-trapping effect of carbon dioxide on global warming. But burning methane curbs its harmful effect on the climate and releases large amounts of useful energy. Methane is a relatively clean fuel that is the main component of natural gas and LP gas used to heat homes and to fuel electricity generation. By capturing methane, 425 landfills across the country turn decomposing garbage into a valuable energy source.³⁹ For decades, some large dairy and swine operations have been managing their immense amounts of manure by processing it using “anaerobic digesters” to produce and store biogas, which is then used to power generators and for thermal energy.

Several digester technologies are in use, the most common of which is a covered manure lagoon, from which biogas is piped to a generator. Most of Missouri has warm enough weather for anaerobic lagoons, but there are also heated “plug flow” and “complete mix” systems, which are primarily used for dairy operations. Some systems are capable of “co-digestion,” which allows other types 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 byproducts

The Economic Benefits of Biogas

As energy prices rise and curbing greenhouse gas emissions becomes national policy, production of biogas is on the verge of becoming a good business opportunity as well, with multiple potential revenue streams:

Biofuel produced from existing waste biomass alone could create thousands of jobs, hundreds of millions of dollars of economic activity, and \$13,000 annually in gross income for the average Missouri corn farmer.

- **Sale of energy to local utility company:** Missouri is among 42 states with a “net metering” statute that allows small scale renewable electricity generators (up to 100 kilowatt capacity under Missouri law) to connect to the grid, and requires utility companies to buy their power at the retail utility price, up to the amount of usage by the customer. In effect, renewable production of power makes the customer’s electric meter “run backwards” to reduce the net monthly electricity bill. If more power is generated than used in a month, the subsequent bill is credited, but not at the full retail price. The credit is limited to the “avoided cost” of fuel that the utility would have used to generate the power, and the total annual electric bill cannot result in a net credit to the customer. Many other states allow for larger systems to net meter and have rules that are more supportive of small-scale renewable electricity development.⁴⁰ New federal laws could enhance and standardize net metering policies to ensure the eligibility of biogas and to more effectively promote onsite renewable power production.
- **Sale of Renewable Energy Credits (RECs):** Each MWh of renewable electricity is given an REC, (sometimes called a “Green Tag”) which is proof of its clean origin. These RECs have can be bought and sold in trading markets. The buyers include utilities that are required to buy green power, plus corporations and individuals who do so voluntarily to support renewable energy development.
- **Sale of carbon credits:** Each metric ton of reduced carbon dioxide generates a carbon credit that can be used to offset emissions under certain carbon reduction plans. While Europe has a mandatory carbon reduction policy and therefore a large market in “Certified Emissions Credits” (CERs), in the United States a small market has emerged for those who wish to voluntarily reduce their “carbon footprint.” A new national mandate to reduce carbon dioxide emissions, such as a carbon cap-and-trade policy, might include issuance of marketable carbon credits for demonstrable carbon reductions. Because methane is 21 times more potent than carbon dioxide as a greenhouse gas, its value as an offset product would be proportionally greater as well.
- **Sale of fertilizer:** The value of digested solids may be even 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, which is biologically stable and largely sterilized, with far fewer pathogens and weed seeds, and less likelihood of causing water pollution than standard commercial fertilizer.
- **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.⁴¹

Sizable biodigesters and related equipment require an investment of \$300,000 to \$600,000. Although several state and federal grants and tax credits are available, the technology is presently used only at about 110 large-scale “Concentrated Animal Feeding Operations” (CAFOs) in the U.S. (compared to about 3,000 farm-scale biodigesters operating in Europe).⁴² The U.S. EPA “AgSTAR” programs estimates that there are 7,000 dairy and swine operations in the U.S. that are good candidates for profitable biodigester systems, having more than 500 head of dairy cows or 2,000 swine.⁴³

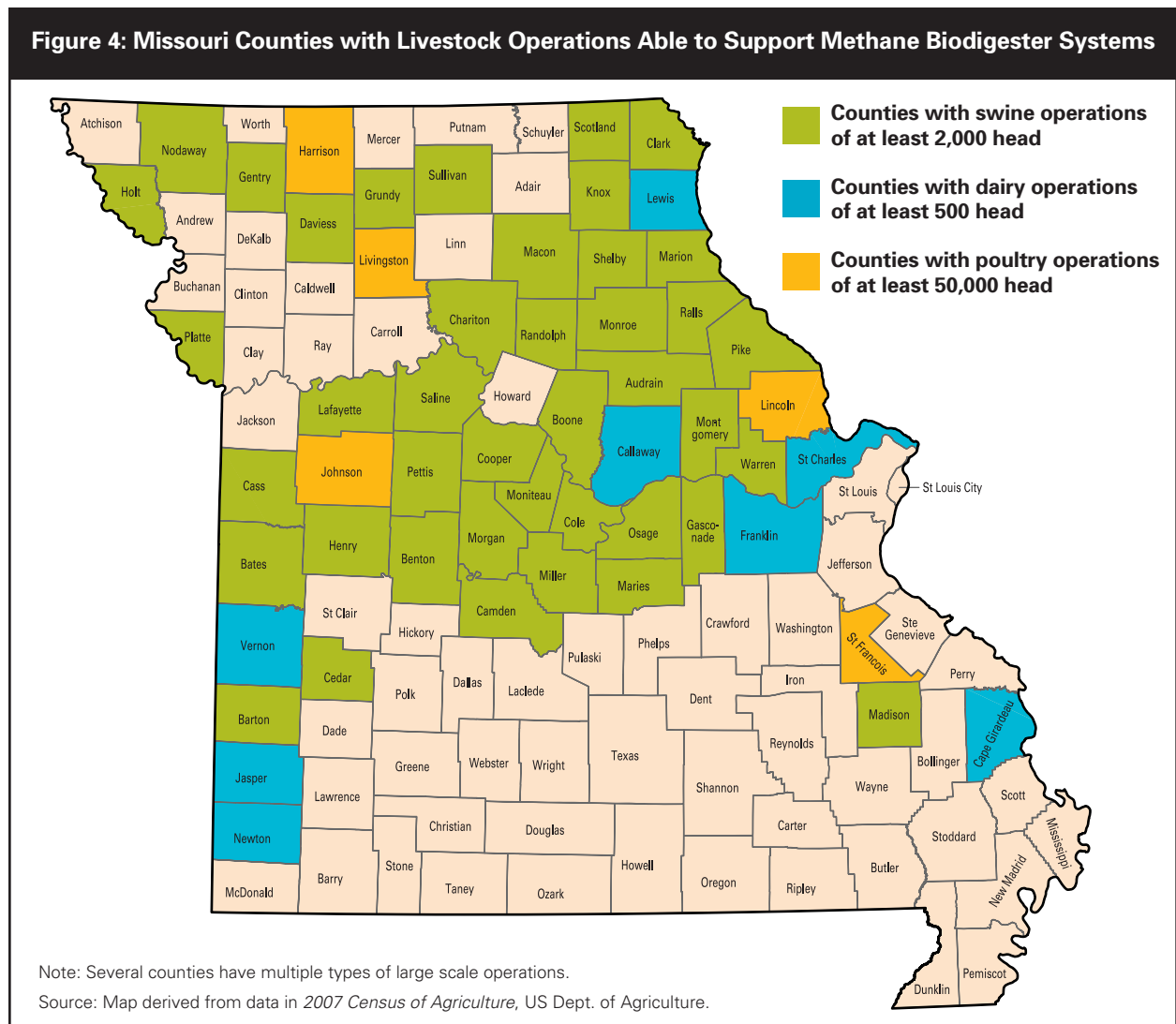
Missouri’s Biogas Capacity

Missouri is in the top five hog producing states, with 259 swine operations of more than 2,000 head, including 86 with more than 5,000 head.⁴⁴ Some of these may not be ideal for biodigester technology because of the design of their manure systems, but AgSTAR reports that 200 are potentially profitable sites. These swine operations are capable of producing 2.7 billion cubic feet of methane and generating 177,000 MWh of electricity from it.⁴⁵ At 6.8 cents/kWh (the average rate paid in Missouri) that amounts to more than \$12 million worth of homegrown power each year, assuming net metering treatment. Adding additional future revenue of perhaps two to four cents/kWh⁴⁶ would be the value of

Renewable Energy Credits (RECs) and the potential value of carbon credits for burning 53,000 tons of methane, if federal policies to control carbon emissions are enacted.

Missouri also has eight farms with more than 500 dairy cows that would be ideal candidates for methane production. Smaller operations could also profit from biogas because centralized systems can allow nearby dairy farms—such as some of the 40 Missouri 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. In addition, Missouri has 9 cattle feedlots with more than 1000 cattle and 8 poultry farms with more than 50,000 chickens, which may also have potential for cost-effective biogas recovery systems, particularly as improved technology reduces biodigester costs and the combination of higher energy prices, renewable resource requirements, and new carbon emission standards increase potential revenue.

Missouri has hardly begun to fulfill its farm biogas potential, with just a couple of biodigesters in operation today. But with the right set of supportive government policies, the benefits of anaerobic biodigestion for Missouri’s farmers and its environment could be realized within a few years.



CHAPTER 3

Other Renewable Energy Opportunities for Missouri

Technological advancements in renewable technologies are expanding the range of cost-effective clean energy opportunities for rural Missourians. Solar power, geothermal, aquatic biomass, and soil carbon sequestration are all innovative technologies with potential to help power Missouri’s clean energy future.

Solar Potential

Solar electricity has always been relatively expensive, but its price is dropping rapidly. Compared to rigid polycrystalline photovoltaic panels, recently developed flexible “thin film” solar cells are far less expensive, and also they can be put on the sides of buildings, on roof shingles, windows—on almost anything. The new Missouri Renewable Electricity Standard provides that 2 percent of renewable electricity be solar, which equates to about 190,000 MWh of annual solar electricity production by 2021. The law establishes financial support of at least \$2 per watt for farm-scale installations, a subsidy of about 20 to 25 percent of today’s cost of a photovoltaic array. Solar electricity production is also eligible for sale to utilities under Missouri’s “net-metering” law (described earlier). Because of their high energy needs and location in open areas, farms have great potential for solar energy applications such as water and space heating, grain drying, greenhouse heating, and electricity production.⁴⁷

Geothermal Potential

Geothermal heat pump technology takes advantage of the constant temperature of about 55 degrees several feet underground. By circulating water through buried pipes, a building can be cooled in the summer and heated in the winter, dramatically reducing utility bills. According to the EPA, geothermal systems are the most clean and cost-effective systems to maintain building temperatures, and they are well suited for installing on farms and in rural areas where buildings are not densely situated and digging and installation are less expensive.

Aquatic Biomass Potential

Aquatic plants such as duckweed and water hyacinth are so prolific that they are major nuisances in some waterways. But they are also potential energy crops with a productivity rate per acre ten times greater than soil-based energy crops like switchgrass. Southern Missouri has a climate suitable for aquatic biomass, which can be used to produce transportation

and electricity fuels, plus a residue of animal feed. National policies to reduce atmospheric carbon dioxide could turn aquatic biomass into a commercially viable Missouri farm product.

Soil Carbon Sequestration Potential

Soil carbon sequestration is the process by which carbon dioxide is transferred from the air and stored in the soil. Certain practices, such as “no-till” or “low-till” farming can retain organic materials and carbon in the soil that would otherwise be released into the atmosphere using common plowing practices. For example, some studies suggest that corn fields can take in and retain about one half ton of carbon dioxide per acre annually using no-till farming methods, though it appears this effect can be enhanced by careful fertilizer use or reduced by overfertilization. Any assessment of carbon sequestration must be subject to site-specific review of soil capacity and farming practices, and a rigorous verification protocol to demonstrate and assure actual performance. Restoring wetlands or planting grass and trees can sequester greater amounts of carbon. Under certain carbon reduction policies, verified sequestration of carbon in soil could earn farmers carbon credits that could be sold to industries that must offset their carbon emissions. In that case, soil carbon sequestration could become a new source of revenue for Missouri farmers.

CHAPTER 4

Reaching the Clean Energy Future: Getting from Here to There

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

Existing Federal and State Funding Sources to Help Develop Renewable Energy Projects in Missouri

The federal government offers several forms of funding assistance for renewable energy investors, developers, and property and system owners. These programs include:

- USDA - Rural Energy for America Program (REAP) Grants⁴⁸
- USDA - Rural Energy for America Program (REAP) Loan Guarantees⁴⁹
- Business Energy Investment Tax Credit (ITC)⁵⁰
- Renewable Electricity Production Tax Credit (PTC)⁵¹
- Modified Accelerated Cost-Recovery System (MACRS)⁵²
- U.S. Department of Treasury - Renewable Energy Grants⁵³
- Residential Renewable Energy Tax Credit⁵⁴
- Clean Renewable Energy Bonds (CREBs) for Municipalities⁵⁵

In addition, the state of Missouri offers a series of incentives for renewable development that are listed in the Database of State Incentives for Renewables and Efficiency (DSIRE) maintained by North Carolina State University.⁵⁶

The American Recovery and Reinvestment Act of 2009 (the \$800 billion “stimulus package”) contains about \$50 billion in energy program funding, including extension of clean energy production tax credits, support for transmission infrastructure, “smart grid” investment, low-income housing weatherization, plug-in hybrid electric vehicles, carbon capture and sequestration technology development, state and local energy efficiency programs, and loan guarantees for renewable energy projects.

Policy Recommendations for Realizing Missouri’s Clean Energy Potential

While federal and state programs are playing a critical role in supporting the embryonic 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 substantial 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.⁵⁷ 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 national renewable energy standard (RES) is another policy that would put consumers’ energy dollars to work at home, creating jobs and building local communities. A mandate that all states derive 25 percent of their electricity from renewable resources by 2025 would save families and businesses \$64 billion in lower energy costs and create almost 300,000 U.S. jobs, in addition to substantially reducing harmful emissions from power plants.⁵⁸ The hidden costs of fossil fuels from air pollution alone are \$120 billion per year, according to a study by the National Academy of Sciences. That comes to \$878 per U.S. household, not including the costs of global warming, damage to ecosystems, or the geopolitical costs of oil dependence.⁵⁹

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.

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
- National appliance standards
- Energy-efficient building codes
- 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 save \$170 billion in lower energy bills and create more than 220,000 jobs, including 533 jobs in Missouri, and \$342 million in annual savings for Missouri consumers. Such a commitment to energy efficiency would also eliminate the need to build 390 new power plants in the United States and avoid pollution emissions equivalent to 48 million automobiles.⁶⁰

The small additional cost to make home appliances more energy efficient is far outweighed by the savings consumers achieve when using them. That’s why strengthened national energy efficiency standards for home appliances are a critical part of a long-term energy strategy.⁶¹ Similarly, a national energy-efficient 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 and nuclear power.⁶² In their developing phases, the nuclear, coal, and oil industries received subsidies an order of magnitude larger than renewable technologies. A recent study by the Environmental Law Institute found that this disparity continues, with fossil fuels receiving 2.5 times more government support than renewable resources from 2002 through 2008.⁶³ Clean energy RD&D has fallen since the 70s 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.

Finally, as mentioned before, sustainable biomass energy must account for real climate and environmental benefits. For this to happen, three critical provisions should be included in the 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 and the current legislation lacks a way to differentiate low-carbon from high-carbon biomass.
2. Accurate accounting for emissions from land use change in the Renewable Fuels Standard. The 2007 RFS requires a science-based, full lifecycle analysis that includes the global ripple effect of increased biofuels production, also known as “indirect land use change.” The latest scientific research confirms that whether biofuels create or reduce global warming pollution hinges on where and how the feedstocks are produced.
3. An appropriate definition of renewable biomass. Renewable biomass helps protect sensitive wildlife habitat and natural ecosystems, while making a wide diversity of feedstocks available for compliance with the renewable electricity and renewable fuels standards. Biomass sourcing guidelines should provide safeguards for native grasslands, sensitive wildlife habitat, old-growth, wilderness, and roadless areas, and other especially sensitive components of our federal lands. It should also 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 huge contributor to global warming.⁶⁴

No single deployment support mechanism is optimal for all stages of innovation. Investment tax credits, for example, can be effective in providing upfront capital incentives to expensive high-risk new technologies. Production tax credits are preferable for more mature technologies to ensure installed systems deliver the energy they promise. Net metering and interconnection rules enables 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 needs to craft 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 without transforming the way we produce and use energy. The nascent transition from fossil fuels to renewable energy resources will be neither easy nor quick, but it presents unprecedented opportunities for Missouri and its abundant natural resources.

Endnotes

- 1 This total includes 82 million MWh of electricity, costing more than \$5 billion; 272 billion cubic feet of natural gas, costing about \$3 billion at today's prices; and about 3.25 billion gallons of gasoline plus 1.5 billion gallons of diesel totaling \$10 billion at today's prices (numbers extrapolated from Energy Information Administration, U.S. Department of Energy, state energy profiles).
- 2 Abundant coal is available in neighboring Illinois (and Missouri itself has some coal resources), however it is high in sulfur content and the cost of removing this pollutant is greater than the cost of transporting low-sulfur Western coal.
- 3 This number is calculated using the EIA 2009 forecast of 1% annual increases in electricity usage, supplied by 84% coal, at heat rate of 10,249 MMBTU/MWh, assuming average car driven 12,000 miles/year @22.4MPG as per Dept of Transportation data, emitting 19.4 lbs/gal. See <http://www.eia.doe.gov/oiaf/aeo/overview.html#trends>, also <http://epa.gov/otaq/climate/420f05001.htm#carbon>
- 4 Source: Missouri Department of Natural Resources
- 5 Source: American Wind Energy Association (AWEA), http://www.awea.org/newsroom/releases/wind_energy_growth2008_27Jan09.html The household-equivalent number per MW is smaller than average because of the variable output of wind facilities.
- 6 According to the American Wind Energy Association, based on an analysis of "An Assessment of the Available Windy Land Area and Wind Energy Potential in the Contiguous United States," a report for the Department of Energy by the Pacific Northwest Laboratory; see http://www.awea.org/faq/wwt_potential.html
- 7 A megawatt-hour is a measure of electricity production equivalent to a million watts of power (one megawatt) that is "on" for an hour; for example, one megawatt-hour is enough electricity to run 10,000 light bulbs of 100 watts for one hour.
- 8 <http://www.nrel.gov/docs/fy07osti/41435.pdf>
- 9 http://www.20percentwind.org/report/Chapter1_Executive_Summary_and_Overview.pdf
- 10 http://www.nationalwind.org/publications/wildlife/avian_collisions.pdf
- 11 http://www.awea.org/pubs/factsheets/WE_Noise.pdf
- 12 It actually found an increase in property values compared to other comparable local property. See: http://www.repp.org/articles/static/1/binaries/wind_online_final.pdf
- 13 Data from U.S. Department of Agriculture.
- 14 Based on typical annual payments of \$3000/MW, as used in the JEDI model described just below.
- 15 <http://www1.eere.energy.gov/windandhydro/pdfs/43025.pdf> p.21
- 16 <http://www.gao.gov/new.items/d04756.pdf>
- 17 http://www.repp.org/articles/static/1/binaries/Missouri_Final.pdf
- 18 "Component Manufacturing: Missouri's Future in the Renewable Energy Industry," REPP, 7/08 by George Sterzinger. This report breaks down the potential Missouri renewable component manufacturing facilities to 311 potential wind component firms, 178 solar, 66 geothermal, and 230 biomass.
- 19 Ibid, Study 6, Appendix 1
- 20 Bluegrass Ridge (Gentry County), Cow Branch (Atchison County), and Conception (Nodaway County); a smaller wind facility, Loess Hills (Atchison County), serves the town of Rock Port.
- 21 For information on economics of Iowa wind, see: http://www.nrel.gov/analysis/seminar/docs/2009/ea_seminar_feb_12.ppt
- 22 Source: AWEA
- 23 EIA, State Energy Profiles
- 24 Worldwatch Institute, "Smart Choices for Biofuels," p.8
- 25 <http://uk.reuters.com/article/oilRpt/idUKN1952406520090219>
- 26 "An Assessment of Biomass Feedstock Availability in Missouri," February, 2006 <http://www.dnr.mo.gov/energy/renewables/biomass-inventory2005-07.pdf>
- 27 Does not include an estimated 150 million tons of wood from beneficial thinning of 13-plus million acres of overgrown commercial timber in Missouri.
- 28 Various studies have estimated cellulosic ethanol yields of up to 110/gal per dry ton; this number assumes no increase in the current yield of about 70 gal/ton.

- 29 See reports of the multiagency Biomass Research and Development Initiative (BRDI) <http://www.brdisolutions.com/default.aspx>
- 30 www.afdc.doe.gov/pdfs/5149.pdf
- 31 BRDI, “Increasing Production for Biofuels,” p.23
- 32 <http://www.newrules.org/de/energyselfreliantstates.pdf>
- 33 See also Oak Ridge National Lab report: <http://bioenergy.ornl.gov/main.aspx#>
- 34 “Biomass Energy Databook,” <https://cta.ornl.gov/bedb/biopower.shtml>
- 35 Lazard, “Levelized Cost of Energy Comparison” 2/08
- 36 The EIA uses 50 miles as a feasible distance for economic transportation of energy crops; see [http://tonto.eia.doe.gov/FTP/ROOT/modeldoc/m069\(2008\).pdf](http://tonto.eia.doe.gov/FTP/ROOT/modeldoc/m069(2008).pdf)
- 37 Calculated by converting 10 percent of the 45 million tons of coal used in Missouri each year (as per EIA data) and assuming 9,000 BTU/lb for coal, and 5,000 BTU/lb for biomass. Some biomass crops such as switchgrass and miscanthus have energy density of up to 7,500 BTU/lb.
- 38 “The Value of the Benefits of U.S. Biomass Power,” NREL, see <http://www.nrel.gov/docs/fy00osti/27541.pdf>
- 39 http://www.jgpress.com/archives/_free/001417.html
- 40 For detailed comparison of state net metering policies, see: <http://www.irecusa.org/index.php?id=90>
- 41 Agstar Powerpoint presentation by Chris Voell
- 42 <http://www.adnett.org/>
- 43 “Market Opportunities for Biogas Recovery Systems,” U.S. EPA Agstar, 2006
- 44 U.S. Department of Agriculture 2007 Census of Agriculture
- 45 USEPA AgSTAR
- 46 The market value of RECs and carbon credits depends on the specific policies adopted. Today, RECs cost from about \$2 to \$30/MWh, depending on source and location.
- 47 For a detailed description of agricultural solar applications, see: <http://www.nyserda.org/programs/pdfs/agguide.pdf>
- 48 http://www.dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=US05F&State=federal¤tpageid=1&ee=1&re=1
- 49 http://www.dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=US46F&State=federal¤tpageid=1&ee=1&re=1
- 50 http://www.dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=US02F&State=federal¤tpageid=1&ee=1&re=1
- 51 http://www.dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=US13F&State=federal¤tpageid=1&ee=1&re=1
- 52 http://www.dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=US06F&State=federal¤tpageid=1&ee=1&re=1
- 53 http://www.dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=US53F&State=federal¤tpageid=1&ee=1&re=1
- 54 http://www.dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=US37F&State=federal¤tpageid=1&ee=1&re=1
- 55 http://www.dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=US45F&State=federal¤tpageid=1&ee=1&re=1
- 56 <http://www.dsireusa.org/library/includes/map2.cfm?CurrentPageID=1&State=MO&RE=1&EE=1>
- 57 <http://www.epa.gov/airmarkets/cap-trade/docs/ctresults.pdf>
- 58 http://www.ucsusa.org/assets/documents/clean_energy/Clean-Power-Green-Jobs-25-RES.pdf
- 59 <http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=12794>
- 60 <http://aceee.org/pubs/e091.pdf?CFID=3643806&CFTOKEN=11807860>
- 61 <http://www.nrdc.org/air/energy/fappl.asp> and <http://www.nrdc.org/globalWarming/cap2.0/files/kick.pdf>
- 62 <http://www.eia.doe.gov/oiaf/servicerpt/subsidy2/pdf/subsidy08.pdf>
- 63 http://www.elistore.org/Data/products/d19_07.pdf
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