2013

Missouri Energy Resource Assessment

MO Department of Economic Development

Division of Energy

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1. Introduction

Missouri spends nearly $23 billion on energy annually. Most of these expenditures (52 percent) are in the transportation sector. Another 22 percent are expenditures by the residential sector, 14 percent in the commercial sector and 12 percent by the industrial sector. Missouri spent $6.7 billion, or 20 percent, of expenditures on the production of electricity in 2010. Between 2009 and 2010, the energy expenditure level per dollar of economic output, measured by state gross domestic product, rose by 12 percent. In 2011, the weighted-average price of electricity across economic sectors ranks Missouri as 34th lowest in the country.

Missouri's energy profile is very diverse, with supplies of both traditional fossil fuel resources and alternative resources. Included in our state's energy resource portfolio are coal, oil, natural gas, hydroelectric, landfill gas, ethanol, biodiesel, wind, solar, biomass and geothermal sources. Energy efficiency is also an energy resource – often the lowest cost resource – that is increasingly becoming an important part of meeting our state's energy needs. The development of each energy resource depends on many factors, including the location of the resource, national and state policy, environmental regulations, transportation issues and national and international market factors. Missouri's ability to sustain energy production from each of these sources depends on the interplay among these factors.

Electricity in Missouri is generated from a mix of coal, hydroelectric power, natural gas, nuclear and renewable resources. Missouri is most dependent upon coal, which produces 82 percent of the total electricity consumed. The next largest source of electricity is nuclear, which accounts for 10 percent. Natural gas, hydropower and wind sources combine to produce the remaining 8 percent of electricity generation.

This first energy assessment catalogs publicly available information about the variety of Missouri's energy resources including fossil fuel resources, as well as energy efficiency and renewable resources. The Department of Economic Development/Division of Energy used the most current data available in the development of this report, but recognizes that new data may be available when it is published. We look forward to annual updates and welcome comments to improve the report. We hope the information in this document is useful and provides a basis for discussions about Missouri's energy and economic future.

2. Coal

2.1 Background and History

Coal production in the state of Missouri has been continuous since 1806. The first site to be mined for coal in Missouri is located near Prairie City in Bates County. As the first state west of the Mississippi River to produce coal on a commercial level, coal mining became a notable part of the state economy by the 1880's.[1] Once coal mining began in earnest in the 1840's, it continued to operate effectively unregulated until 1971. The first legislation in Missouri to regulate coal mining passed in 1971; by 1978, state law conformed to federal law (Public Law 95-87), which placed restrictions on coal mining activities.[2] The enactment of the Surface Mining Control and Reclamation Act of 1977 (SMCRA) impacted about 67,000 acres in 48 counties. Coal mines in Missouri were underground until the late 1920's. The method used to mine coal in Missouri gradually changed from underground mining to strip mining during the 1930's to 1960's.[3]

2.2 Resource Overview

The majority of coal in the state is located in the western, northern and central regions. Most coal in Missouri ranges from lignite to bituminous. Lignite coal is also called brown coal. It is a brown carbonaceous sedimentary rock with a woody texture that consists of accumulated layers of partially decomposed vegetation. Lignite is located in the Bootheel or southeastern corner of the state (Figure 1-1).

Bituminous coal is a soft black coal, rich in volatile hydrocarbons that burn with a smoky yellow flame. It has high sulfur content and when burned, gives off sulfurous compounds that contribute to air pollution and acid rain. Bituminous coal is located on the western edge and northern half of the state. Missouri's coal typically has relatively high sulfur content, averaging

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[1] "Missouri Coal", *Missouri Department of Natural Resources, Division of Geology and Land Survey*. N.d. Web. August 28, 2012. <http://www.dnr.mo.gov/geology/docs/BRO006MissouriCoal.pdf>.
[2] "Regulated Mining Activity", *Missouri Department of Natural Resources, Land Reclamation Program*. N.d. Web. August 28, 2012. < http://www.dnr.mo.gov/env/lrp/mininfo.htm>.
[3] "Missouri Coal", *Missouri Department of Natural Resources, Division of Geology and Land Survey*. N.d. Web. August 28, 2012. <http://www.dnr.mo.gov/geology/docs/BRO006MissouriCoal.pdf>.

more than 2.5 pounds per million BTU (MMBtu) or 4 percent by weight. Approximately 33 percent of the state's land, or 23,000 square miles, are in coal bearing areas.[4]

More than half of the twenty identified coal seams have been mined. The total coal reserve in Missouri is estimated to be about six billion tons, which accounts for less than 2 percent of the total coal reserve in the United States. It is also estimated that underground and surface mineable deposits in Missouri are 689 and 3,156 million short tons, respectively, for 2010.[5] The composition and production levels of Missouri coal restrict its influence on the state and the nation's economy and energy stability.

Figure 1-1. Coal Resource Distribution in Missouri

[4] "State Overview - Missouri", *United States Department of the Interior, Office of Surface Mining Reclamation and Enforcement.* N.d. Web. February 6, 2013. <http://www.mcrcc.osmre.gov/MCR/States/Missouri.shtm>.
[5] "Table 15. Recoverable Coal at Producing Mines […]", *United States Energy Information Administration*, 2011. Web. August 28, 2012. <http://www.eia.gov/coal/annual/pdf/table15.pdf>.

2.3 Coal Production

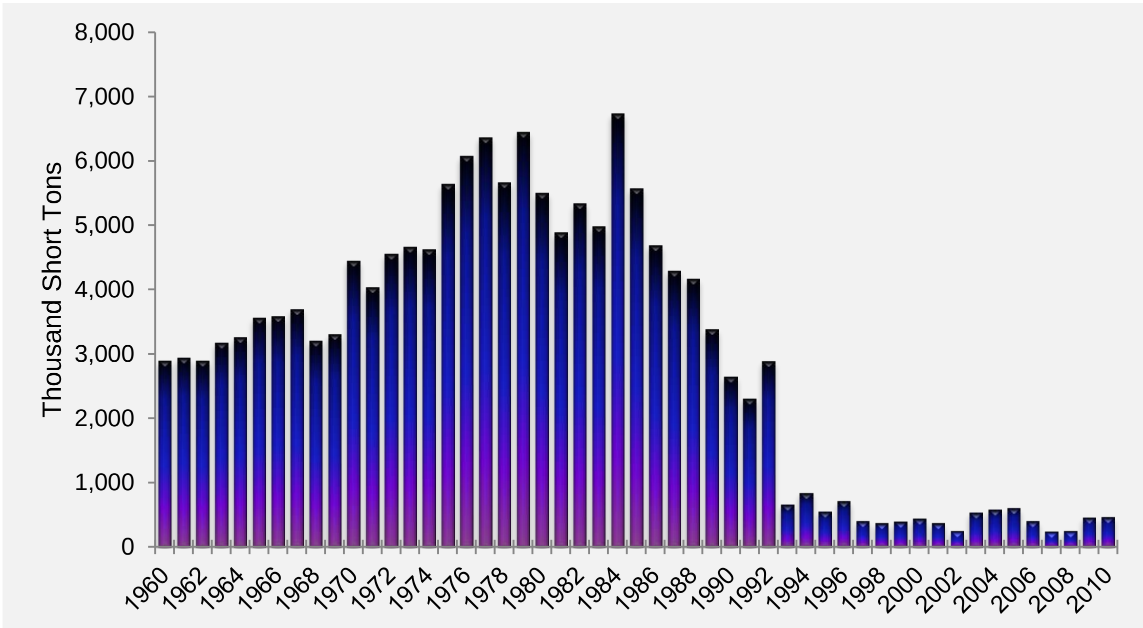


Figure 2-2. Coal Production in Missouri (1960-2010)[6]
(Refuse recovery is included beginning in 2001)

Coal production in Missouri reached its peak from the mid-1970s to mid-1980s (Figure 2-2). The highest production of 6,733,000 short tons occurred in 1984, after which production began a steady decline in the state. A dramatic decrease in coal production occurred in 1993. The decrease in production was attributed, in part, to the 1990 Clean Air Act amendments that restricted sulfur dioxide emissions. Coal-fired plants were faced with a decision to install sulfur dioxide scrubbers in their plants or purchase lower sulfur content coal. Due to Missouri coal's high sulfur content, demand for Missouri coal decreased. Increased regulation on surface coal mining also contributed to the drop in production.[7] As of 2010, Missouri had two active surface mines that produced 458,000 short tons of coal.[8] This level of production ranks Missouri as 23rd

[6] "Table PT1. Energy Production in Physical Units, Missouri, 1960-2010", *United States Energy Information Administration*, 2010. August 28, 2012. <http://www.eia.gov/state/seds/sep_prod/pdf/PT1_MO.pdf>.
[7] "Overview: The Clean Air Acts Amendments of 1990", *United States Environmental Protection Agency*. N.d. Web. August 28, 2012. < http://www.epa.gov/oar/caa/caaa_overview.html>.
[8] "Table 1. Coal Production and number of mines by State and Mine Type, 2011 and 2010", *United States Energy Information Administration.* 2012. Web. February 6, 2013. <http://www.eia.gov/coal/annual/pdf/table1.pdf>.

in the nation.[9] However, this low level of production means that nearly all coal supplies are imported from out of state.[10]

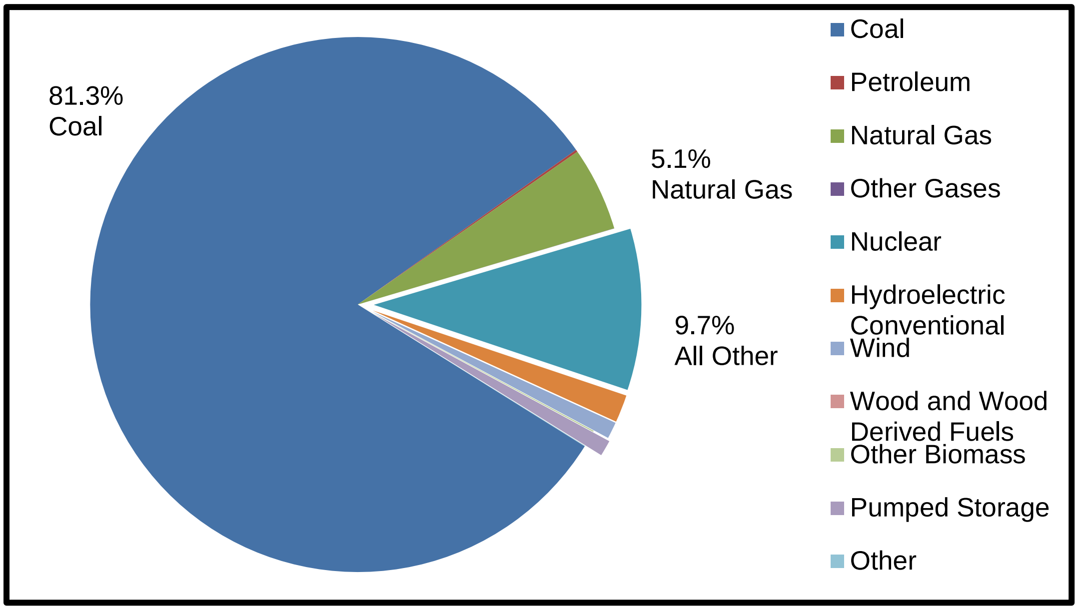


Figure 2-3. Net Electrical Generation by Energy Source (2010)[11]

2.4 Coal Consumption

In 2010, Missouri produced 75,047 gigawatt hours (GWh) of electricity from coal, which accounts for about 81 percent of annual net generation by all energy resources (Figure 2-3). In 2009, Missouri power plants burned approximately 699 billion BTUs of coal to generate electricity.[12] Electric power producers consumed 9,913,000 tons in coal stocks during 2010.

The coal consumption in Missouri and selected neighboring states (Illinois, Indiana, Iowa, Kansas and Arkansas) for 2010 and 2011 is shown in Figure 2-4. Figure 2-5 shows the total coal consumption per capita for those states, including electricity generation and other industrial usage. Between 1989 and 2009, coal use increased in Missouri by 1.27 percent. Most coal produced in Missouri has been sold out of the state (Figure 2-6). In fact, Kansas buys most

[9] "Rankings: Coal Production, 2011 (thousand short tons)", *United States Energy Information Administration.* 2012. Web. October 2, 2012. <http://www.eia.gov/state/state-energy-rankings.cfm?keyid=30&orderid=1>.
[10] "Missouri Fossil Fuel Use at a Glance", *Missouri Department of Economic Development, Division of Energy*. N.d. Web. February 6, 2013. < http://ded.mo.gov/energy/docs/Missouri%20Fossil%20Fuel%20Use%202010.pdf>.
[11] "Detailed State Data, Net Generation by State", *United States Energy Information Administration, Electricity.* 2012. February 6, 2013. <http://www.eia.gov/electricity/data/state/>.
[12] "Missouri Fossil Fuel Use at a Glance", *Missouri Department of Economic Development, Division of Energy*. N.d. Web. February 6, 2013. < http://ded.mo.gov/energy/docs/Missouri%20Fossil%20Fuel%20Use%202010.pdf>.

of the coal produced in Missouri. Due to the state's heavy reliance upon coal and its low production levels, Missouri's ability to import a reliable supply of coal is vital for the production of electricity and supporting the state's overall economy. In 2011, Missouri purchased more than 44.5 million tons of coal in order to generate this power (Figure 2-7).[13] In 2010, 97 percent of the coal purchased was imported from Wyoming (Figure 2-8).

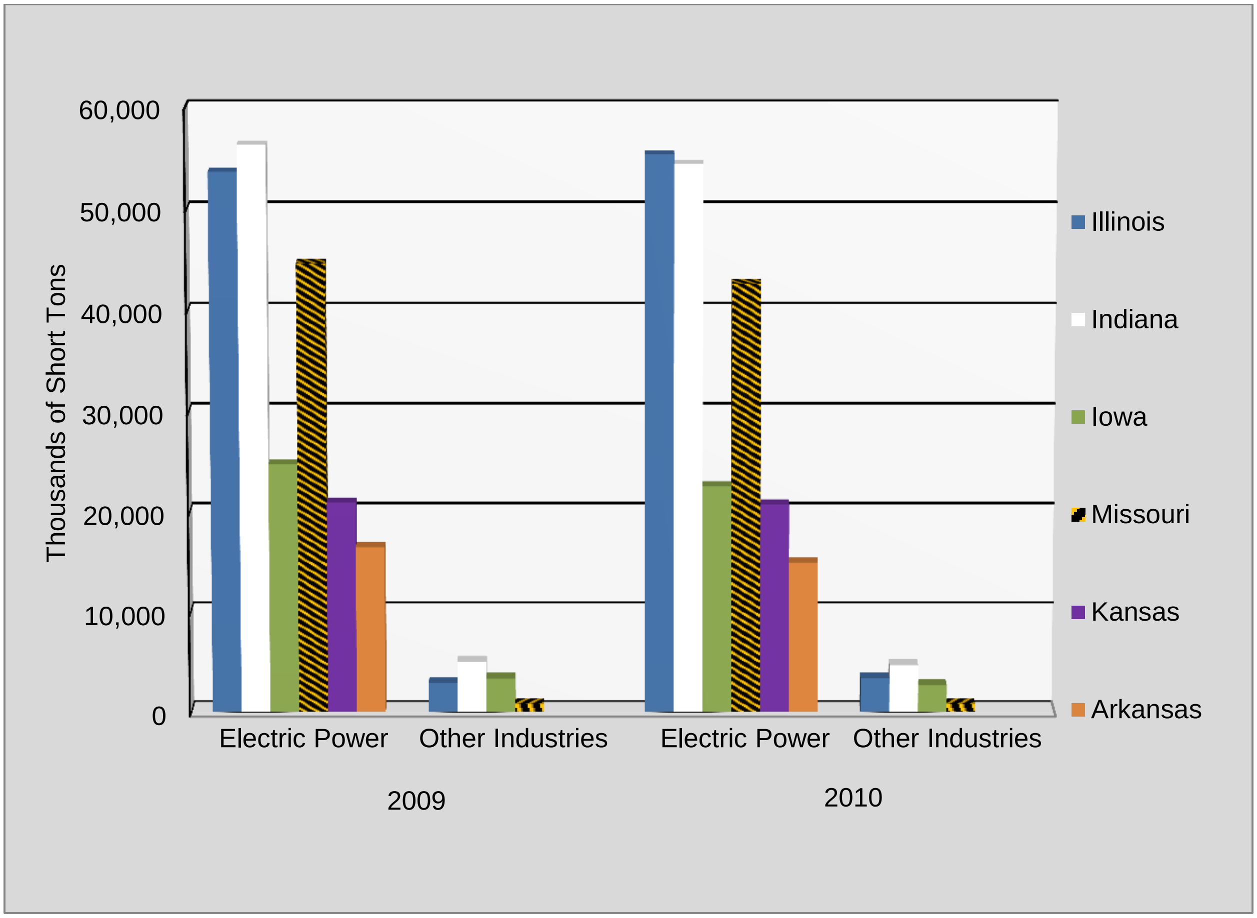


Figure 2-4. Coal Consumption in Missouri and Neighboring States

[13] "Missouri Electricity Profile 2010", *United States Energy Information Administration.* January 2012. Web. August 28, 2012. <http://www.eia.gov/electricity/state/missouri/>.

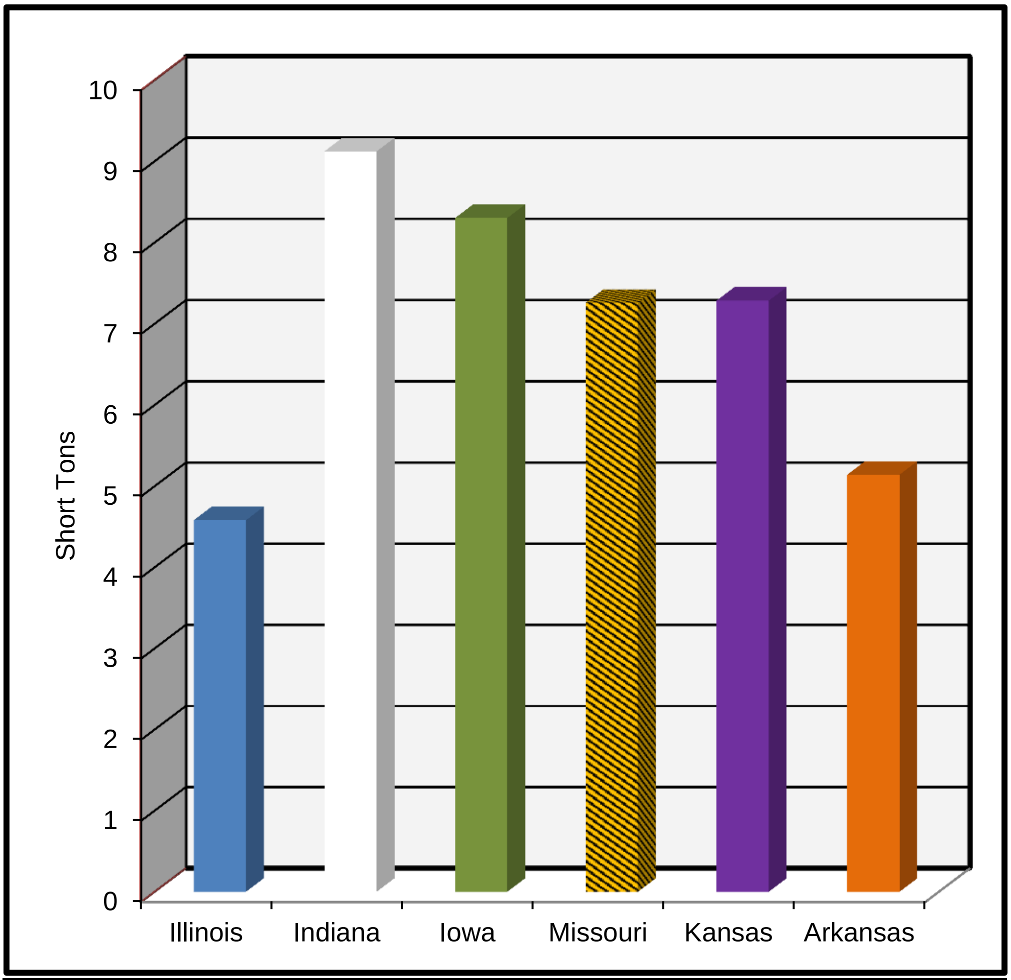


Figure 2-5. Total Coal Consumption per Capita in Selected States (2010)

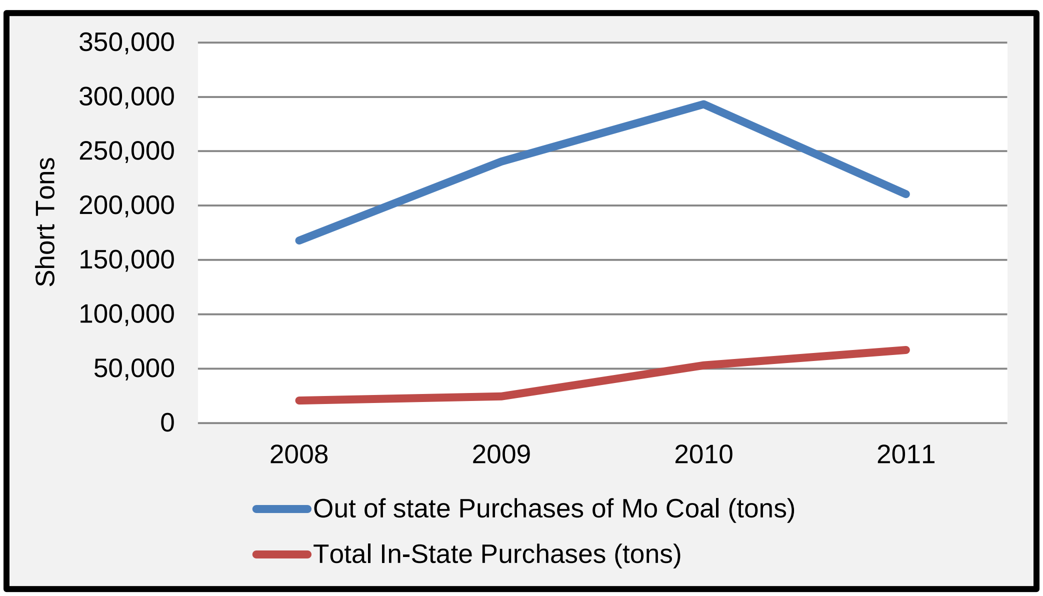


Figure 2-6. Missouri's Indigenous Coal Destinations

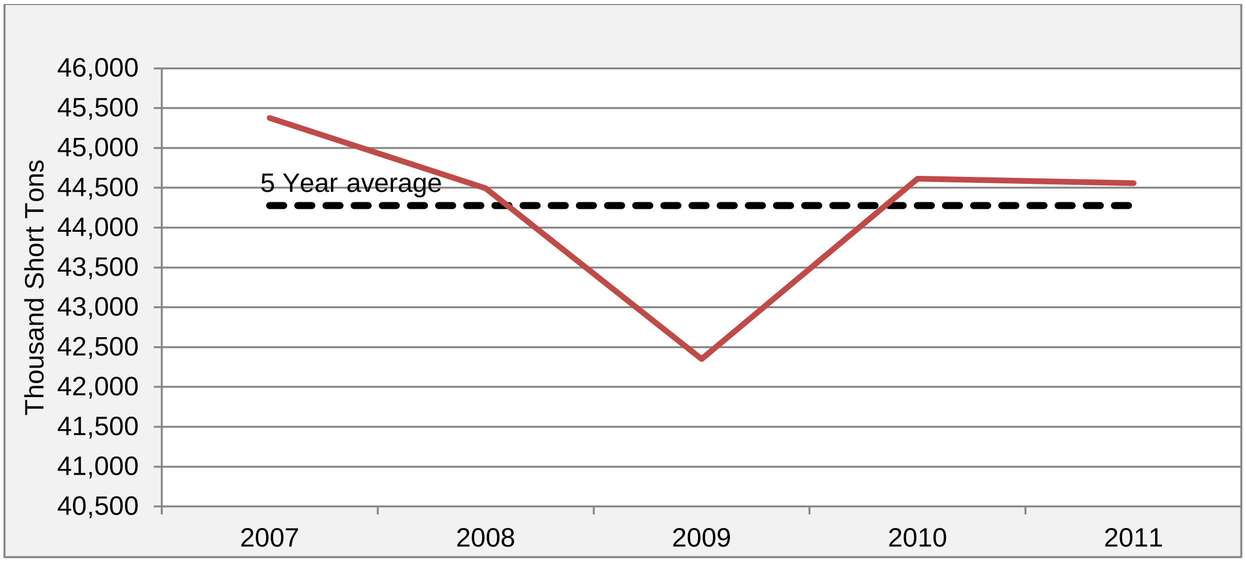


Figure 2-7. Total Coal Consumption for Electricity Generation (2008-2011)

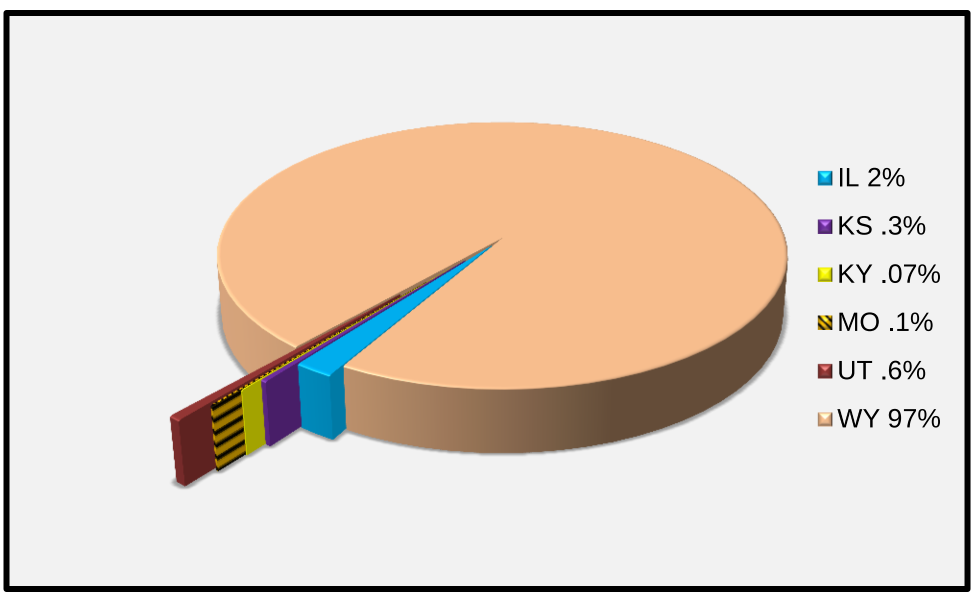


Figure 2-8. Missouri's Coal Purchase by State of Origin (2010)

Missouri ranks 6th in the nation for the total coal consumption used in electric power generation.[14] Nearly all coal purchased by Missouri, either in-state or out-of-state, is used to fire generation plants for electric utilities (Figure 2-9 and Figure 2-10).[15] In 2009, Missouri power plants burned approximately 699 billion BTUs of coal to generate electricity.[16] In April 2012, coal generated slightly less than 22,500 megawatt hours of electricity compared to April 2011, which produced slightly over 25,000 megawatt hours.

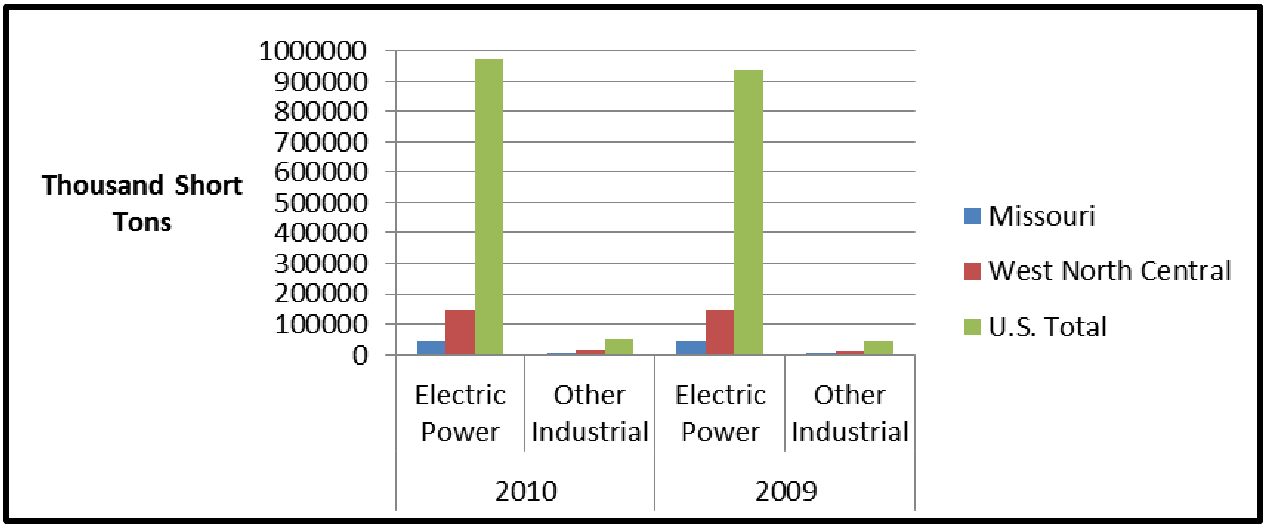


Figure 2-9. Coal Consumption - State, Region and U.S. (2009 and 2010)

[14] "Coal: Consumption By End Use Sector, by Census Division and State", *United States Energy Information Administration.* November-December 2012. Web. October 2, 2012. <http://www.eia.gov/coal/data.cfm#consumption>.
[15] "Missouri: Profile Overview", *United States Energy Information Administration.* July 2012. Web. February 6, 2013. <http://www.eia.gov/state/state-energy-profiles.cfm?sid=MO>.
[16] "Missouri Fossil Fuel Use at a Glance", *Missouri Department of Economic Development, Division of Energy*. N.d. Web. February 6, 2013. < http://ded.mo.gov/energy/docs/Missouri%20Fossil%20Fuel%20Use%202010.pdf>.

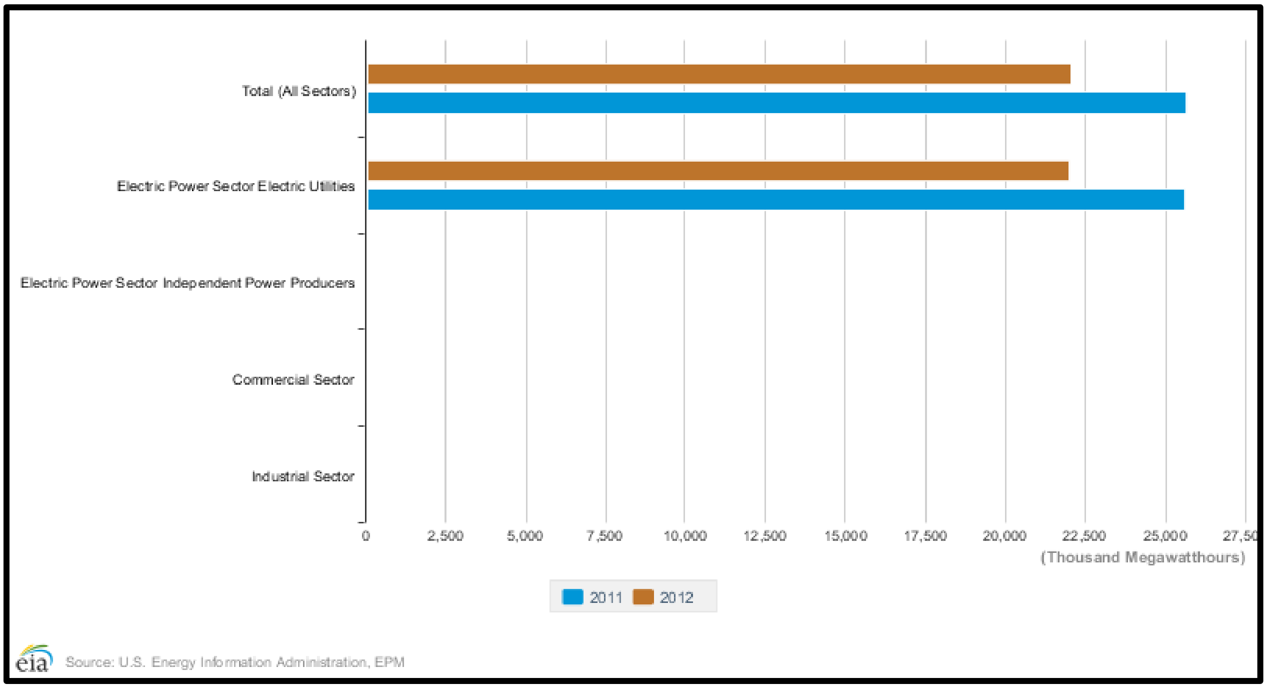


Figure 2-10. Net Generation from Coal in Missouri (2011 and 2012)[17]

Figure 2-11 shows the annual amount of coal purchased by Missouri's investor-owned utilities (IOUs) from 2008 to 2011. These include Ameren Missouri, Kansas City Power & Light Company, Kansas City Power & Light Greater Missouri Operations (formerly Aquila, Inc. and St. Joseph Light & Power service areas before 2009), and the Empire District Electric Company. Figure 2-12 shows the annual amount of coal purchased by utilities (IOUs, municipal utilities and rural electric cooperatives) from 2008 and 2011.

[17] "Table 1.7.B. Net Generation from Coal", *United States Energy Information Administration, Electric Power Monthly.* January 2013. Web. February 6, 2013. <http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_1_7_b>.

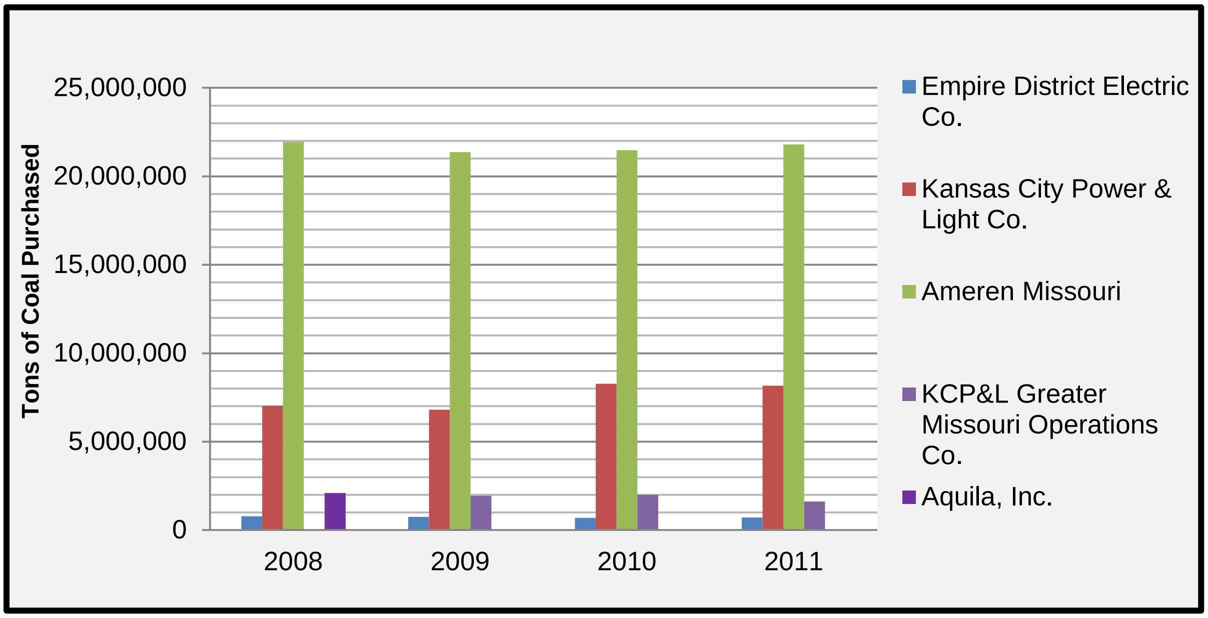


Figure 2-11. Coal Purchased by Missouri's Investor-Owned Utilities (2008-2011)

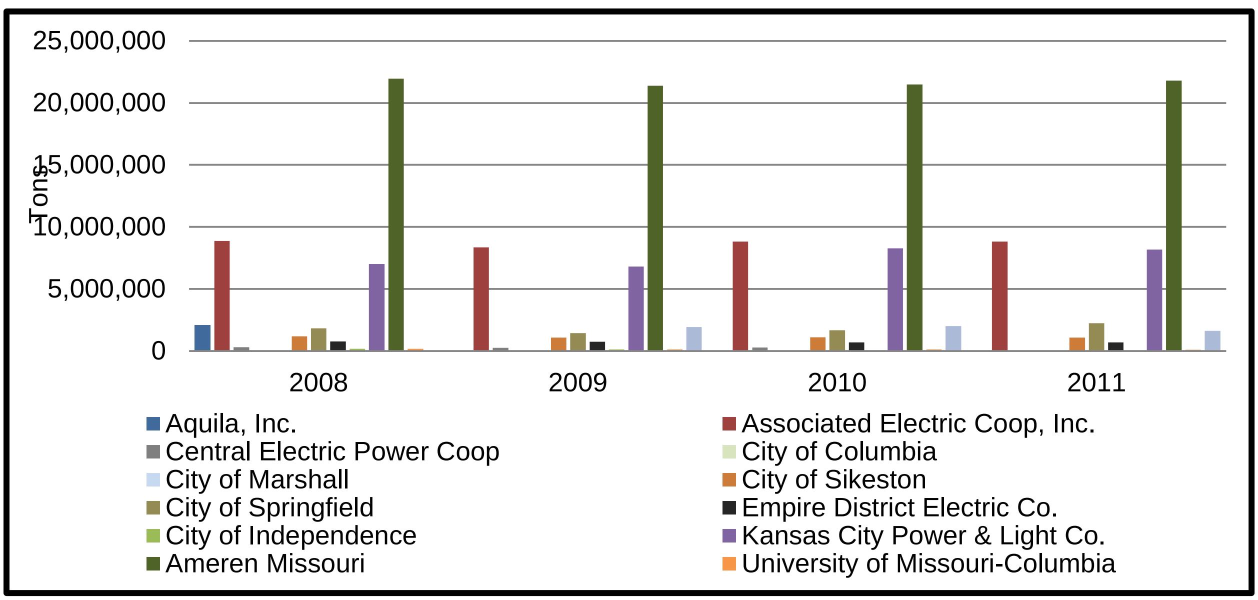


Figure 2-12. Coal Purchases by Missouri's Electric Utilities (2008-2011)

Compared with the electricity rates of other states, Missouri's utilities provide electricity at reasonable lower rates, even with Missouri's reliance upon coal imported from out-of-state suppliers. Figure 2-13 shows the cost for electricity in Missouri is lower than both the national and regional average price.

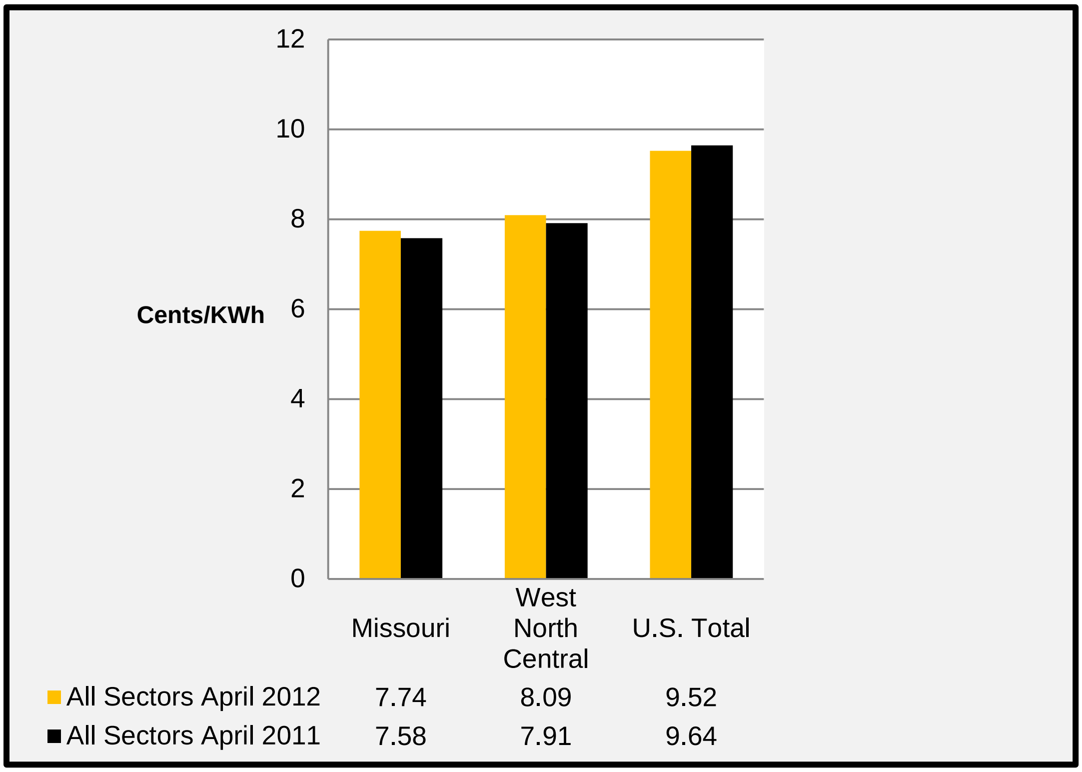


Figure 2-13. Average Retail Price of Electricity to Customers

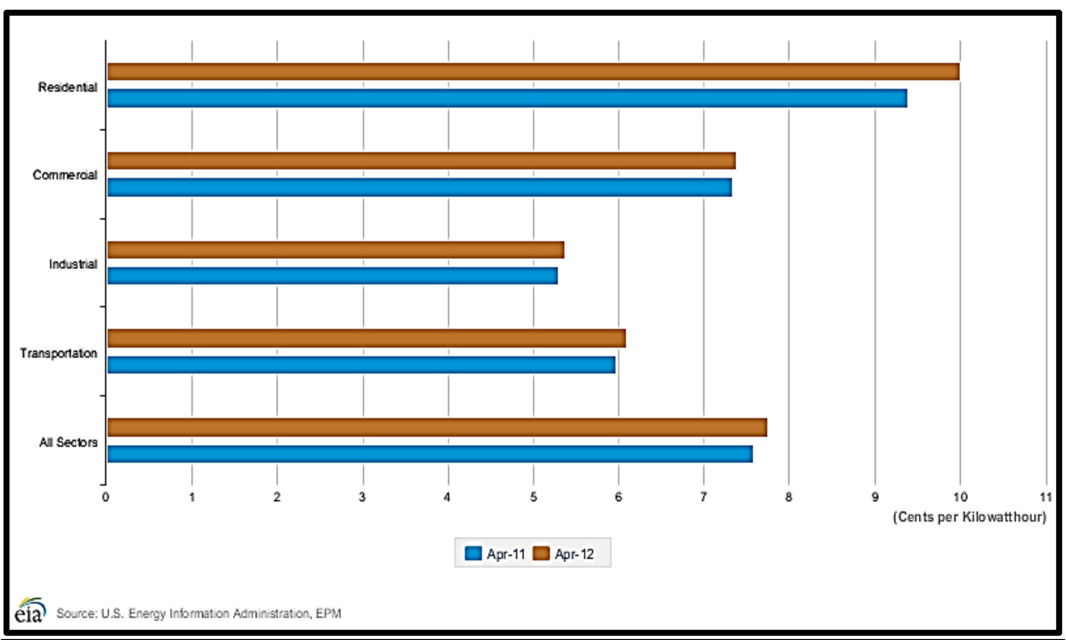


Figure 2-14. Average Retail Price of Electricity to Customers[18]

[18] "Table 5.6.A. Average Retail Price of Electricity to Ultimate Consumer by End-Use Sector", *United States Energy Information Administration*, *Electric Power Monthly.* January 2013. Web. February 6, 2013.<http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_6_a>.

Figure 2-14 shows the average retail price of electricity to different sectors, including customers from residential, commercial, industrial and transportation. Based on the U.S. Department of Energy's Energy Information Administration (EIA) rankings, Missouri is currently ranked 38th for average retail price for electricity with a price of 7.78 cents/kWh in 2010.[19] In 2012, the average price of electricity was 9.83 cents/kWh for the United States and 7.74 cents/kWh for Missouri.[20]

The average sales price of coal in Missouri has been withheld in EIA data for the most recent years (2009 and 2010) due to proprietary classification. The average cost of coal delivered for electricity generation in Missouri increased by 6.9 percent between 2011 ($1.74 per MMBTU) and 2012 ($1.86 per MMBTU).[21] Historical electricity prices by sector are shown in Figure 2-15 (nominal price) and Figure 2-16 (inflation adjusted price).

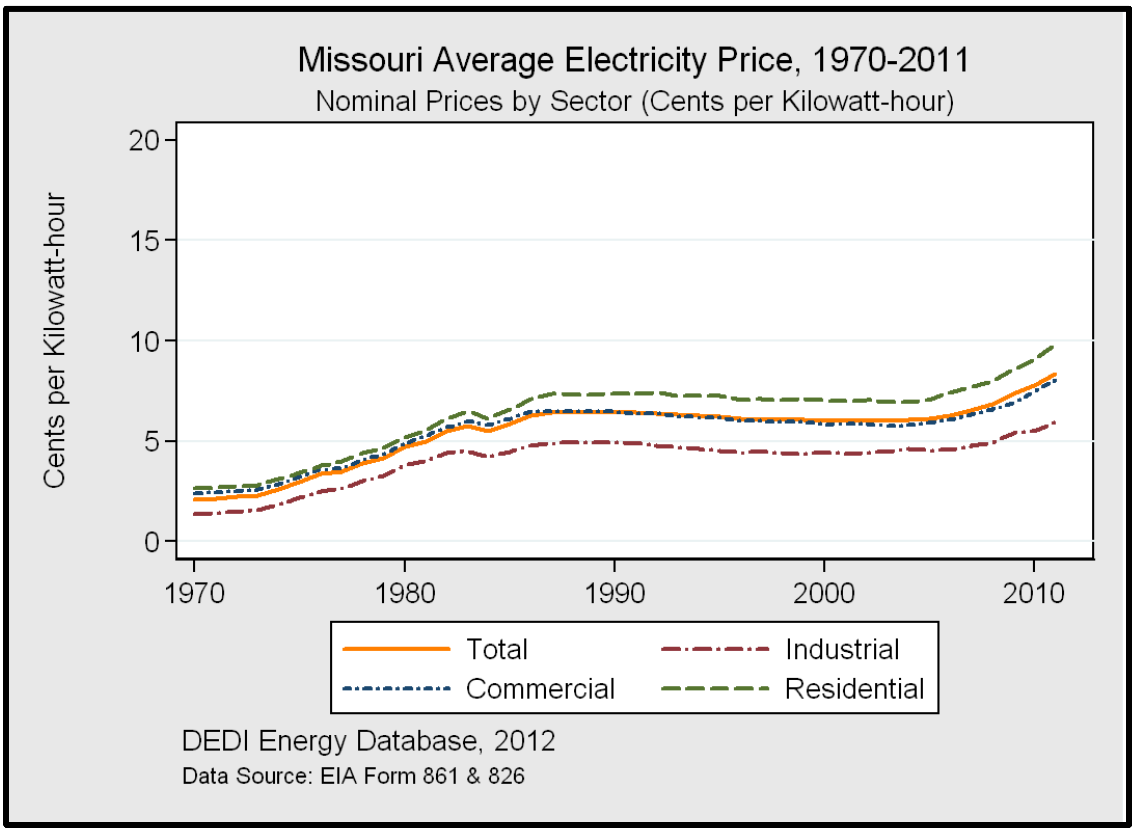


Figure 2-15. Missouri Average Electricity Price, 1970-2011 (nominal price)

[19] "Table 1. 2010 Summary Statistics (Missouri)", *United States Energy Information Administration*. 30 January 2012. Web. 2 October 2012. <http://www.eia.gov/electricity/state/missouri/>.
[20] "State Electricity Profiles." *United States Energy Information Administration*. January 2012. Web. October 2, 2012. <http://www.eia.gov/electricity/state/>.
[21] "Missouri Data: Prices", *United States Energy Information Administration.* January 2013. Web. February 6, 2013. <http://www.eia.gov/state/state-energy-profiles-data.cfm?sid=MO#Prices>.

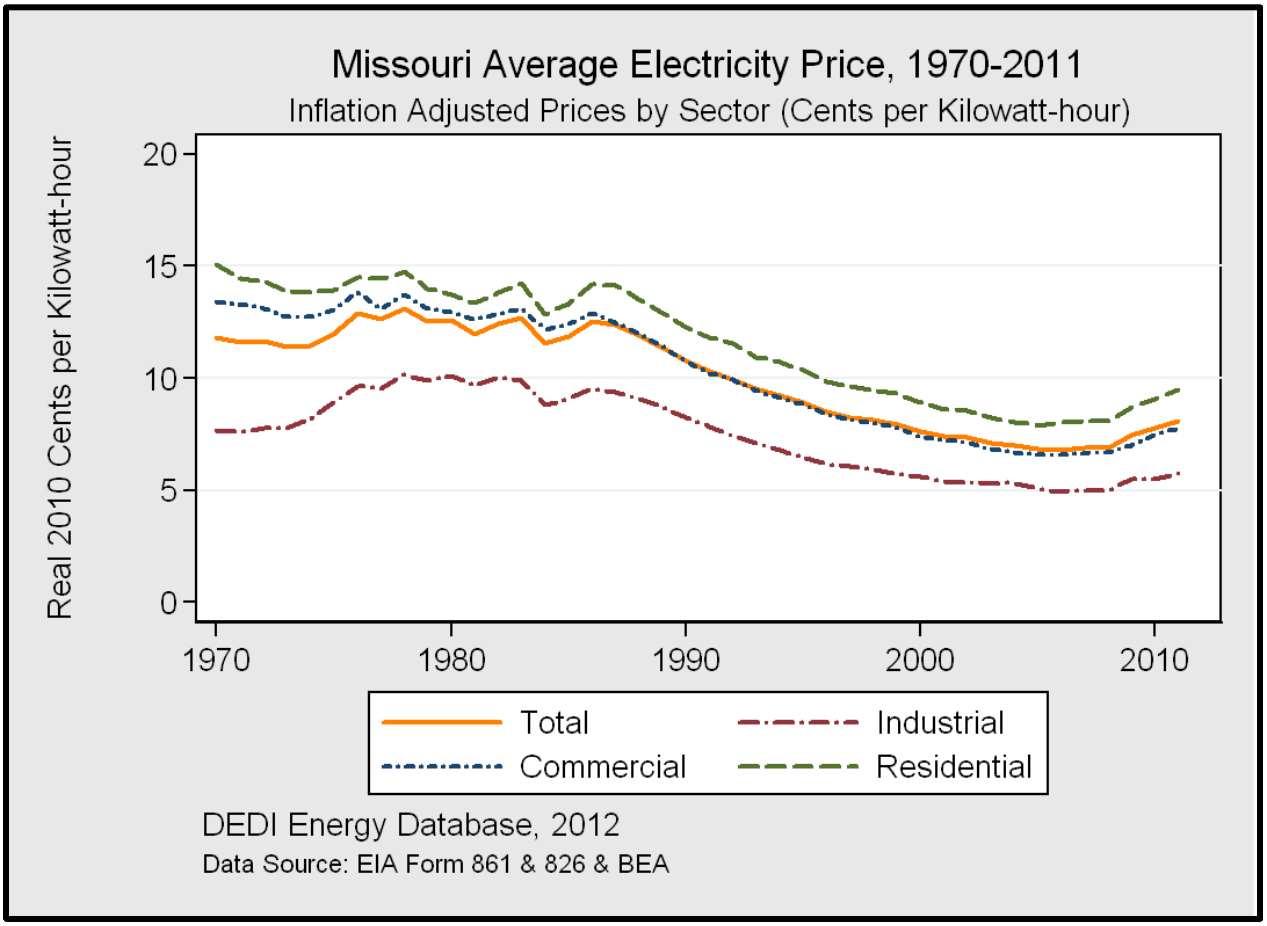


Figure 2-16. Missouri Average Electricity Price, 1970-2011 (inflation adjusted price)

3. Oil and Gas

3.1 Background and History

The first oil and gas deposits were discovered in Missouri shortly after the Civil War in the 1860's when water wells were being drilled in the Kansas City area. More than 2,500 oil and gas wells were drilled before the 1940's. The newest oil and gas field in the state was discovered in northwest Missouri along the Holt and Atchison county border in 1987.[22]

3.2 Description of Resource

There are three traditional oil and gas producing sections in the state (Figure 3-1): the Forest City Basin in northwestern Missouri, the Bourbon Arch in western Missouri and the Lincoln Fold in northeastern Missouri. Nearly all of the current oil and gas production in Missouri uses conventional drilling technologies.

[22] "Oil and Gas in Missouri", *Missouri Department of Natural Resources*. June 2008. Web. August 31, 2012. <http://www.dnr.mo.gov/pubs/pub652.pdf>.

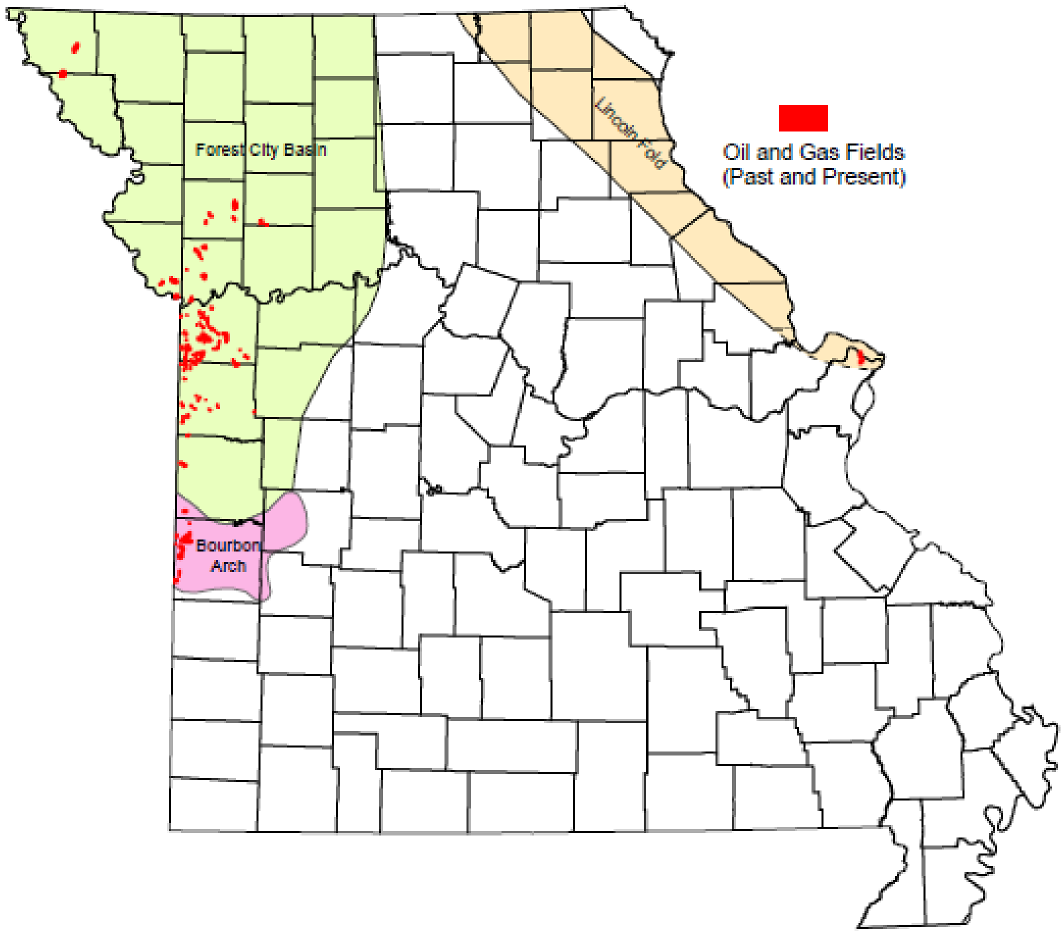


Figure 3-1. Oil and Gas Producing Areas in Missouri[23]

Even though Missouri has historically had limited supplies of traditional hydrocarbons, relatively large deposits of "heavy oil" exist. Missouri potentially possesses large deposits of unconventional oil and gas. The three primary unconventional resources of oil and gas include[24]:

1) Tar sand

   Tar sand heavy oil can be found in the Bourbon Arch south of Kansas City. Nearly 800,000 barrels of oil have been produced in Vernon County since 1960. It is estimated the Bourbon Arch has 1.4 to 1.9 billion barrels of oil from tar sands.

2) Coalbed methane gas

[23] "Oil and Gas in Missouri", *Missouri Department of Natural Resources*. June 2008. Web. August 31, 2012. <http://www.dnr.mo.gov/pubs/pub652.pdf>.

[24] "Oil and Gas in the Show-Me State", *The Geologic Column of Missouri*, Volume 2, Issue 1, Summer 2007. Web. August 31, 2012. < http://www.dnr.mo.gov/geology/docs/gcsummer7.pdf>.

Coalbed methane gas is found within deeply buried coal seams and is located primarily in northwest, north central and west central Missouri. In 2006, more than 3,200 coalbed methane wells in Kansas produced nearly 24 billion cubic feet of gas. Many of these wells are located in the same coal seams that occur in western Missouri. While coalbed methane has not yet been produced economically in Missouri, it is likely that the methane will be extracted, given Missouri's extensive coal deposits.

3) Oil shale

Oil shale has been found overlying some coal beds in northern Missouri and in portions of the Chattanooga Shale formation in the extreme southwest part of the state. Only the most preliminary analyses have been conducted on Missouri oil shale. Even though the possibility remains that a certain level of oil shale is present, many technical, economic and environmental issues need to be solved before the resource can be developed commercially.

3.3 Current Production and Usage

Missouri historically has limited oil and gas production. In 2012, 172,512 barrels of crude oil were produced from 405 oil wells in the state, which ranks as the third least among all 33 oil-producing states (Figure 3-2)[25]. With the price range between $65.00 and $99.25 per barrel, the sale of crude oil was valued at over $14.3 million, which almost tripled the oil value of $4.8 million in 2006[26]. Figure 3-3 illustrates the trend for field production of monthly crude oil from January 1981 to November 2013. Figures 3-4 shows the oil production in the state over the past 30 years.

[25] "Crude Oil Production, 1981-2012", *United States Energy Information Administration.* September 2013.Web. January 30, 2014. < http://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbbl_a.htm>.

[26] "2012 Oil and Gas Activities and Production Report", *Missouri Department of Natural Resources, Division of Geology and Land Survey.* April 2013. Web. January 30, 2014. <http://www.dnr.mo.gov/geology/docs/2012-OGC-report-April-2013.pdf>.

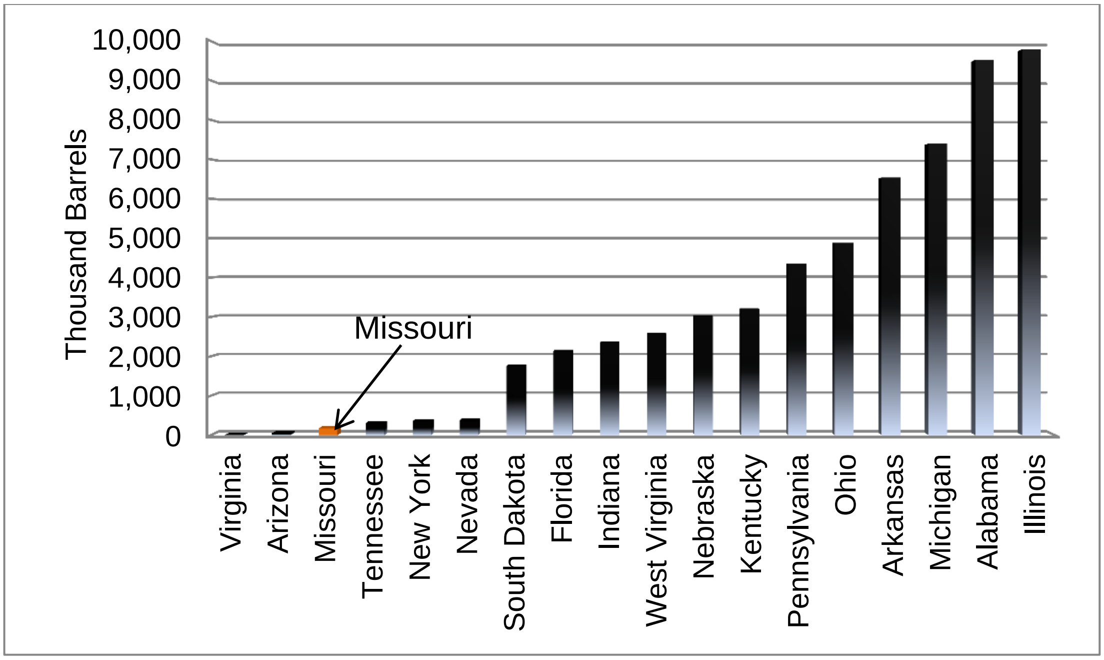


Figure 3-2. Crude Oil Producing States Under 20 Million Barrels (2012)

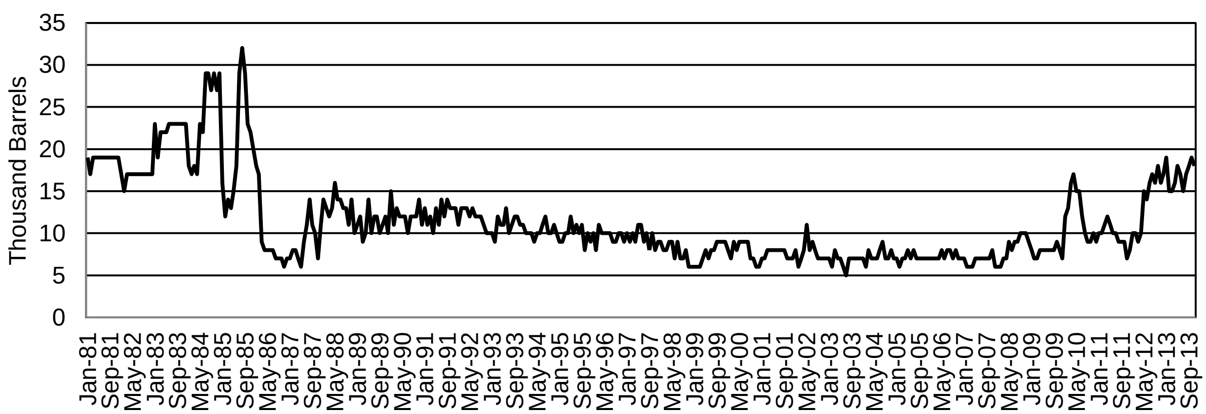


Figure 3-3. Missouri Monthly Field Production of Crude Oil (Jan. 1981~ Nov. 2013)[27]

Oil is currently produced by 18 companies in six counties (Figure 3-5). Figure 3-6 shows the oil production along with its respective percentage and sale value for each county. Cass County is the largest oil producing county in the state with 94,950 barrels in 2012, which accounts for 55 percent of the total

[27] "Missouri Field Production of Crude Oil (Monthly)", *United States Energy Information Administration.* January 2014. Web. January 30, 2014. <http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=mcrfpmo1&f=m>.

crude oil produced in Missouri.[28] Table 3-1 and Figure 3-7 give the oil production in 2012 by each operator.

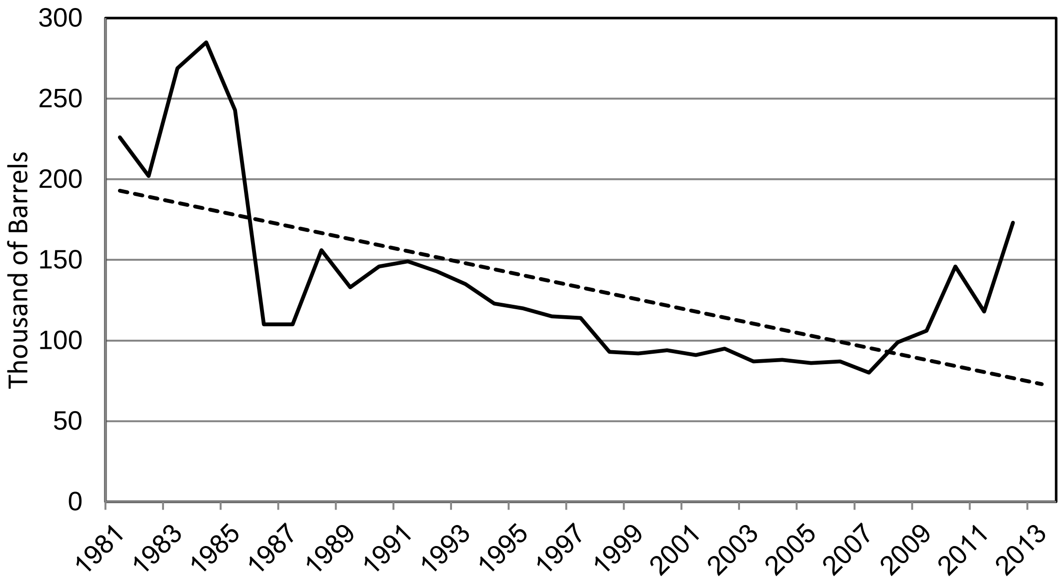
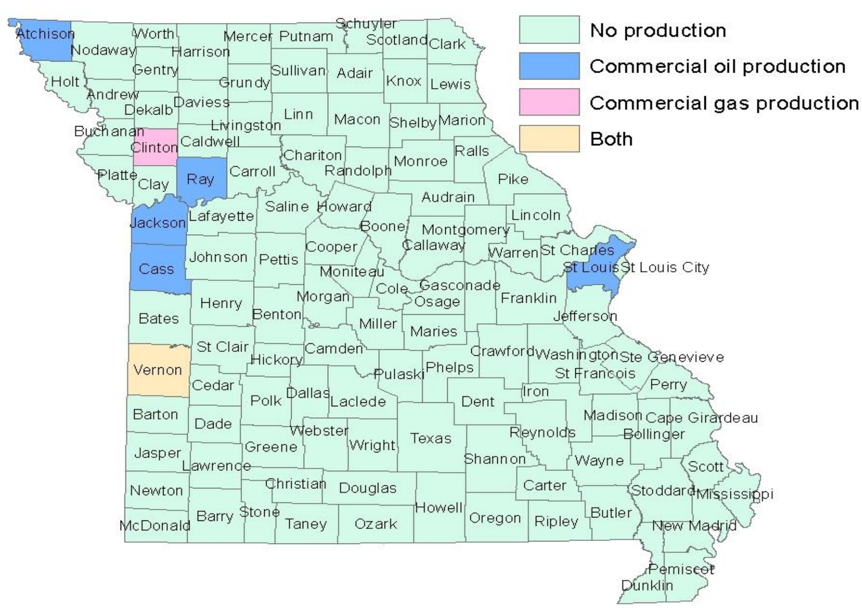


Figure 3-4. Missouri Annual Crude Oil Production (1981~ 2012)[29]



[28] "2012 Oil and Gas Activities and Production Report", *Missouri Department of Natural Resources, Division of Geology and Land Survey.* April 2013. Web. January 30, 2014. <http://www.dnr.mo.gov/geology/docs/2012-OGC-report-April-2013.pdf>.
[29] "Missouri Field Production of Crude Oil (Annual)", *United States Energy Information Administration.* January 2013. Web. January 30, 2014. <http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=mcrfpmo1&f=a>.

Figure 3-5. Commercial Oil and Gas Producing Counties in Missouri (2012)

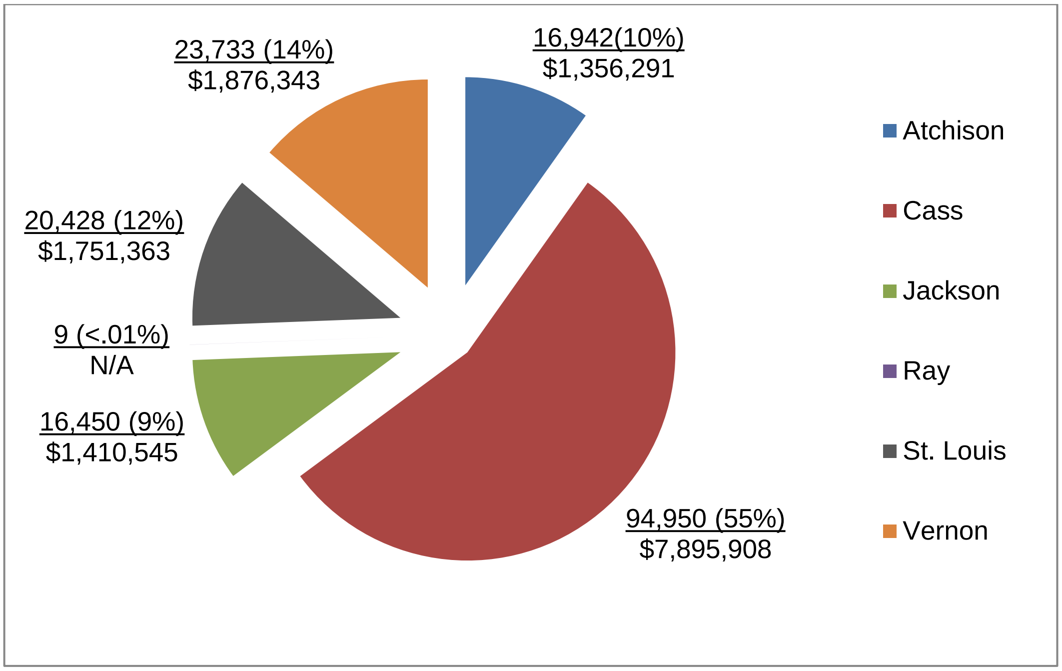


Figure 3-6. Missouri Crude Oil Production and Value by County (2012)

Table 3-1. Missouri Crude Oil Production by Operator (2012)

Operators	Barrels	Production Percentage
Kansas Res. Expl. & Dev.	86,649	50.2%
Running Foxes, Inc.	20,407	11.8%
Investment Equipment	16,942	9.8%
Colt Energy, Inc.	16,079	9.3%
Laclede Gas Company	14,228	8.2%
Laclede Oil Company	6,200	3.6%
AltaVista Energy	3,793	2.2%
T-5 Leasing	3,448	2.0%
All Others	4,766	2.8%
Total Barrels	**172,512**	**100.0%**

In 2012, over 10,053 thousand cubic feet (MCF) of gas was produced in eight commercial gas wells in the state. With an average price of $2.66/MCF, the total gas sale value was approximately $25,745.[30]

[30] "2012 Oil and Gas Activities and Production Report", *Missouri Department of Natural Resources, Division of Geology and Land Survey.* April 2013. Web. January 30, 2014. <http://www.dnr.mo.gov/geology/docs/2012-OGC-report-April-2013.pdf>.

Commercial gas production activities currently occur only in Vernon County. However, permits have been issued to construct new commercial gas wells in Clinton County.

Four counties (Cass, Clay, Clinton and Jackson) have approximately 500 private gas wells in the state. The status of most of those wells is unknown due to the lack of required production reporting. Of the 50 known active private gas wells in use, 32 wells are located in Cass County. Almost all of the gas from private gas wells is being used in private homes and small businesses to fuel heating appliances. The total marketed production for the state from 1960-2010 is illustrated in Figure 3-8.[31] The cumulative natural gas production for the top six counties in Missouri from 1928 through 2013 is represented in Figure 3-9.[32]

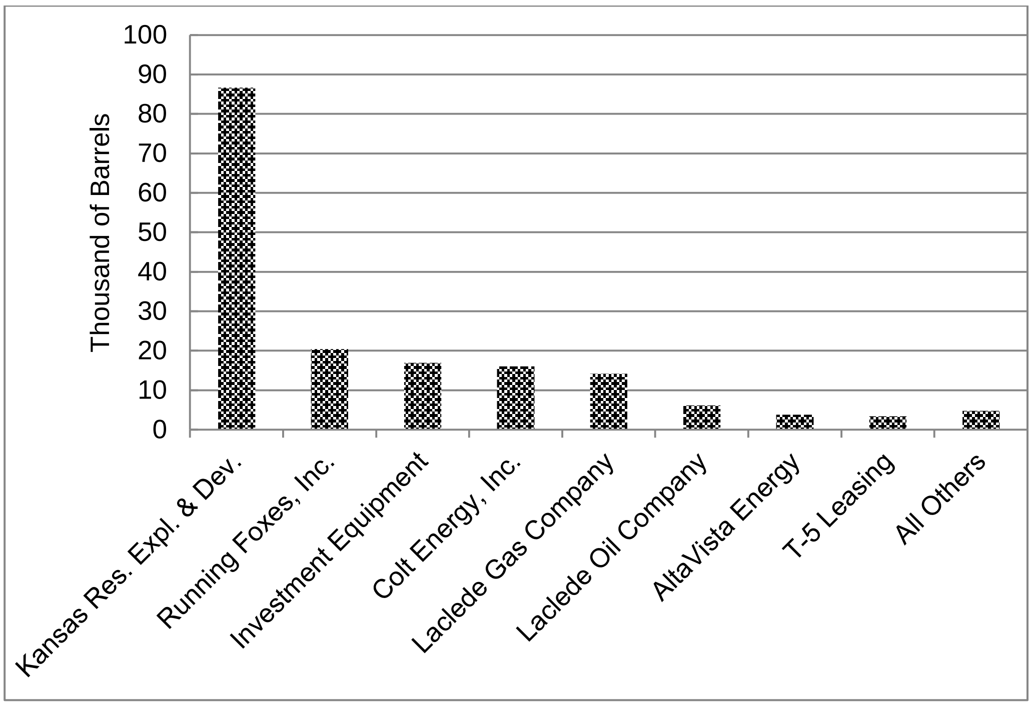


Figure 3-7. Missouri Crude Oil Production by Operator (2012)

[31] "Table 13. Natural Gas Production, Transmission, and Consumption by State, 1967-2000", *United States Energy Information Administration. N.D.*Web. January 30, 2014. <http://www.eia.gov/pub/oil_gas/natural_gas/data_publications/historical_natural_gas_annual/current/pdf/table_13.pdf>.

[32] "Gas Production by Gas Field", *Missouri Department of Natural Resources, Division of Geology and Land Survey*. Web. January 30, 2014. <http://www.dnr.mo.gov/geology/docs/CumulativeGasProductionthru2010.xls>.

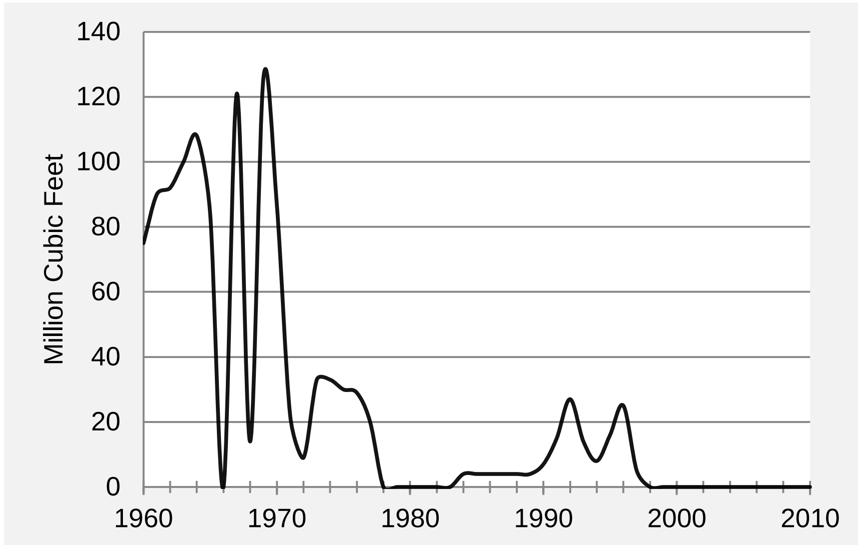


Figure 3-8. Missouri Natural Gas Marketed Production (1960-2010)

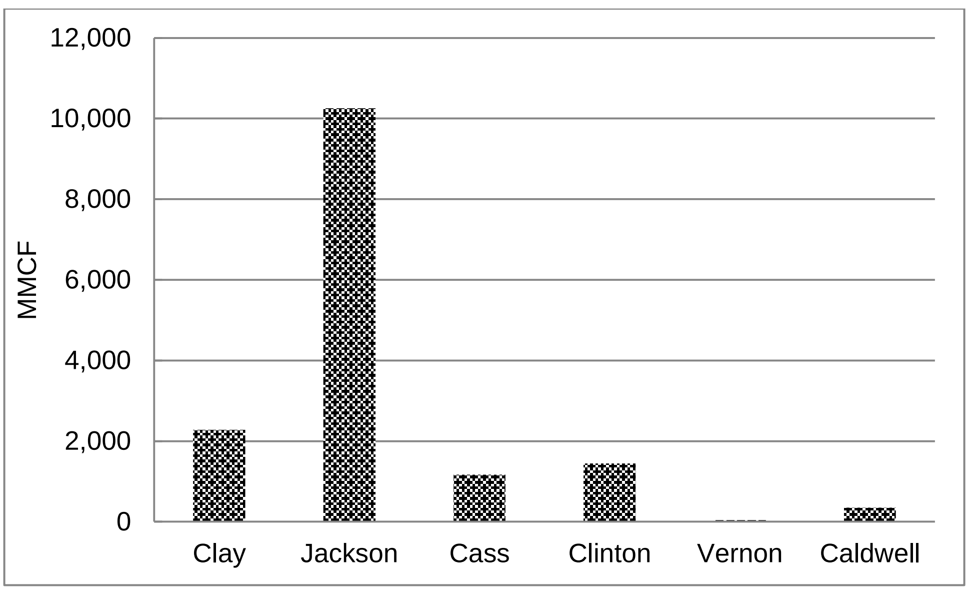


Figure 3-9. Total Cumulative Natural Gas Production by County (1928-2012)

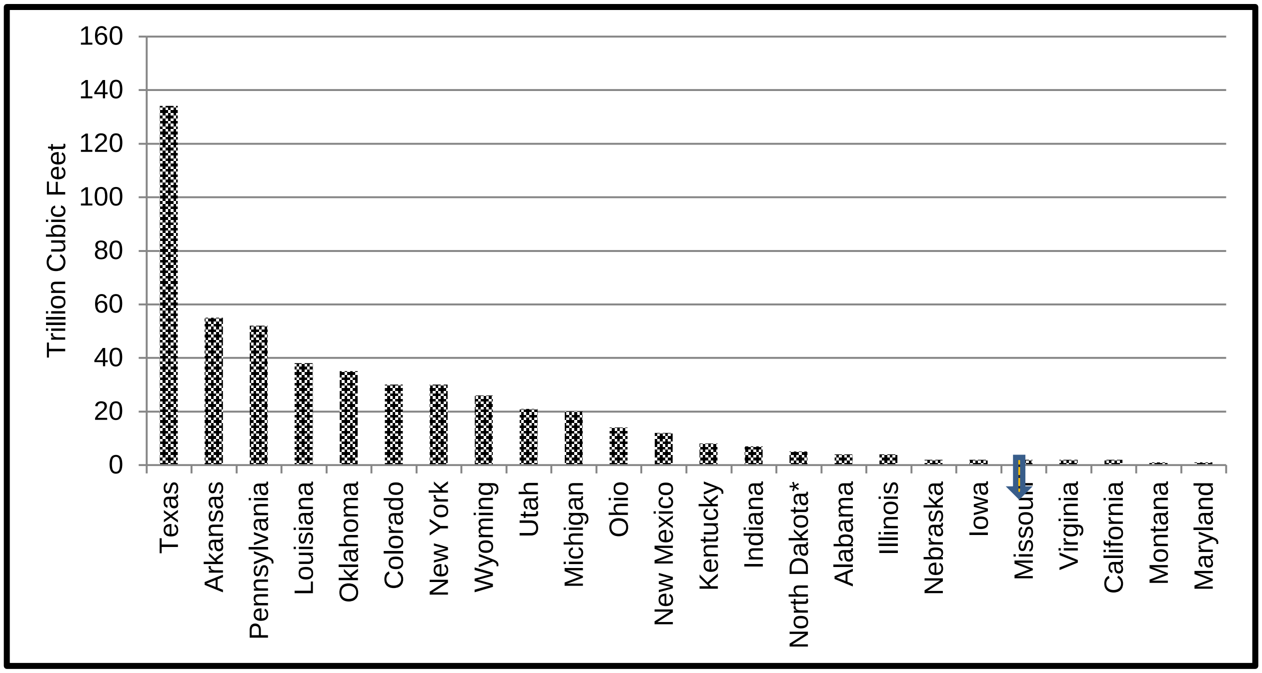


Figure 3-10. Estimated Recoverable Shale Gas Reserves in Selected U.S. States

Even though hydraulic fracturing has been utilized by the gas industry for decades, it has experienced a resurgence in popularity with the development of horizontal drilling. Technological advancements in drilling techniques have made previously unavailable gas deposits within reach. The development of horizontal drilling has increased the productivity of individual wells. The Bureau of Economic Analysis estimates that Missouri has two trillion cubic feet (TCF) of shale gas deposits that are currently economically recoverable, amounting to $217 billion in 2010 real state GDP (at a price of $4/mcf).[33] Figure 3-10 displays a comparison of estimated recoverable shale gas deposits for the top 24 states. This amount of potential shale gas is comparable to what is found in Nebraska, Iowa and Virginia, but still is small on the national scale with several states having hundreds and into the thousands of TCF.

[33] "Potential Impact of Natural Gas Fracking on Municipal Bond Issuers", Kroll Bond Rating Agency, Inc. January 2012. Web. August 28, 2012. < http://www.magny.org/event-presentations/01-20-12_potential_impact_of_%20natural_gas_fracking.pdf>.

4. Landfill Gas

4.1 Landfill Gas Production

Landfill gas is created by the anaerobic decomposition of waste materials in a landfill. The captured gas can be used either to produce heat for thermal applications or to generate electricity. While the use of landfill gas as a renewable resource in the state is relatively small compared to other energy resources, it has been actively recovered in recent years to generate significant amounts of energy. From 2006 to 2010, the net electricity generation from landfill gas has tripled from less than 20 to 60 gigawatt hours (GWh) (Figure 4-1).

According to the Environmental Protection Agency's (EPA) Landfill Methane Outreach Program (LMOP), there are currently ten landfills in the state capturing landfill gas and using it for direct heating and/or electricity generation. Seven of these ten landfills employ the landfill gas to produce electricity with a combined generating capacity of 29 MW. Another 1.6 MW capacity landfill gas-to-electricity project is under development at the State Fair Community College in Sedalia, Missouri. When it is completed, it will add to the total generation capacity from landfill gas for a total amount of about 30 MW in the state. Table 4-1 lists all landfill gas-to-energy projects already in operation and under development.

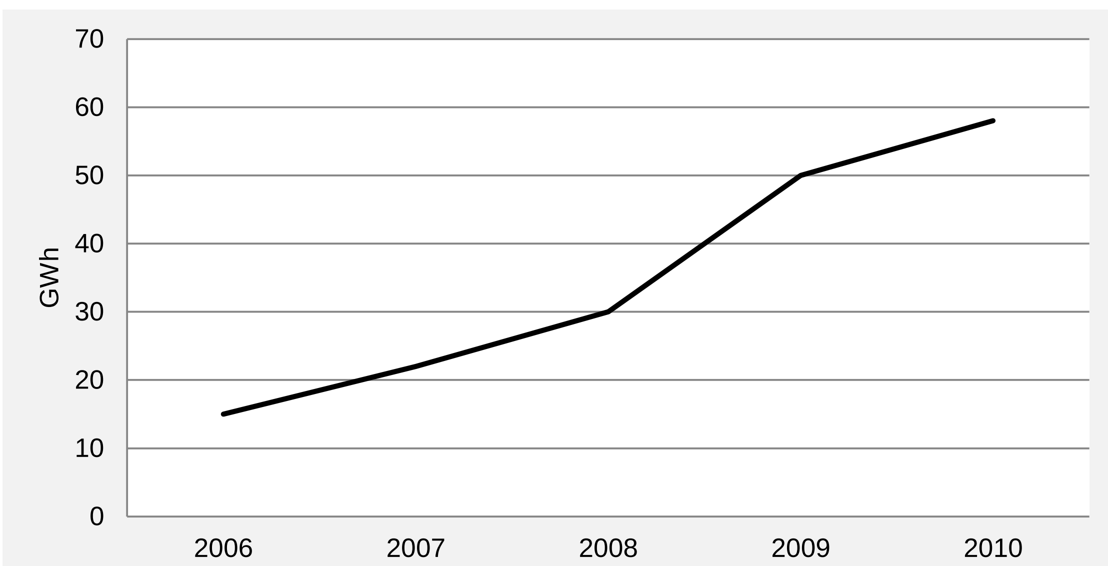


Figure 4-1. Net Electricity Generation by Landfill Gas in Missouri (2006-2010)

4.2 Landfill Gas Resources

The LMOP defines a candidate landfill for an energy project as one that is currently accepting waste or has been closed for less than five years, has at least one million tons of waste in place, and does not have an operating or under construction landfill gas-to-energy project. Many of the active landfills in the state have landfill gas-to-energy projects in place or plan to put the systems in place. As these landfills continue to accept more waste, their potential for energy production increases, producing more renewable recoverable gas for energy generation.

Table 4-1. Landfill Gas-to-Energy Projects in Missouri

Landfill Name	Landfill City	Landfill County	Landfill Owner Organization	Project Start Date	LFGE Utilization	LFGE Project Type	MW Capacity	LFG Flow to Project (mmscfd)	Emission Reductions (MMTCO2E/yr)
City of Columbia SLF	Columbia	Boone	City of Columbia, MO	6/16/2008	Electricity	Reciprocating Engine	3.1		0.089
City of Columbia SLF	Columbia	Boone	City of Columbia, MO	8/31/2011	Electricity	Cogeneration	0.0		0.000
Courtney Ridge Landfill, LLC	Independence	Jackson	Republic Services, Inc.	5/1/2009	Direct	Direct Thermal		2.880	0.237
Fulton SLF	Fulton	Callaway	City of Fulton, MO	8/31/2011	Electricity	Reciprocating Engine	0.2		0.010
IESI Landfill	Maryland Heights	St. Louis	Progressive Waste Solutions Ltd.	1/1/1983	Direct	Direct Thermal			
IESI Landfill	Maryland Heights	St. Louis	Progressive Waste Solutions Ltd.	1/1/1986	Direct	Greenhouse		0.058	0.005
IESI Landfill	Maryland Heights	St. Louis	Progressive Waste Solutions Ltd.	1/1/1997	Direct	Boiler		0.300	0.025
IESI Landfill	Maryland Heights	St. Louis	Progressive Waste Solutions Ltd.	1/1/2009	Direct	Direct Thermal		0.010	0.001
Jefferson City Sanitary Landfill	Jefferson City	Cole	Republic Services, Inc.	3/31/2009	Electricity	Cogeneration	3.2	1.728	0.135
Lamar Landfill	Lamar	Barton	City of Lamar, MO	6/30/2010	Electricity	Reciprocating Engine	5.6		0.236
Rumble SLF I & II	Sugar Creek	Jackson	Waste Management, Inc.	1/1/1998	Direct	Greenhouse		0.022	0.002
Rumble SLF I & II	Sugar Creek	Jackson	Waste Management, Inc.	9/1/2005	Direct	Direct Thermal		1.400	0.115
Springfield Sanitary Landfill	Willard	Greene	City of Springfield, MO	5/10/2006	Electricity	Reciprocating Engine	3.0	1.580	0.127
St. Joseph City SLF	St. Joseph	Buchanan	City of St. Joseph, MO	3/30/2012	Electricity	Reciprocating Engine	1.6		0.068
Central Missouri SLF*	Sedalia	Pettis	WCA Waste Corporation				1.6		

Landfill Name	Landfill City	Landfill County	Landfill Owner Organization	Project Start Date	LFGE Utilization	LFGE Project Type	MW Capacity	LFG Flow to Project (mmscfd)	Emission Reductions (MMTCO2E/yr)
Veolia ES Oak Ridge Landfill, Inc.	Ballwin	St. Louis	Veolia ES Solid Waste, Inc.	6/1/2009	Direct	Direct Thermal		1.150	0.094
IESI Landfill	Maryland Heights	St. Louis	Progressive Waste Solutions Ltd.	Ameren Missouri	Electricity	Reciprocating Engine	14.7		0.635
Total							**33.0**		**1.779**

*under development as of January 2014

Source: EPA LMOP; Updated Lamar Landfill - MW Capacity from Missouri Public Utility Alliance and Emission Reduction calculation by MDED/DE.

Table 4-2 gives the locations of the 16 candidate landfills in the state. A preliminary analysis estimates that a total of an additional approximately 30 MW capacity could be realized from these candidate landfills if they were all developed for electricity generation.

Table 4-2. Candidate Landfills for Energy Projects

Landfill Name	Landfill City	Landfill County	Landfill Owner Organization	Waste in Place (tons)	Year Landfill Opened	Landfill Closure Year	Landfill Owner
Backridge Landfill	La Grange	Lewis	Republic Services, Inc.	890,000	1990	2021	Republic Services, Inc.
Black Oak Recycling & Disposal SLF	Hartville	Wright	WCA Waste Corporation	4,460,000	1989	2031	WCA Waste Corporation
Bridgeton Landfill	Bridgeton	St. Louis	Republic Services, Inc.	9,692,739	1976	2004	Republic Services, Inc.
Butler County Landfill	Poplar Bluff	Butler	Republic Services, Inc.	1,950,000	1980	2011	Republic Services, Inc.
Central Missouri SLF	Sedalia	Pettis	WCA Waste Corporation	2,518,656	1972	2043	WCA Waste Corporation
Eagle Ridge SLF	Bowling Green	Pike	WCA Waste Corporation	2,500,000	1972	2023	WCA Waste Corporation
IESI Timber Ridge Landfill	Richwoods	Washington	Progressive Waste Solutions Ltd.			2082	Progressive Waste Solutions Ltd.
Joplin SLF	Joplin	Jasper	City of Joplin, MO	1,324,368	1974	1990	City of Joplin , MO
Lee's Summit SLF	Lee's Summit	Jackson	City of Lee's Summit, MO	2,700,000	1982	2017	City of Lee's Summit, MO
Lemons East Sanitary Landfill	Dexter	Stoddard	Republic Services, Inc.	1,200,000	1994	2051	Republic Services, Inc.
Newton-McDonald County SLF	Neosho	Newton	Newton-McDonald County SLF Board	900,500	1975	1993	Newton-McDonald County SLF Board, MO

Landfill Name	Landfill City	Landfill County	Landfill Owner Organization	Waste in Place (tons)	Year Landfill Opened	Landfill Closure Year	Landfill Owner
Show-Me Regional Landfill	Warrensburg	Johnson	Republic Services, Inc.	1,017,600	1992	2044	Republic Services, Inc.
Southeast SLF	Kansas City	Jackson	Republic Services, Inc.	8,071,606	1974	2002	Republic Services, Inc.
St. Francois County SLF	Park Hills	St. Francois	St. Francois Environmental Corporation	894,820	1974	1993	St. Francois Environmental Corporation
Veolia ES Maple Hill Landfill, Inc.	Macon	Macon	Veolia ES Solid Waste, Inc.	2,274,141	1976	2079	Veolia ES Solid Waste, Inc.
Woods Chapel SLF	Blue Springs	Jackson	The Links at Stone Canyon, Inc.	2,100,000	1974	1994	The Links at Stone Canyon, Inc.

4.3 Spotlight on Missouri's Landfill Gas Facilities

Columbia Landfill Gas Energy Plant, *Columbia, Missouri*

In 2004, Columbia voters passed a proposal to adopt a renewable portfolio standard. The goals are a stepped program requiring Columbia to increase its use of renewable energy sources to 15 percent of electric retail sales by December 31, 2022. In January 2014, Columbia voted to increase its goals to reach 15 percent by 2017 and 25 percent by 2022. The City of Columbia partnered with Sexton Energy, LLC in 2008 to complete a landfill gas-to-energy project. With the addition of the third generator in 2013, the plant's generation capacity currently reaches 3.1 MW. In 2013, Columbia's landfill gas operations generated 13,326 MWh of consistent power accounting for 1.12 percent of Columbia's electric power at $47.38 per megawatt hour.

Of all of the resources in Columbia's renewable energy portfolio, landfill gas has had one of the lowest impacts on rates. The average non-renewable cost in 2013 was $54.88 per megawatt hour. The fourth generator may be added in the future that will allow enough electricity production to account for approximately 2.5 percent of Columbia's energy profile for the next ten years. Additionally, Columbia's landfill gas generation serves as a renewable base load resource.[34]

[34] "2013 Renewable Energy Report." *Columbia Water & Light*. February 2013. Web. February 6, 2013. <http://www.gocolumbiamo.com/WaterandLight/Documents/RenewReport.pdf>.

St. Joseph Landfill Gas Electricity Plant, *St. Joseph, Missouri*

In 2010, the Kansas City Power & Light Greater Missouri Operations Company (KCP&L GMO) partnered with the City of St. Joseph and Burns & McDonnell to develop a landfill gas–to-electricity project at the St. Joseph Sanitary Landfill. The project was awarded a $450,000 Energize Missouri Renewable Energy Biogas subgrant from the Missouri Division of Energy using American Recovery and Reinvestment Act funds. This $6 million dollar project became fully operational in March of 2012[35] with a 1.6 MW generator and the capacity to power nearly 1,000 homes annually.[36]

Jefferson City Landfill Gas Utilization Project, *Jefferson City, Missouri*

The Jefferson City landfill gas project brought together the City of Jefferson, the City of Columbia, the State of Missouri's Department of Corrections, Ameresco and Republic Services (the landfill owner) to meet the needs of all parties. This 3.2 MW facility saves approximately $500,000 annually and has the carbon reduction equivalent of the removal of nearly 1,000 cars from the road. The power is purchased by Columbia Water & Light through a 20-year contract, which helps the city meet its renewable portfolio standard requirements. Additionally, Ameresco developed a system that utilizes the heat waste generated from the facility for steam and hot water in the Jefferson City Correctional Center and Algoa Correctional Center.[37]

IESI Champ Landfill**,** *Champ, Missouri*

The IESI Champ Sanitary Landfill has one of the longest histories in Missouri of utilizing landfill gas for energy generation. This sanitary landfill has collected landfill gas and used it for fuel in its asphalt plant burner and concrete ready mix plant boiler since 1992. In 1997, the nearby Pattonville High School partnered with Fred Weber (the previous landfill owner) to utilize the landfill gas to power the school's boilers after the recommendation was made by the school's ecology club. The project was funded by the Missouri Division of Energy's Energy Loan Program, a grant from St. Louis County Solid Waste Commission and Fred Weber. The savings amount to approximately $27,000 annually, due in part to the fact that Fred Weber provided the gas free of charge to the school. The environmental benefits are equal to

[35] "American Recovery and Reinvestment Act, Energize Missouri Renewable Energy Biogas Grants." *Missouri Department of Natural Resources*. N.d. Web. 6 February 2013. <http://www.dnr.mo.gov/transform/energizemissourirenewablebiogas.htm>.
[36] "Landfill gas-to-energy project will create enough renewable energy to power nearly 1,000 homes." *Missouri Governor Jay Nixon News Releases, Office of Missouri Governor Jay Nixon. 2010.* Web. February 6, 2013. <http://governor.mo.gov/newsroom/2012/Gov_Nixon_and_KCP_L_cut_ribbon_on_renewable_energy_project_in_St_Joseph>.
[37] "Algoa and Jefferson City Correction Centers." *Ameresco*. 2011. Web. February 6, 2013. <http://www.ameresco.com/sites/default/files/jefferson_city_0.pdf>.

the carbon sequestered annually by 22,700 acres of pine or fir forest and the annual energy savings equal to heating 3,100 homes.[38]

The landfill was producing more gas than was used by the school, and it was being burned off or flared. To capture and utilize this unused gas, Ameren Missouri partnered with the new landfill owner, IESI Inc., to develop an additional landfill gas utilization project in 2010, frequently referred to as Ameren's Maryland Heights Renewable Energy Center. This landfill gas electricity generation project is one of the largest in the nation and became operational in the summer of 2012. It consists of three 4.9 MW turbines with the capacity to power 10,000 homes. The landfill is expected to last into 2070, providing consistent power to the St. Louis area and allowing Ameren to use the power generated for compliance with Missouri's renewable energy standard. [39]

State Fair Community College, *Sedalia, Missouri*

State Fair Community College partnered with the West Corporation, which owns the Missouri Central Landfill, various local, state and federal government agencies and private businesses to develop the landfill gas project to generate electricity for the college and to provide training opportunities for students. The initial phase of the operation is expected to have a 1.6 MW capacity. The second phase seeks to develop an energy technology incubator to assist emerging businesses with exploring next generation energy technologies and allow training opportunities for students.[40] This project was under development as of early 2014.

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[38] "Landfill Methane Outreach Program, Project profile: Fred Weber", *United States Environmental Protection Agency*. 15 July 2010. Web. February 6, 2013. <http://www.epa.gov/lmop/projects-candidates/profiles/fredweberpattonvillehighs.html>.
[39] Tomich, Jeffrey. "*Five Questions with Ameren Missouri's Bill Barbieri*". St. Louis Post-Dispatch. April 27, 2012. Web. February 6, 2013. <http://www.stltoday.com/business/local/five-questions-with-ameren-missouri-s-bill-barbieri/article_6426b2f6-8fb8-11e1-aac1-0019bb30f31a.html>.
[40] "Missouri Center for Waste to Energy", *State Fair Community College*. 2010. Web. February 6, 2013. <http://www.sfccmo.edu/pages/1446.asp>.

5. Biomass

5.1 Resource Overview

Biomass typically means any organic matter from plants or animals. Domestic biomass resources include agricultural crops and residues, manure and wastes from animal feeding facilities, forest and wood processing residues, municipal wastes and terrestrial and aquatic energy crops grown solely for energy purposes. As a valuable renewable resource, biomass provides a wide range of products such as food, fiber, heat, power, fuels and chemicals. In addition, biomass, like field crop and forest residues, can provide necessary organic matter and nutrients for plant growth and reduce soil erosion.

As a major producer of agricultural and forest commodities in the nation, Missouri has an abundant and diverse biomass resource base, which holds a significant potential for bioenergy, biofuels and biochemicals. Various uncertainties like availability, sustainable management and technical and economic constraints, have resulted in limited scale development of Missouri's biomass resources. However, increasing environmental and energy independence concerns make biomass production, conversion and use a more promising option for Missouri. Increased use of biomass resources can reduce dependence on imported fossil energy sources, create more job opportunities and stimulate the rural economy.

The types of biomass currently produced in the state include agricultural biomass, forest biomass and municipal wastes. The agricultural biomass comes primarily from field and seed crops and their residue, animal manure and wastes and food processing operations. Forest biomass is the residue and waste produced mostly from timber harvesting and processing and from forest thinning and other forest management practices. In addition, municipal solid waste (MSW) generates a large quantity of biomass. According to the Missouri Department of Natural Resources' Solid Waste Management Program, the average MSW generation rate per capita in Missouri is approximately seven pounds per day, which is much higher than the national average of 4.6 pounds.[41] Dedicated energy crops and algae are also attracting more interest in the state.

[41] "The 2006-2007 Missouri Municipal Solid Waste Composition Study," *Missouri Department of Natural Resources, Solid Waste Management Program*. October 2007. Web. February 6, 2013. <http://www.dnr.mo.gov/env/swmp/docs/wcsintroduction.pdf>.

5.2 Biomass Resources Availability and Opportunities

A 2005 study from the National Renewable Energy Laboratory (NREL)[42] examined the availability of technical biomass resources in the United States. The biomass categories in this study include agricultural residues (crop residues and animal manure), wood residues (forest residues, primary mill residues, secondary mill residues and urban wood residues), methane from landfills and domestic wastewater treatment and dedicated energy crops in the Conservation Reserve Program (CRP) lands.

According to this study, the total technically available biomass in Missouri is estimated at 18,439,000 tons annually. Table 5-1 shows the estimated results for each category, and the total biomass distribution by county in Missouri is illustrated in Figure 5-1.

Table 5-1. Total Biomass Resource Available in Missouri in 2005 NREL Study

Category	Yearly Technical Availability (thousand tons)
Agricultural Residues	
- **Crop residues**	6,007
- **Methane from manure management**	120
Wood Residues	
- **Forest residues**	1,840
- **Primary mill residues**	1,036
- **Secondary mill residues**	69
- **Urban wood residues**	613
Municipal Discards	
- **Methane from landfills**	273
- **Methane from domestic wastewater treatment**	9
Switchgrass from CRP Lands	8,473
Total	18,439

[42] Milbrandt, A. *A Geographic Perspective on the Current Biomass Resource Availability in the United States.* National Renewable Energy Laboratory. December 2005. Web. February 6, 2013. <http://www.nrel.gov/docs/fy06osti/39181.pdf>.

5.2.1 Field and Seed Crops

As a major agricultural state, Missouri has approximately 30 million acres of farm lands with an average farm size of 270 acres. Crops included in calculating the agricultural residues are corn, wheat, soybeans, cotton, sorghum, barley, oats, rice, rye, canola, beans, peas, peanuts, potatoes, safflower, sunflower, sugarcane and flaxseed. By assuming that 30 percent residue cover is reasonable for soil protection and 35 percent of the total residue could be collated as biomass, the total technically available crop residues in Missouri is estimated at 6,007,000 tons annually. Most crop residues in Missouri are located in the northern area. A number of counties in that region are able to provide as much as 200,000 dry tons/year of crop residues for bioenergy projects.

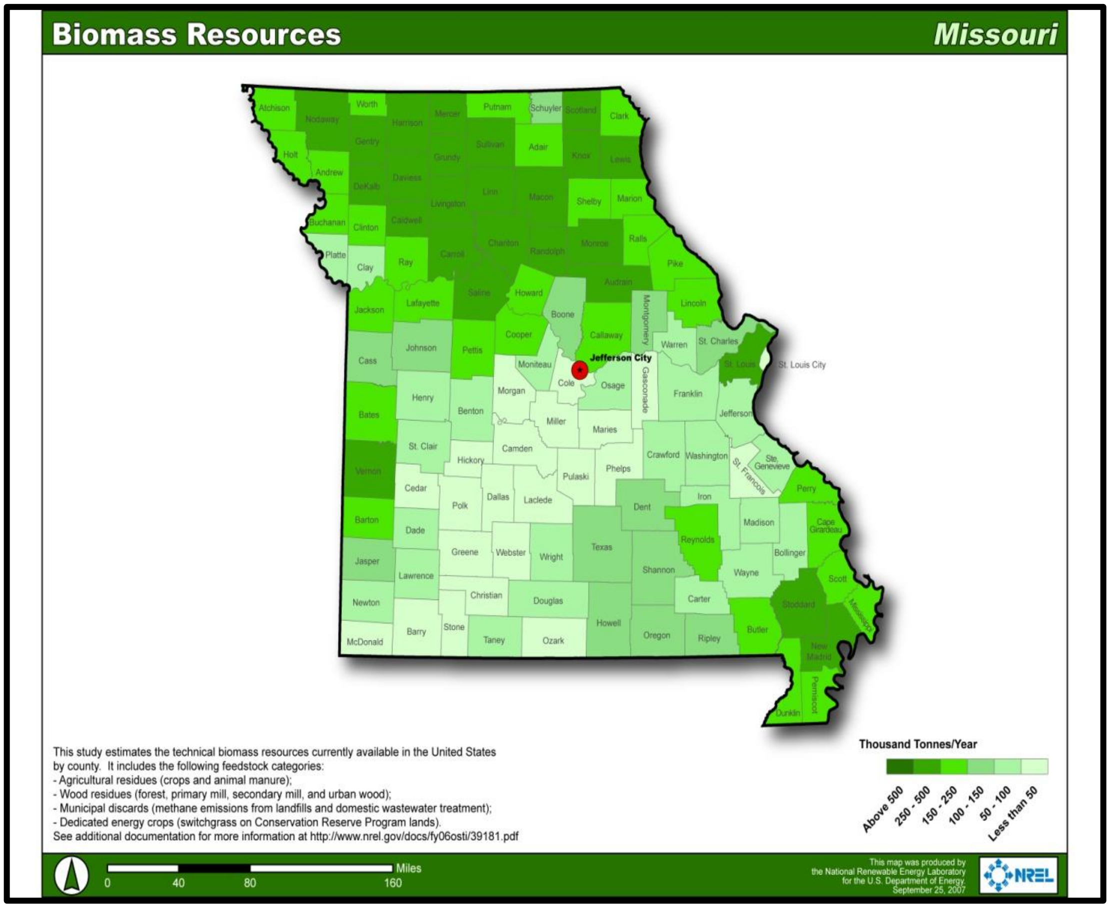

Figure 5-1. Technical Biomass Resource in Missouri by County

5.2.2 Animal Waste

Animal waste is organic matter from animal production and processing. In addition to manure, animal waste also includes dead animals, bedding, unused feed and other waste from slaughter and meat processing. The agricultural livestock population in Missouri includes 4.3 million cows, 3.1 million swine, 287.2 million chickens and 77,100 sheep and lambs. According to the 2007 Missouri Census of Agriculture provided by the U.S. Department of Agriculture's National Agricultural Statistics Service (NASS)[43], the total cattle population in the state includes 2.09 million beef cows, 110,358 milk cows and 2.09 million other cows (heifers that have not calved, steers, calves and bulls). A number of factors can affect the animal sizes and manure production rates, such as weather conditions, types of confinement, feed and reproduction. Based on the typical characteristic data of manure production published by the American Society of Agricultural Engineers (ASAE)[44], the estimated annual amount of animal manure on a wet basis for cattle, swine, sheep and lambs, and poultry layers and broilers in Missouri's counties is illustrated from Figure 5-2 to Figure 5-5. Figure 5-6 shows the total manure availability by county in the state.

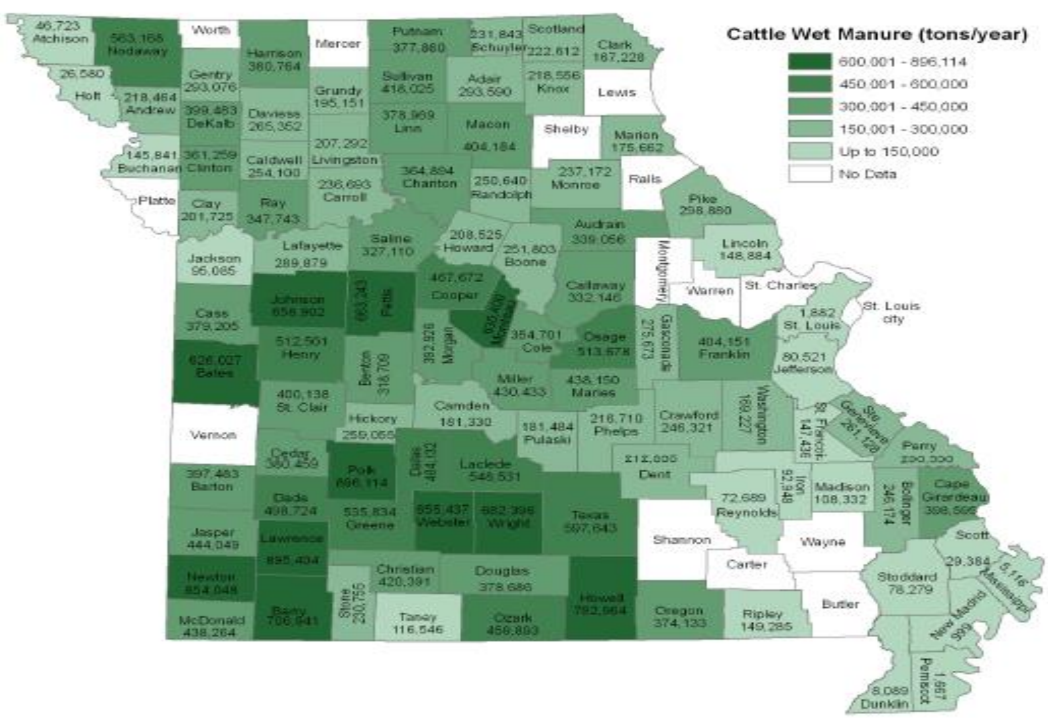

Figure 5-2. Wet Cattle Manure Availability by County

[43] "2007 Census of Agriculture." *United States Department of Agriculture, National Agricultural Statistics Service*. 2007. Web. February 6, 2013. <http://www.agcensus.usda.gov/Publications/2007/index.asp>.

[44] "Manure Production and Characteristics (ASAE D384.2 MAR 2005)", *the American Society of Agricultural Engineers*.

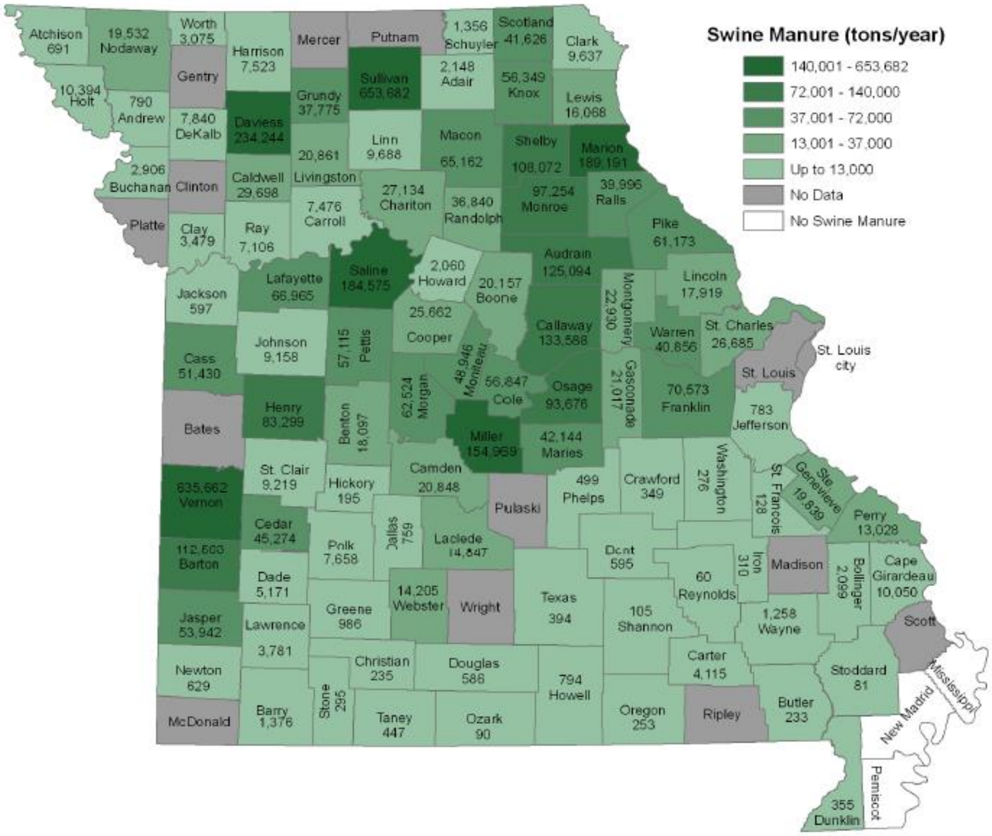

Figure 5-3. Swine Manure Availability by County

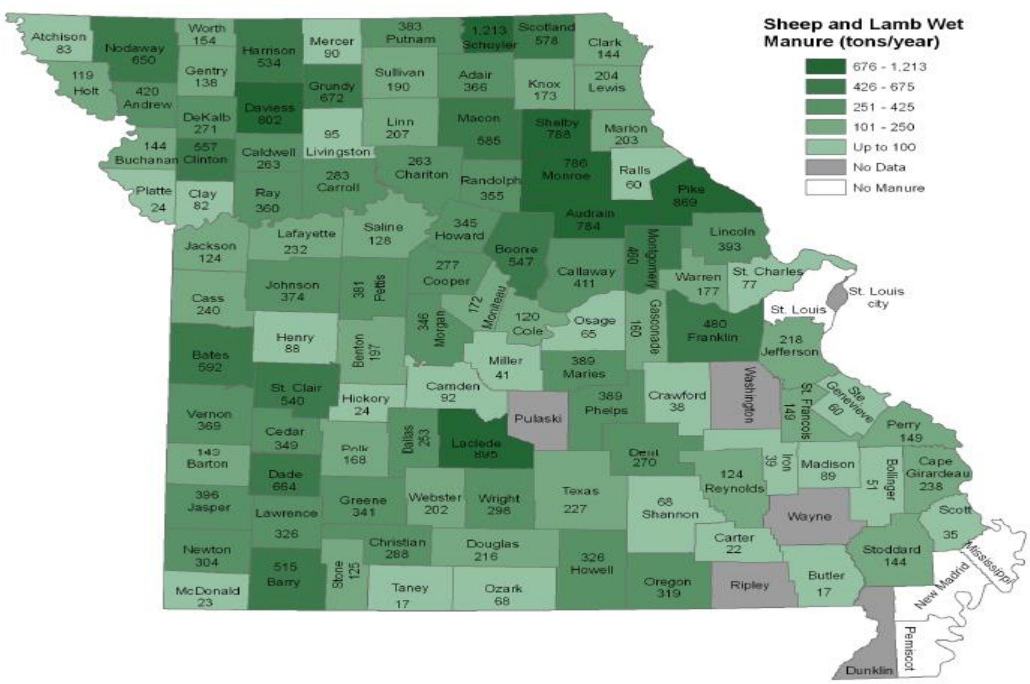

Figure 5-4. Sheep and Lamb Manure Availability by County

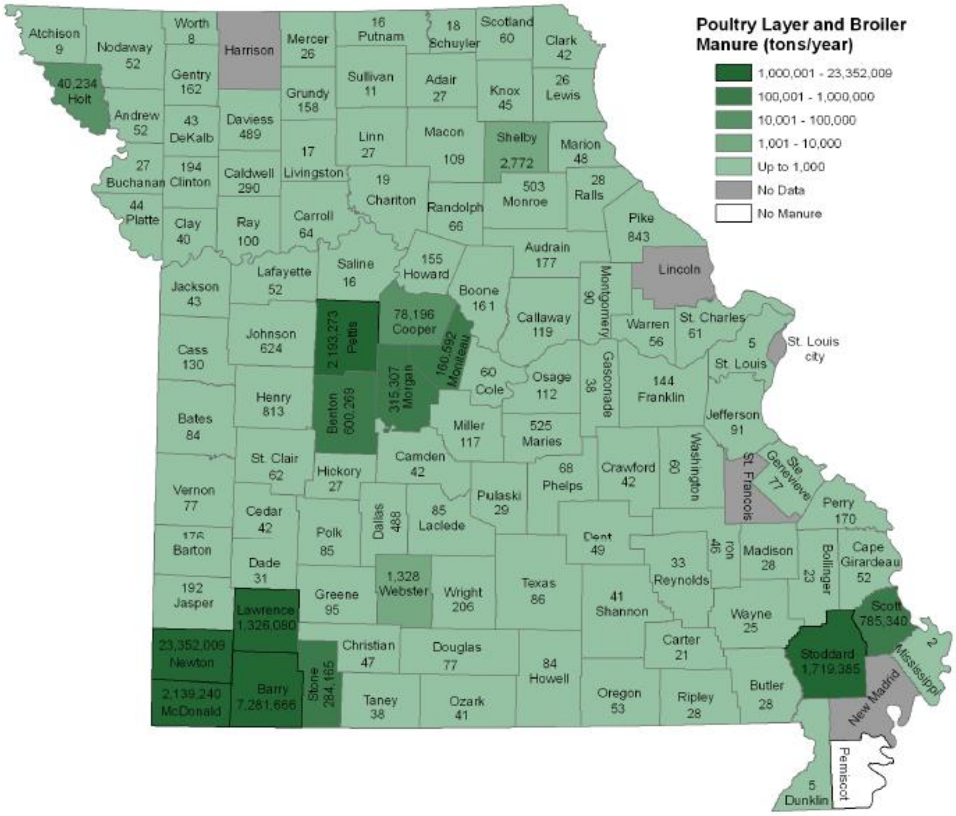

Figure 5-5. Poultry Layer and Broiler Manure Availability by County

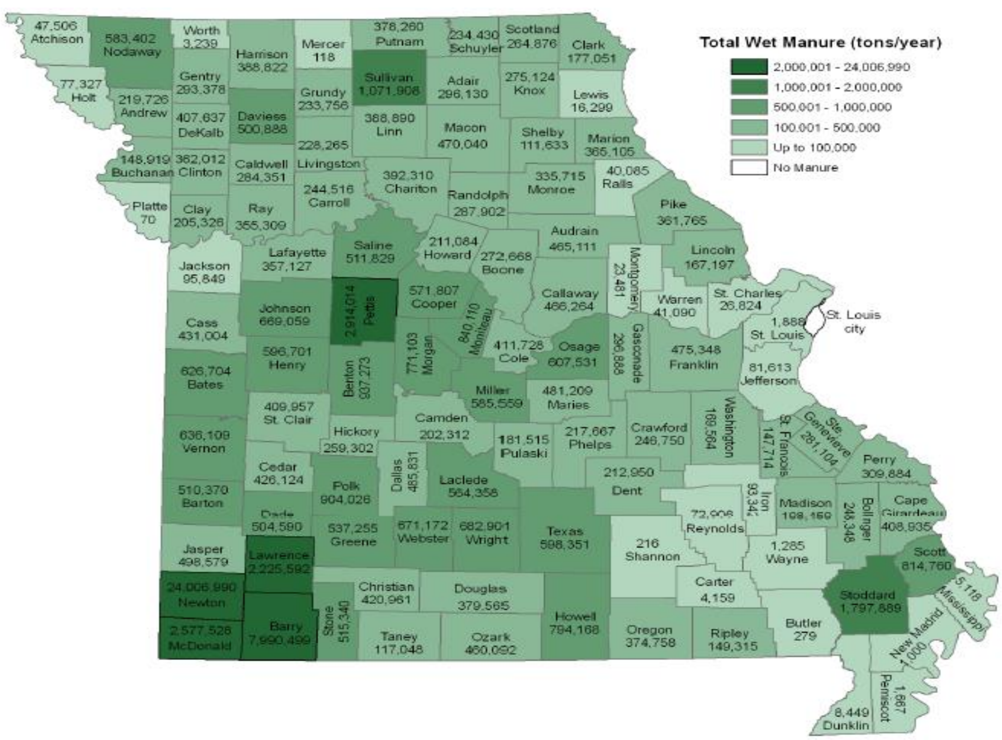

Figure 5-6. Total Animal Manure Availability by County

5.2.3 Woody Biomass

Forest residues include logging residues and other removals after carrying out silviculture operations and site conversion. Logging residues are the unused portions of trees cut or killed by logging and left in the woods. Other removals are considered trees cut or otherwise killed by cultural operations (e.g. pre-commercial thinning, weeding, etc.) or land clearings and forest uses that are not directly associated with round wood product harvests. Most southeast and southeast central counties in Missouri have at least 25,000 dry tons/year forest residues and more than ten counties are even in the range of 50-100,000 dry tons/year. Furthermore, the U.S. Billion-Ton report update in 2011[45] estimated the economic availability of logging residues. About one million dry tons of logging residues are available annually at $80 per dry ton in the next 20 years in Missouri. A simulation model also indicated that annual biomass from forest thinning are 300,000, 560,000 and 810,000 dry tons for the price of $20, $40 and $100, respectively.

Primary mill residues are composed of wood materials (coarse and fine) and bark generated at manufacturing plants (primary wood-using mills) when round wood products are processed into primary wood products like slabs, edgings, trimmings, sawdust, veneer clippings and cores and pulp screenings. It includes mill residues recycled as by-products as well as those left unutilized and disposed of as waste. Secondary mill residues include wood scraps and sawdust from woodworking shops— furniture factories, wood container and pallet mills and wholesale lumberyards. Those resources are located in southeast Missouri. Combining all forest residues and primary and secondary mill residues, the forest and its product industry are able to provide as much as 2,945,000 dry tons of biomass every year.

Urban wood waste includes wood residues from municipal solid waste (wood chips, pallets and yard waste), utility tree trimming and/or private tree companies and construction/demolition wood. The availability of urban wood waste largely depends on population density, economic condition and industrial structure. The recently updated national urban wood waste availability shows Kansas City and St. Louis areas are still the primary sources for urban wood wastes. Both areas can provide more than 50,000 dry tons/year of urban wood wastes. The Springfield area can also provide considerable amounts of this biomass resource. The amount of urban wood waste is increasing in the Columbia area due to city expansion.

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[45] "U.S. Billion-Ton Update", *United States Department of Energy.* August 2011. Web. February 6, 2013. <http://www1.eere.energy.gov/biomass/pdfs/billion_ton_update.pdf>.

The Missouri Department of Conservation issued the State's Forest Resource Assessment and Strategy in 2010,[46] which identified the goal of steering emerging woody biomass markets in a sustainable direction. This report identified a number of forest opportunity areas (FOA) which could offer Missouri's best geographic opportunities for sustaining forest resources and the associated beneficial usage like bioenergy. FOAs include rural, wildland-urban interface (WUI) and urban settings. Figure 5-7 shows the existing forest resources identified in this report. Approximately 50 percent of Missouri's existing forestland is recognized as FOA (Figure 5-8). Table 5-2 shows the identified urban FOAs with the population and Figure 5-9 illustrates those areas.

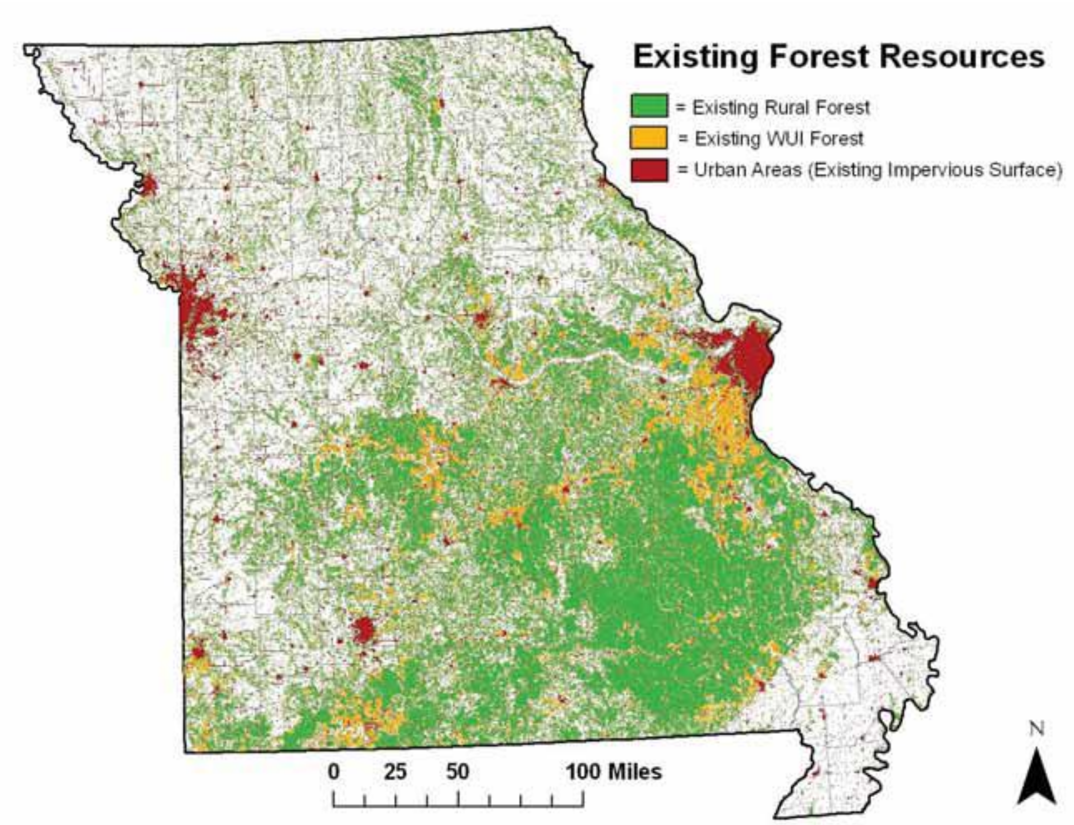

Figure 5-7. Missouri Existing Forest Resource Map

[46] "Missouri's Forest Resource Assessment and Strategy." *Missouri Department of Conservation, et. Al.* 2010. Web. February 6, 2013. <http://mdc.mo.gov/sites/default/files/resources/2010/08/9437_6407.pdf>.

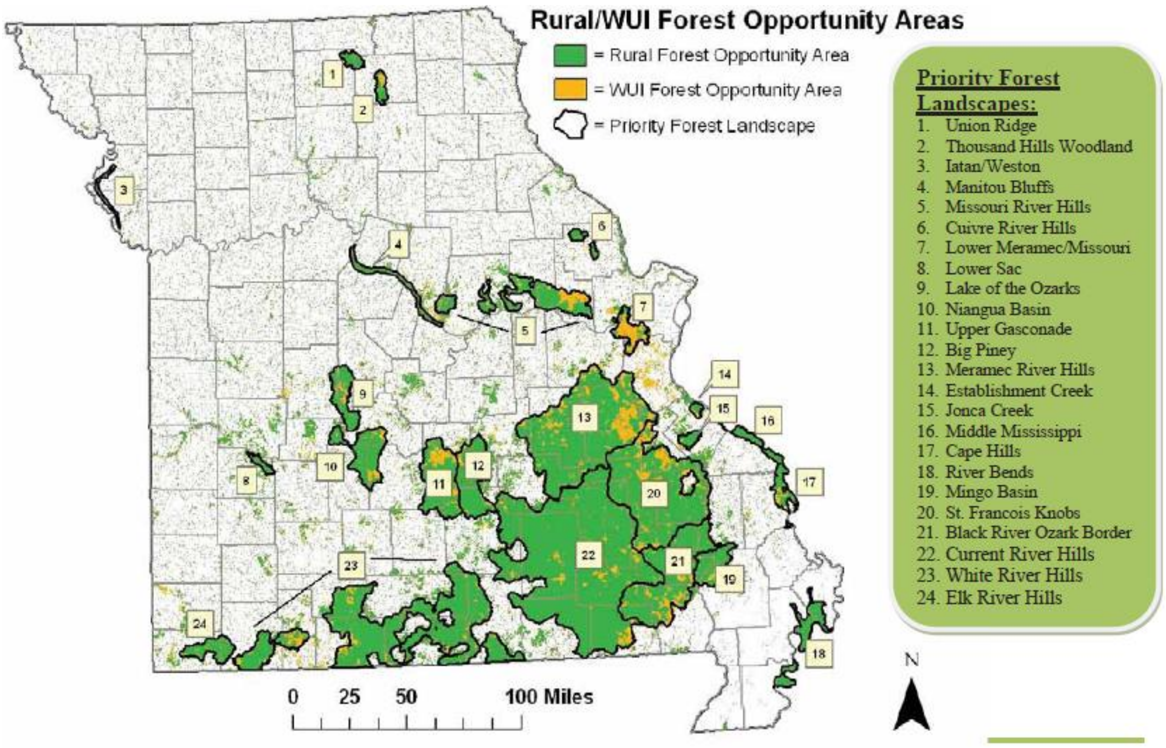

Figure 5-8. Rural/WUI Forest Opportunity Areas

Table 5-2. Urban Forest Opportunity Areas in Missouri

Urban FOA	U.S. Census Bureau Population Estimate	Population estimate includes these counties
St. Louis	2,014,235	St Louis County and City, St. Charles, Jefferson, Franklin
Kansas City	1,091,894	Jackson, Clay, Cass, Platte, Ray
Springfield	342,423	Greene, Christian
Columbia/Jefferson City	272,142	Boone, Cole, Callaway
Joplin	172,933	Jasper, Newton
St. Joseph	106,331	Andrew, Buchanan
Lake of the Ozarks	86,474	Camden, Morgan, Miller
Branson	78,574	Stone, Taney
Cape Girardeau	73,243	Cape Girardeau

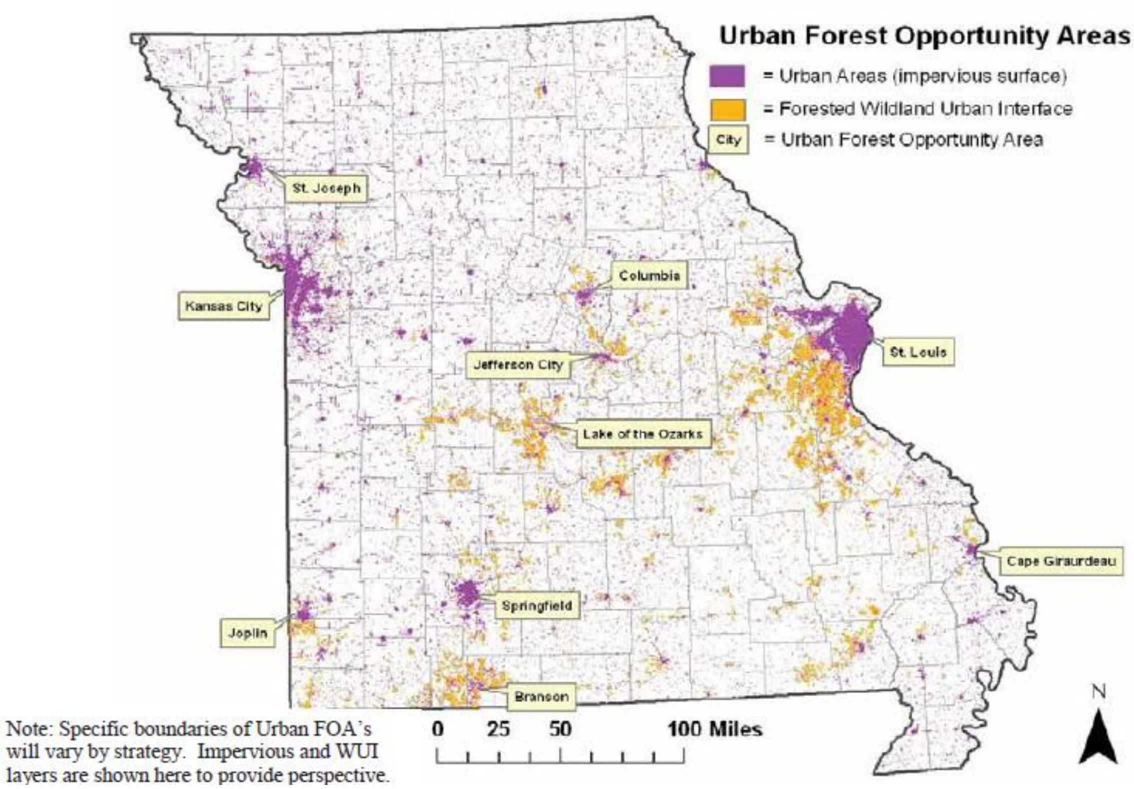

Figure 5-9. Urban Forest Opportunity Areas

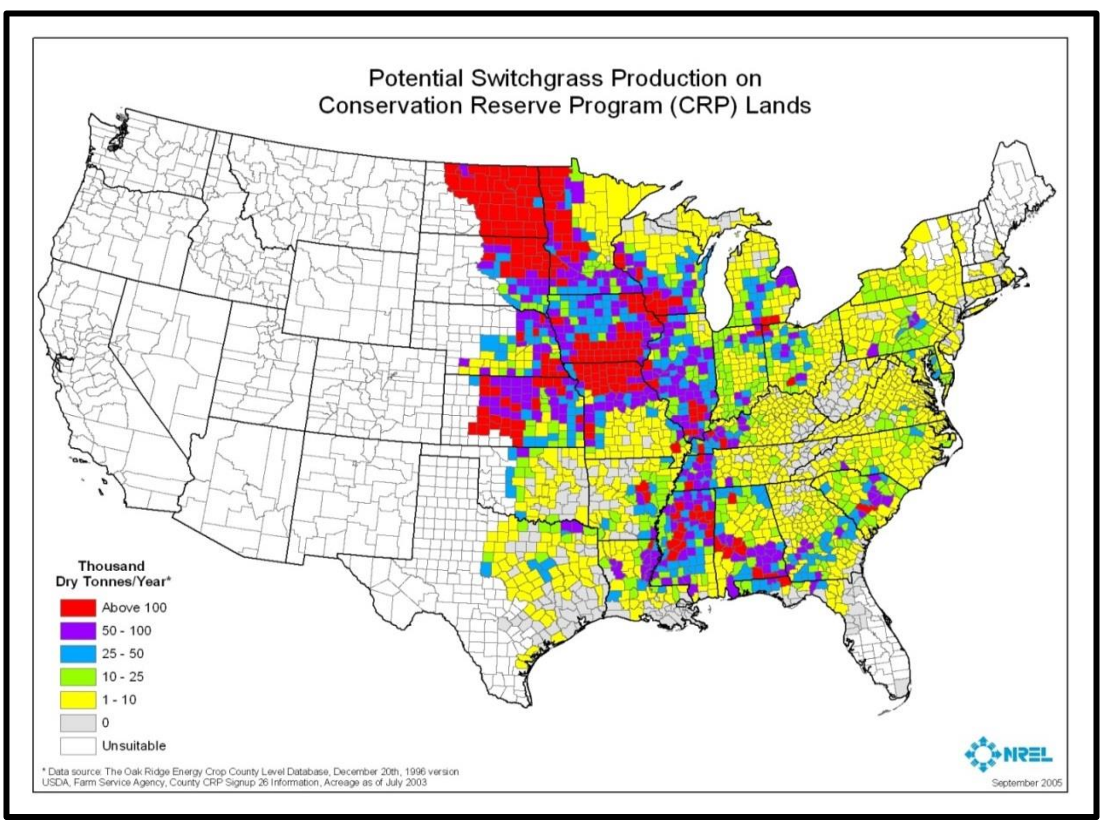

Figure 5-10. National Switchgrass Potential on CRP Land

5.2.4 Energy Crops

As a promising herbaceous energy crop, switchgrass has been increasingly attractive as a feedstock for biomass pellets and biofuels production over the past decade. Missouri, particularly in the northern region, has a great potential for growing switchgrass on Conservation Reserve Program (CRP) lands. It was estimated that the state can supply nearly nine million dry tons of switchgrass annually, which accounts for more than 10 percent of national switchgrass potential. Woody energy crops like willow or hybrid poplar can potentially be grown on CRP land, too. A rough estimate indicates that the potential production of seven million dry tons of willow or hybrid poplar yearly can be achieved from CRP lands in Missouri. It accounts for over 15 percent of national potential.

5.2.5 Municipal Waste

Municipal wastes include mostly municipal solid waste (MSW) along with municipal wastewater sludge from treatment facilities. Municipal solid waste includes primarily household wastes in addition to some commercial wastes collected by a municipality within a given area. Municipal solid waste normally excludes industrial hazardous wastes even though household hazardous waste, such as batteries and light bulbs, is considered as municipal solid waste in some definitions, considering the very limited amount. Municipal solid waste can be categorized as biodegradable waste (food, kitchen waste and paper), recyclable material (paper, glass, metals, cans and some plastics), inert waste (construction and demolition waste, concrete and dirt) and composite wastes (clothing and waste plastics).

The quantity and composition of municipal solid waste varies significantly with population, size and economic activities conducted in a specific area. For instance, rapidly growing areas will typically have larger scale construction activities, which would result in greater amounts of construction wastes, like wood and dirt. In contrast, if tourism is a major local industry, municipal solid waste in that area may contain more vegetable and food wastes. Thus, project developers should consider those factors when evaluating the local biomass availability derived from MSW.

According to the Missouri Department of Natural Resources’ Solid Waste Management Program, it is estimated that the total amount of waste disposed in Missouri landfills during 2006 was 4,500,160 tons, which is equivalent to 1,698 pounds per capita annually. Since around 60 percent of the waste stream generated in the state is MSW, the quantity of MSW in the Missouri waste stream for disposal in 2006 was estimated to be 2.7 million tons. The annual waste generation per capita is around 2.14 tons, which corresponds to 7.0 pounds MSW per capita per day, much higher than the national average of 4.6 pounds per capita per day. Table 5-3 gives the detailed composition of MSW by averaging the samples taken from several landfills and transfer stations in the state. The available biomass from the MSW composition categories in Table 5-3 includes paper and organics, such as food and wood waste.

Another biomass source from municipal waste, biosolids or sewage sludge, is the by-product of the treatment of domestic wastewater in a wastewater treatment plant (WWTP). Those waste residuals can be further treated to reduce pathogens and vector attraction by a number of approved methods. Biosolids in their liquid form look like muddy water and contain between 1-10 percent solids. Biosolids may be dewatered in a second step of the treatment process, which turns it into a "cake" with the texture of a wet sponge. In this stage, the content could increase to 11-40 percent biosolids. Biogas produced from anaerobic digesters at WWTPs can be used as a fuel source to generate reliable electricity and heat necessary for the WWTPs, which can displace purchased fossil fuels and reduce emissions of greenhouse gases and other air pollutants. Table 5-4 lists the WWTPs in Missouri which currently either flare biogas or employ biogas for energy uses.

Table 5-3. Typical Municipal Solid Waste Composition in Missouri[47]

	% by weight	**% by volume**
Cardboard	8.20%	13.50%
Newsprint	5.17%	3.48%
Magazines	3.66%	1.78%
High grade paper	6.40%	6.51%
Mixed paper	10.20%	12.09%
Total paper	33.63%	37.45%

[47] "The 2006-2007 Missouri Municipal Solid Waste Composition Study," *Missouri Department of Natural Resources*, *Solid Waste Management Program*. October 2007. Web. February 6, 2013. <http://www.dnr.mo.gov/env/swmp/docs/wcsintroduction.pdf>.

	% by weight	% by volume
Clear glass	2.71%	1.29%
Brown glass	1.77%	1.10%
Green glass	0.63%	0.61%
Other glass	0.32%	0.33%
Total glass	5.44%	3.34%
Aluminum cans	1.59%	2.58%
Other aluminum	0.34%	0.57%
Non ferrous	0.23%	0.28%
Food cans	2.93%	2.45%
Ferrous	0.87%	0.73%
Oil filters	0.08%	0.10%
Total metals	6.04%	6.72%
PET #1	2.55%	4.63%
HDPE #2	1.90%	4.06%
Plastic film	4.82%	10.23%
Other plastic	7.99%	12.42%
Total plastic	17.25%	31.34%
Food waste	17.22%	8.26%
Wood waste	1.19%	0.68%
Textiles	4.73%	3.28%
Diapers	5.48%	3.02%
Other organics	2.97%	2.12%
Total organics	31.59%	17.36%
Fines	0.93%	0.88%
Other inorganics	3.21%	1.80%

	% by weight	% by volume
Total inorganics	4.14%	2.68%
HHW	0.92%	0.88%
Electronic waste	0.99%	0.50%
Total special waste	1.91%	1.10%
Total composition	100%	100%

Table 5-4. WWTPs Employing Biogas Technology in Missouri (million gallons per day)[48]

Name	City	County	Flow Design (MGD)	Flow Average (MGD)
Carrollton WWTP	Carrollton	Carroll	3.3	0.7
Shoal Creek Facility	Joplin	Newton	6.5	3.5
Kirksville WWTP	Kirksville	Adair	3.16	2.35
Springfield SW WWTP	Springfield	Greene	42.5	35
Turkey Creek WWTP	Joplin	Jasper	15	9.3
Missouri River WWTP	St. Louis	St. Louis	28	30
Columbia WWTP	Columbia	Boone	20.6	15.5
St. Joseph WWTP	St. Joseph	Buchanan	27	19
Mexico WWTP	Mexico	Audrain	6	2.2
K.C. Blue River STP	Kansas City	Jackson	105	70
Sedalia North WWTP	Sedalia	Pettis	2.5	1

5.2.6 Algae

Algal biofuels have been generating considerable interest over the past few years in the state and hold the potential to solve many of the sustainability challenges facing other biofuels today. The Missouri Technology Corporation (MTC) conducted a study in 2011 that developed a roadmap for algae research, development, demonstration and commercialization in Missouri, with a $180,000 grant using American Recovery and Reinvestment Act funds awarded by the

[48] *Biogas Data*. 2012. Web. February 6, 2013. <http://www.biogasdata.org>.

Missouri Division of Energy. The final report, titled *"Energize Missouri: Algae-based Renewable Energy Study,"* [49] assesses the potential benefits to the state economy from a healthy and robust algae industry, and makes a number of recommendations to maintain and strengthen Missouri's leadership in the algae biofuels area.

As indicated in this report, a host of Missouri-based institutions are active in addressing research needs in the algal biofuels field. Missouri excels in algae research and development and is one of only two algae hubs supported by the U.S. Department of Energy. The report concluded that the Bootheel is the most favorable area of the state and capable of accommodating large or smaller scale facilities for algae production.

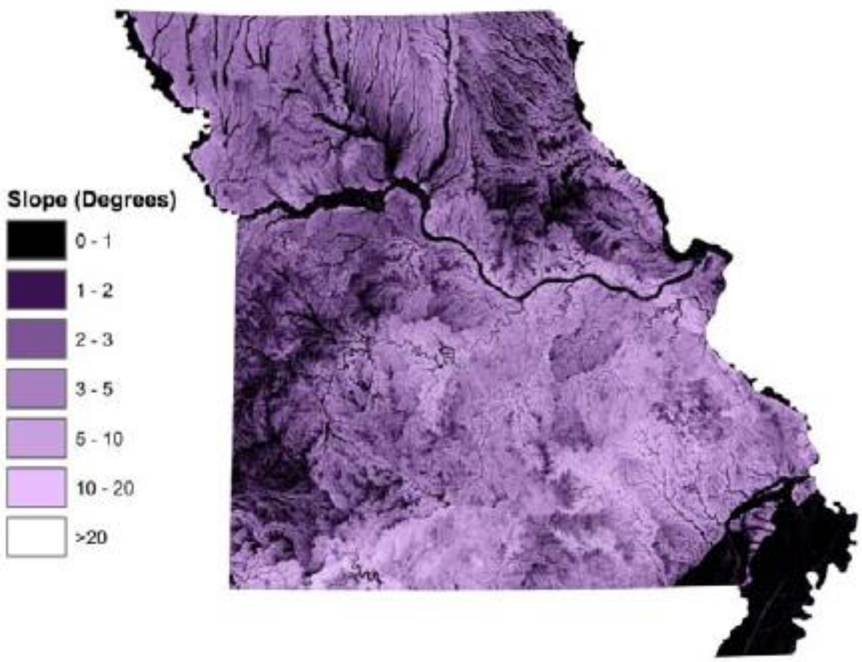

Figure 5-11. Degree of Slope in Missouri

[49] "Energize Missouri: Algae-Based Renewable Energy Study." *Missouri Division of Energy.* September 2011. Web. February 6, 2013. < http://ded.mo.gov/energy/docs/MTCAlgaeStudyFinalReport.pdf>.

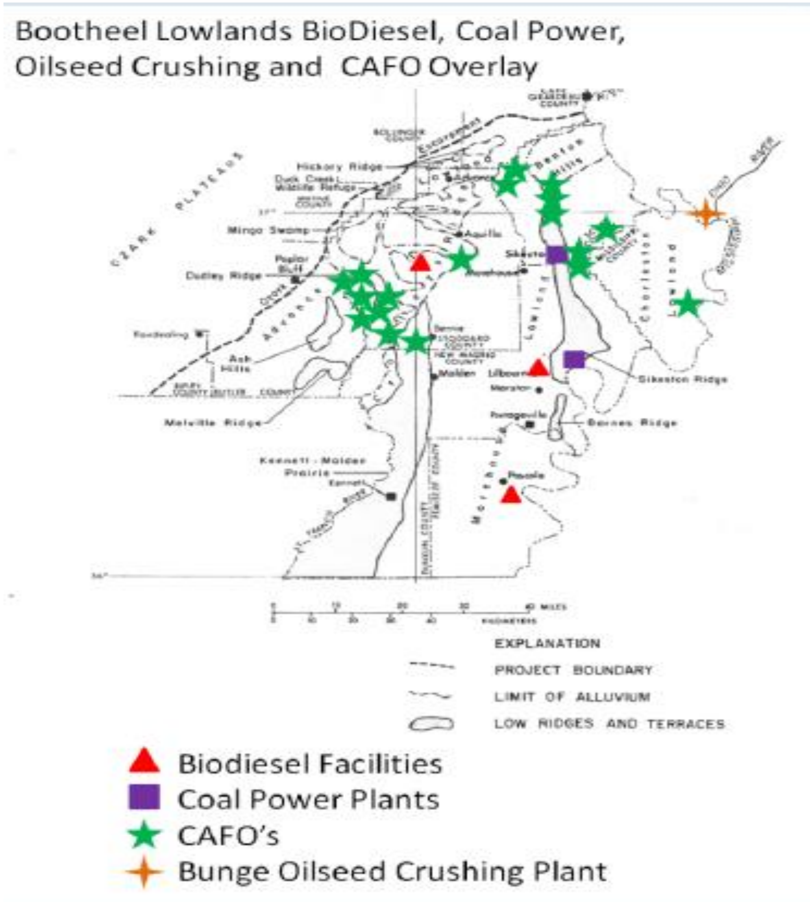

Figure 5-12. The Existing Infrastructure in the Bootheel for Algae Production

The Bootheel consists of the counties of Dunklin, New Madrid and Pemiscot. For the purpose of this study, the Bootheel includes the entire southeastern lowlands province, including all or parts of Ripley, Butler, Stoddard, Mississippi, Scott, Bollinger and Cape Girardeau counties. Figure 5-11 shows the degree of slope for the state. The large, dark area in the southeastern corner of the state is the "Bootheel" and shows an area of approximately 4,000 square miles with less than one degree land slope, which makes it a potential location for large scale algae production. The Bootheel area has an abundance of available fresh water, and it contains the greatest volume of ground water per unit area than almost any other part of the United States. Days with direct sunlight average about 60 percent annually and solar radiation of 4.5 to 5.0 $kWh/m^2/day$. Other strengths of the Bootheel for algae production include nutrients from confined animal feeding operations (CAFOs), carbon dioxide from two coal plants near Sikeston and New Madrid, and existing biodiesel infrastructure (Figure 5-12).

6. Biofuels

6.1 Ethanol

6.1.1 Background and History

While ethanol can be produced from a wide variety of feedstock, corn is most commonly used in Missouri and nationwide.[50] Missouri ranks 10th in total U.S. corn production. Corn is the state's second largest crop. In 2012, over 3.3 million acres were harvested, producing over 251.2 million bushels.[51] A study conducted by Iowa State University's Center for Agricultural and Rural Development[52] indicated that between "January 2000 and December 2011, the growth of ethanol production reduced wholesale gasoline prices by $0.29 per gallon on average". The Midwest has experienced the greatest impact, reducing wholesale gasoline prices through a price reduction of $0.45 per gallon. The relationship between ethanol blends of 85 percent (E85) and conventional gasoline prices at the pump in Missouri can be seen in Figure 6-1.

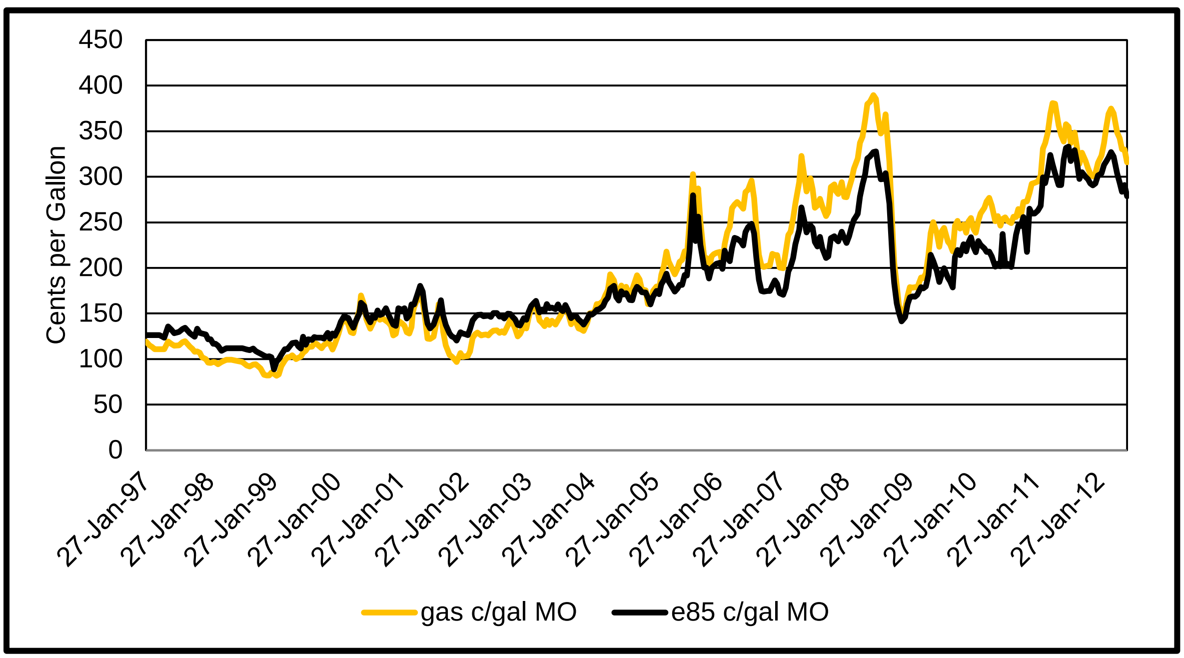

Figure 6-1. Conventional Gas and E85 Ethanol: Missouri Prices at the Pump

[50] "Ethanol Feedstocks", *United States Department of Energy, Alternative Fuels Data Center*. 2012. Web. October 9, 2012. <http://www.afdc.energy.gov/fuels/ethanol_feedstocks.html>.
[51] "Quick Stats: U.S. & All States Data – Crops", *United States Department of Agriculture, National Agricultural Statistics Service.* 2012. Web. October 9, 2012. < http://www.nass.usda.gov/Quick_Stats/>.
[52] Du, Xiaodong and Hayes, Dermot. *Iowa State University, Center for Agricultural and Rural Development*. "The Impact of Ethanol Production on U.S. and Regional Gasoline Markets: An Update to 2012." May 2012. Web. August 31, 2012. <http://www.card.iastate.edu/publications/dbs/pdffiles/12wp528.pdf>.

6.1.2 Description of Resource

Missouri’s six ethanol plants are all located north of the Highway I-70 corridor to take advantage of the large amount of corn production in northern Missouri and Iowa. Ethanol facilities in close proximity to feedstock are vital for biofuel production to simultaneously remain profitable and reduce the carbon footprint through the life-cycle of its production. Due to the heavy reliance upon corn for fuel ethanol production in Missouri, the relationship between corn production and price per bushel is an extremely important factor for ethanol’s future as a viable energy resource (Figure 6-3).

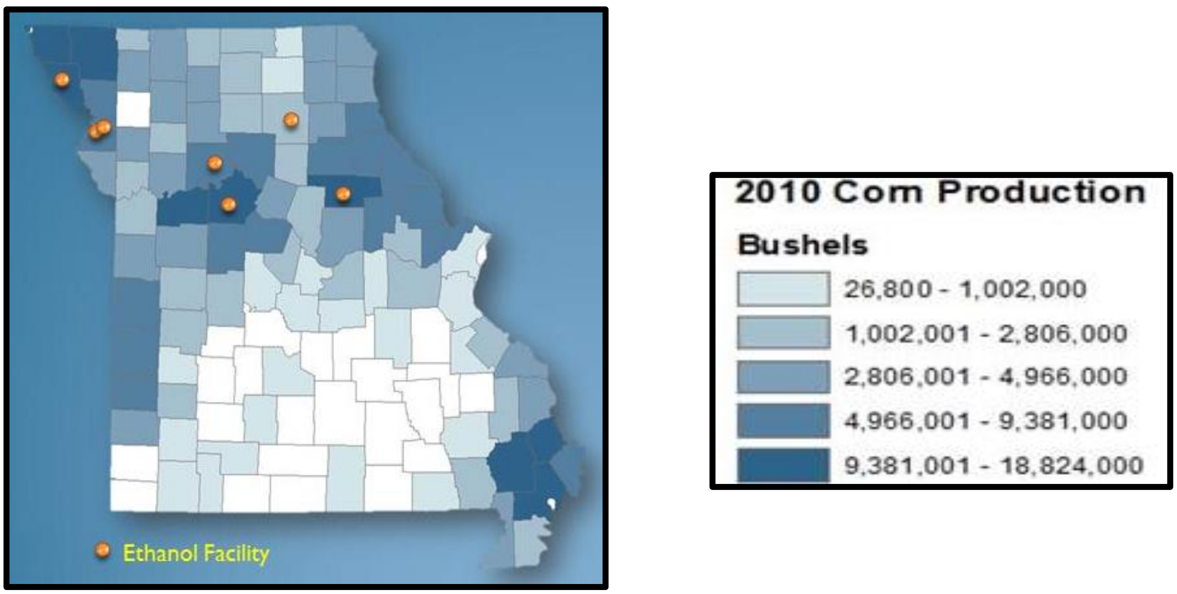

Figure 6-2. Ethanol Facility Locations and 2010 Corn Production in Missouri

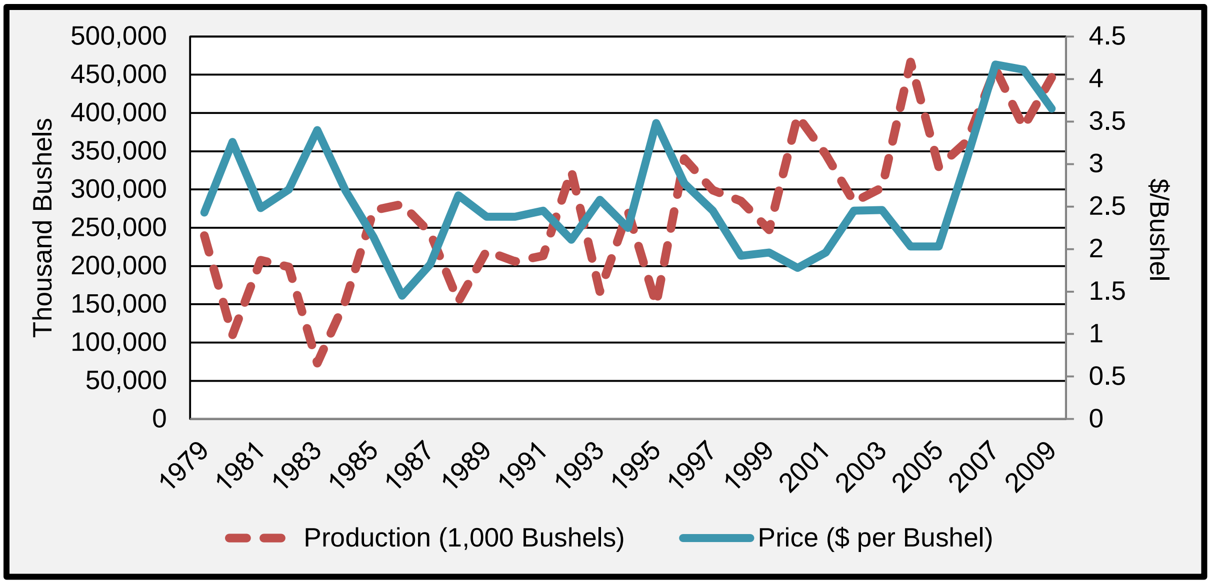

Figure 6-3. Corn Production and Price in Missouri: 1979-2009

6.1.3. Current State of Ethanol Production

As of August 2012, Missouri had nameplate ethanol production capacity of 271 million gallons a year (MMGY) and ranked 13th in the nation in ethanol production (Figure 6-4).[53]

The breakdown of six individual Missouri ethanol plants in production capacity is shown in Figure 6-5. Missouri legislation has encouraged the expansion of the ethanol industry by providing financial incentives to Missouri citizen majority-owned plants and by requiring conventional gasoline to be blended with ethanol as long as the price of ethanol does not exceed that of conventional gasoline.[54]

[53] "Ethanol Facilities' Capacity by State", *State of Nebraska, Nebraska Energy Office.* August 2012. Web. October 9, 2012. <http://www.neo.ne.gov/statshtml/121.htm>.
[54] "The Missouri Renewable Fuel Standard Act." *Missouri Department of Agriculture*. 2012. Web. August 31, 2012. <http://mda.mo.gov/weights/fuel/renewablefuelstandard.php>.

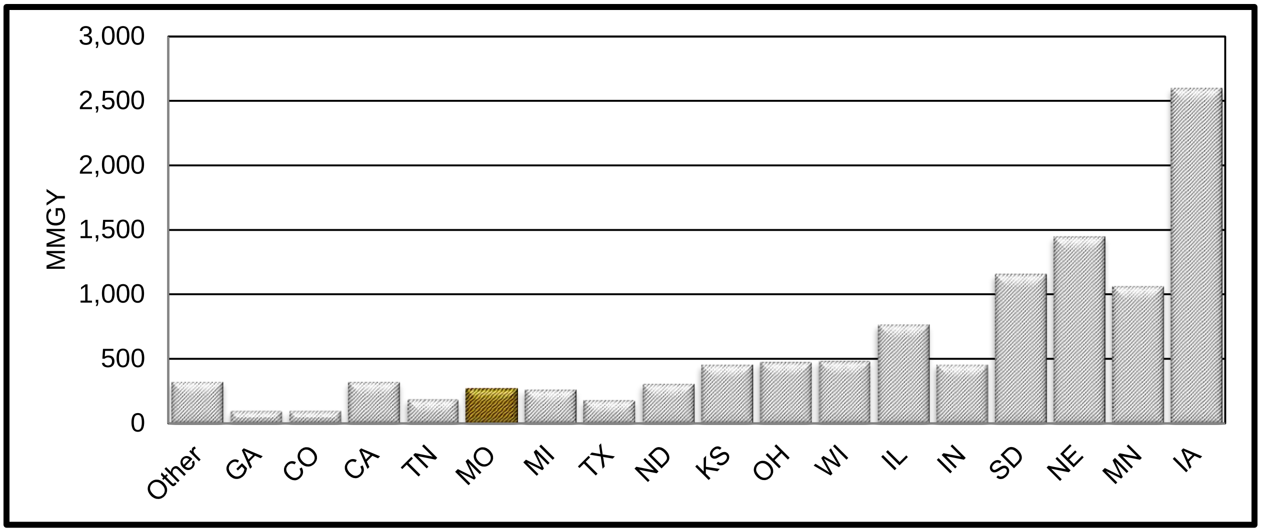

Figure 6-4. U.S. Ethanol Nameplate Capacities by State (2012)

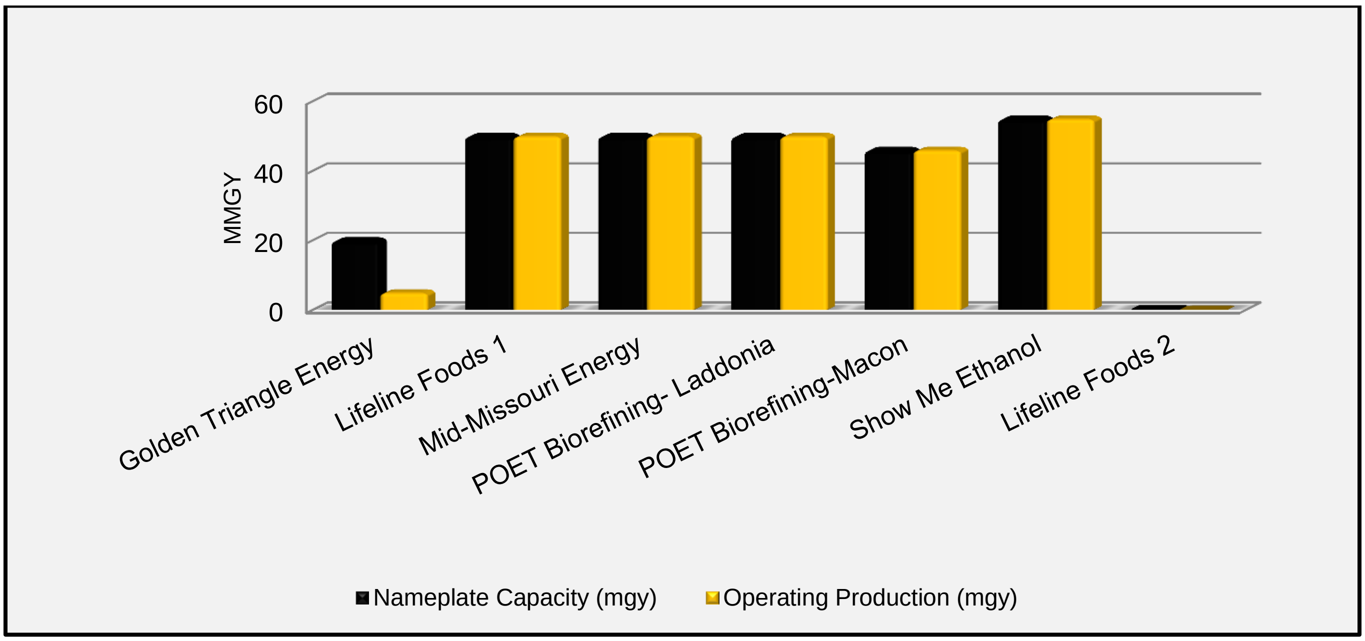

Figure 6-5. Missouri Ethanol Refineries (2012)

6.2 Biodiesel

6.2.1 Description of Resource

In 2002, the Missouri Department of Agriculture (MDA) established and implemented the first fund to encourage biodiesel production.[55] The Biodiesel Producers Incentive Fund was established to encourage Missouri-owned biodiesel production from 100 percent U.S. originated

[55] "Missouri Biodiesel Producer Incentive Fund", *Missouri Department of Agriculture, Assistance for Producer.* 2012. Web. August 31, 2012. <http://mda.mo.gov/abd/financial/biodiesel.php>.

feedstock and 80 percent Missouri-owned. Missouri had eight biodiesel production facilities with a production capacity of approximately 250 million gallons in 2012 (Figure 6-6). Production capacity and actual production differ greatly among the eight facilities. Missouri biodiesel production is derived primarily from soy oil. To meet this demand for soy oil, biodiesel facilities are located near soybean producing counties and soybean crushing facilities. Missouri ranks 7th in total U.S. soybean production. The top five soybean producing counties in Missouri are Audrain, Saline, New Madrid, Stoddard and Nodaway.

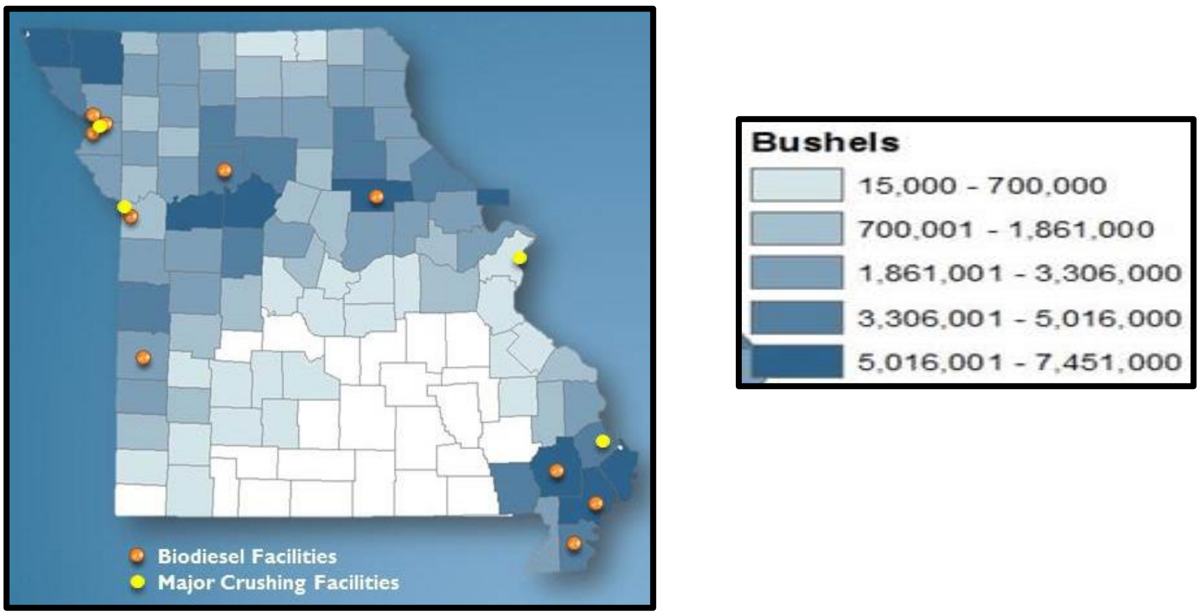

Figure 6-6. Map of Biodiesel Facilities and 2010 Soybean Production

6.2.2 Current State of Biodiesel Production

A historical comparison of the price of conventional diesel and biodiesel at 20 percent blends (B20) for 2002 to 2011 is provided in Figure 6-7.[56] The primary producers of biodiesel in Missouri are shown in Figure 6-8 with their production capacity totals. The existing composition of feedstock used by Missouri biodiesel producers is noted in Figure 6-9.

[56] "Fuel Prices", *United States Department of Energy*, *Alternative Fuels Data Center*. July 2012. Web. October 9, 2012. <http://www.afdc.energy.gov/fuels/prices.html>.

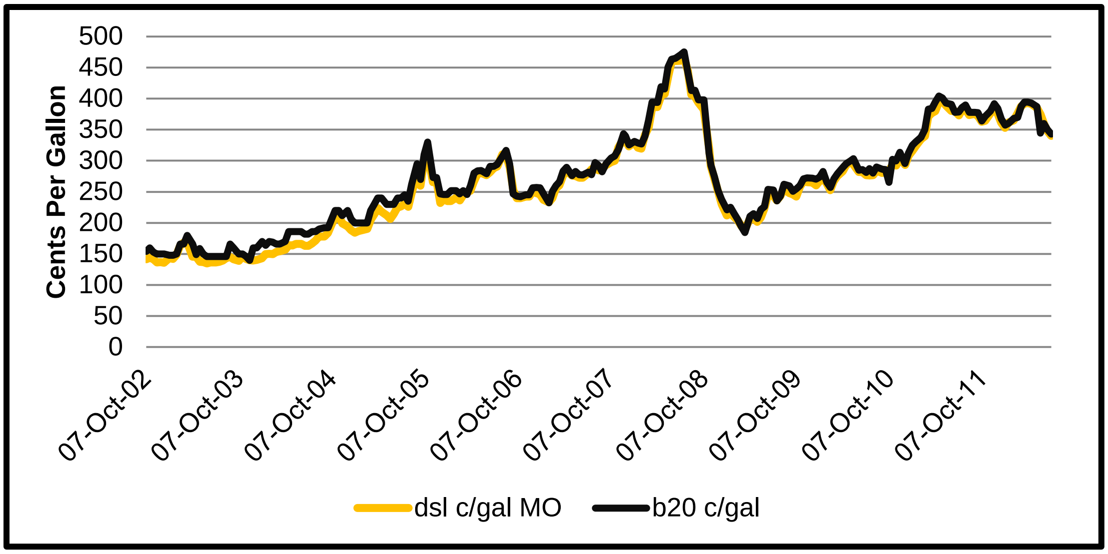

Figure 6-7. Missouri Diesel & B20 Biodiesel Price at Pump

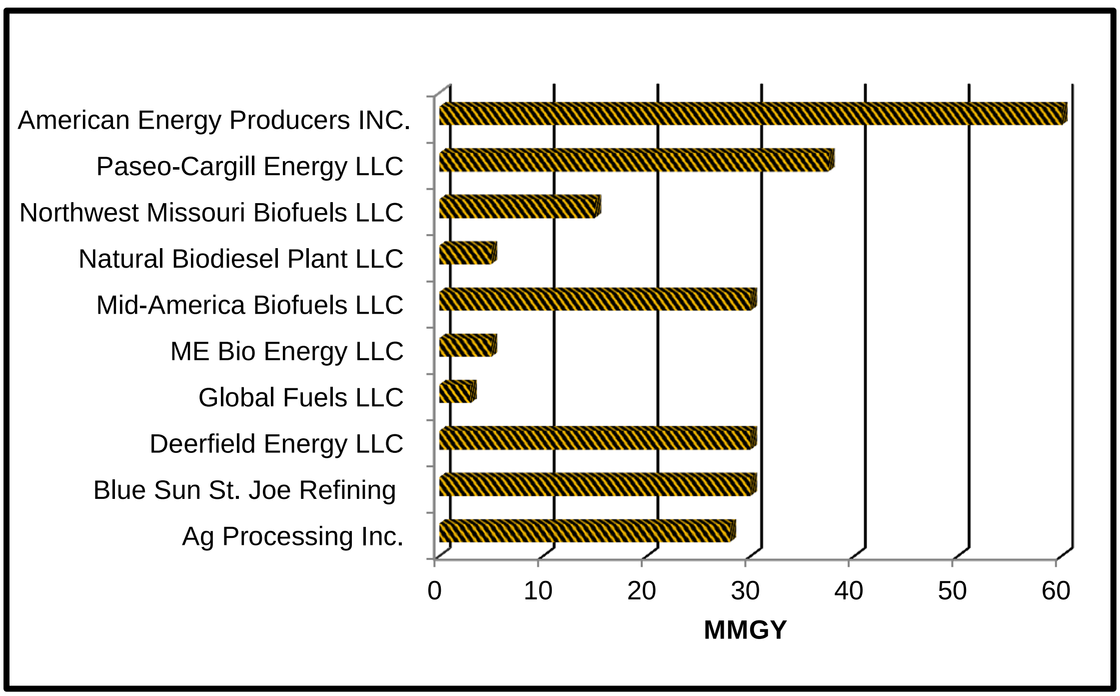

Figure 6-8. Biodiesel Production Capacities in 2012
(million gallons per year)

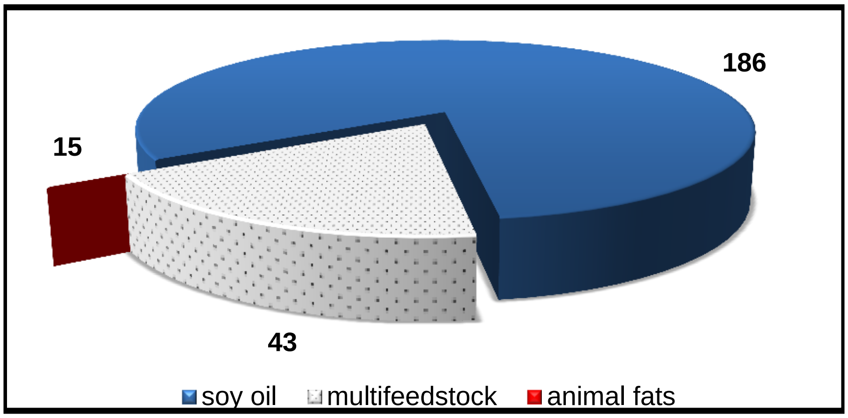

Figure 6-9. MO Biodiesel Feedstock by MMGY Nameplate in 2012
(million gallons per year)

The future of the biofuels industry in Missouri and the nation relies heavily on several factors including conventional fuel prices, state and federal renewable fuel standards, commodity prices and emerging technology. New non-food feed stocks, such as switchgrass and algae, are being studied as possible alternatives to food-based feed stocks for biofuel production.

7. Wind

7.1 Background and History

Missouri has been considered a fast growing wind market over recent years. The first utility scale wind farm in Missouri was developed by Wind Capital Group in Gentry County. It became operational in early 2007 with a generation capacity of 57 Megawatts (MW). Missouri currently has several utility scale wind installations in a few northwest counties of the state (Atchison, Gentry, Nodaway and Dekalb). The combined generating capacity of the six installations is 460 MW. (Table 7-1). Wind power in the state provides roughly one percent of the total electricity generation by all energy resources. The installed wind capacity in Missouri over the past few years is illustrated in Figure 7-1. Figure 7-2 shows the historical growth for selected Midwest states from 1999 to 2011.

Table 7-1. Utility Scale Wind Farms in Missouri (2011)

Wind Farms	City	County	Capacity MW	Year Online	Developer	Power Purchaser
Blue Grass Ridge	King City	Gentry	57.0	2007	Wind Capital Group	Associated Electric Cooperative Inc.
Conception	Conception	Nodaway	50.4	2008	Wind Capital Group	Associated Electric Cooperative Inc.
Cow Branch	Tarkio	Atchison	50.4	2008	Wind Capital Group	Associated Electric Cooperative Inc.
Loess Hills	Rockport	Atchison	5.0	2008	Wind Capital Group	Missouri Joint Municipal Electric Utility Commission
Farmers City	Tarkio	Atchison	146.0	2009	Iberdrola Renewables	
Lost Creek Ridge	N/A	Dekalb	150.0	2010	Wind Capital Group	Associated Electric Cooperative Inc.
Lost Creek Ridge	N/A	Dekalb	1.5	2011	Wind Capital Group	Associated Electric Cooperative Inc.
Capacity Total			460.3			

7.2 Description of Resource

The U.S. wind industry had over 60,000 MW capacity of wind power operating at the end of 2012. An additional 1,300 MW of wind power was under construction at the end of the second quarter of 2013.[57] The average turbine capacity at planned wind farms is between 1.0 and 1.5 MW. The turbines are typically on towers that reach hub heights of 70 meters. These utility scale wind installations produce more energy than needed by the surrounding communities and have been connected to distribution networks through high voltage transmission lines.

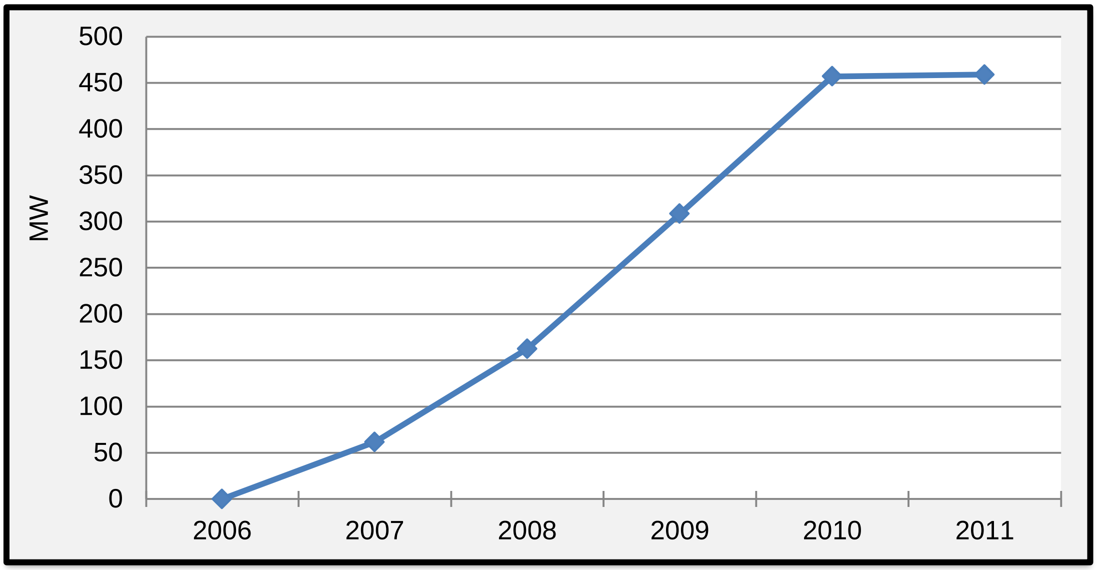

Figure 7-1. Missouri's Installed Wind Capacity (2006-2011)

[57] "Wind Energy Facts: Missouri", *American Wind Energy Association.* Third Quarter of 2011. Web. September 7, 2012. <http://www.awea.org/learnabout/publications/upload/Missouri.pdf>.

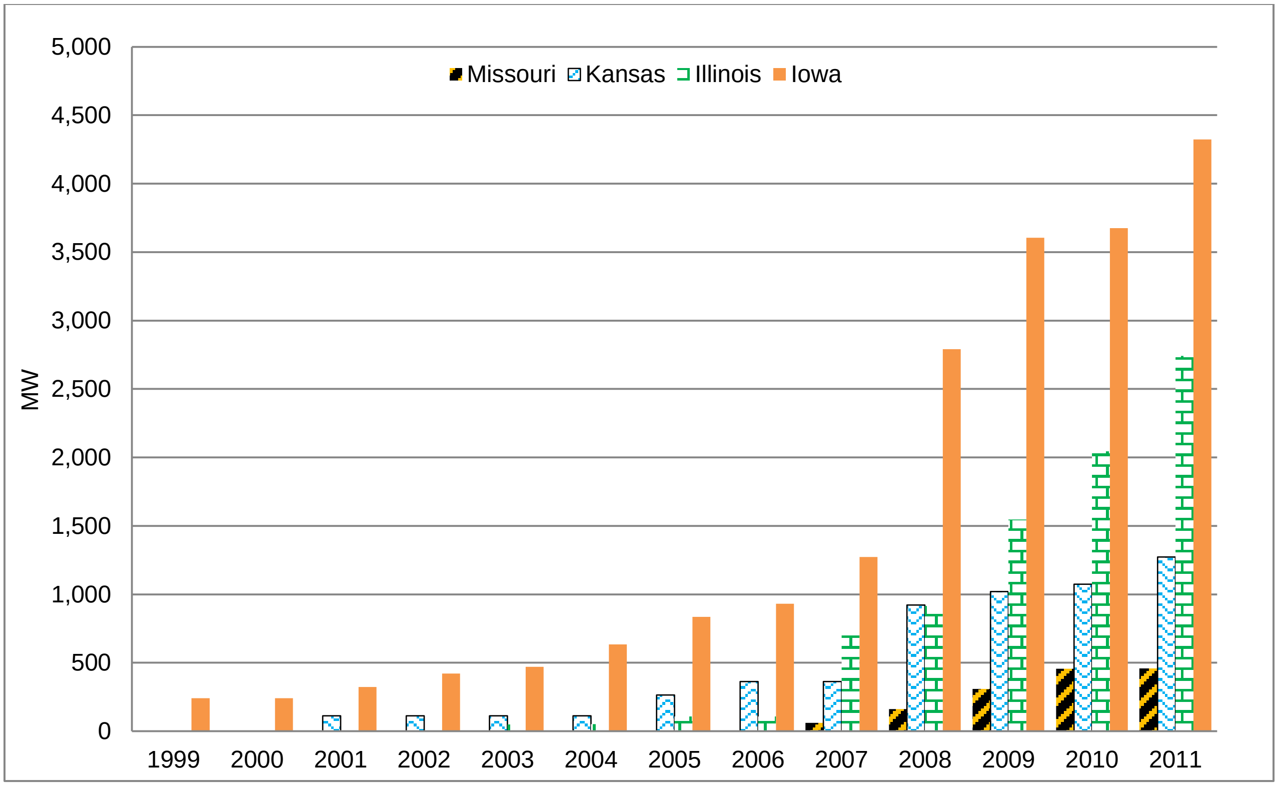

Figure 7-2. Installed Wind Capacities in Midwest States (1999-2011)

In addition to the utility-scale wind farms, there are also several hundred kilowatts (kW) of generating capacity through small wind farms in Missouri. These small wind turbines are typically rated at less than five kW and are at tower hub heights of 30 meters or less. These small wind turbines are owned by individuals and businesses and are typically interconnected to the electric grid through agreements with local utilities. These interconnection agreements are on a net-metering basis that allow the wind turbines to get credit for each kilowatt hour (kWh) of excess electricity produced that can then be drawn down in the same billing cycle when the turbine is not meeting the electric needs of the residence or business.

According to the U.S. Department of Energy's (DOE) Wind Powering America (WPA) program, Missouri also has two small school wind projects primarily for education and research purposes.[58] Crowder College in Neosho, MO, installed a 68 kW Nordtank wind turbine in 2008. The turbine is currently used by Crowder College as part of its Alternative Energy Associate's

[58] "School Wind Project Locations", *U.S. Department of Energy*. December 2011. Web. September 7, 2012. <http://www.windpoweringamerica.gov/schools/projects.asp>.

Degree program.[59] Northwest Missouri State University in Maryville utilizes wind energy through a 10 kW wind turbine that supplies electricity to the university farmhouse. In addition, in the Fall of 2012, the University of Missouri-Columbia installed a 20 kW wind turbine on campus primarily for research purposes that supplies power to the beef barn, an adjacent campus facility.

7.3. Current State of Wind

According to the American Wind Energy Association (AWEA), the wind resource in Missouri is ranked 13th in the U.S. and the wind resource in Missouri would provide over nine times the state's current electricity needs.[60] In 2011, 49 percent of Missouri's renewable electricity generation was provided by wind (Figure 7-3).

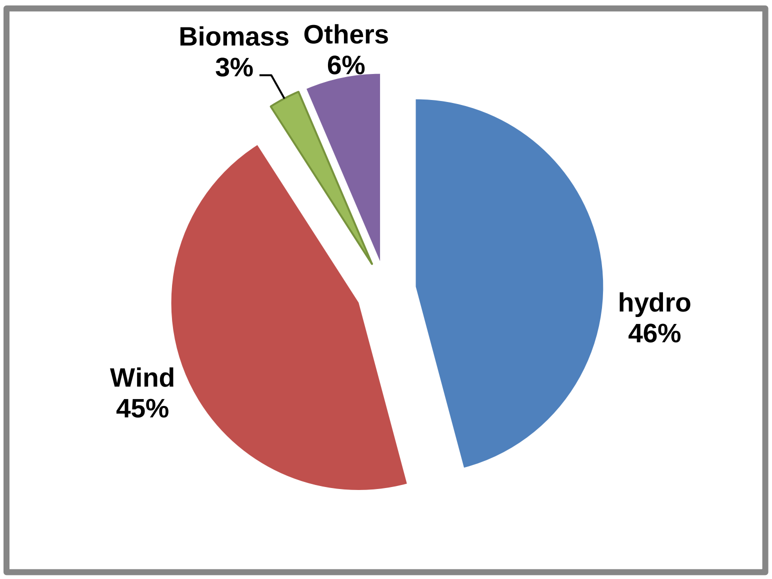

Figure 7-3. Missouri Renewable Electricity Generation by Fuel Type (2011)

In collaboration with the National Renewable Energy Laboratory (NREL) and independent consultants, AWS Truewind (AWS) prepared a comprehensive report on Missouri's wind resource for the Missouri Division of Energy through the DOE's WPA program in 2005. AWS produced several maps of mean wind speed at heights of 30, 50, 70 and 100 meters above

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[59] "Crowder College Wind Turbine." *Crowder College*. Web. January 16, 2014. <http://www.crowder.edu/academics/departments/alternative-energy/wind/wind-turbine-at-crowder>

[60] "Wind Energy Facts: Missouri." *American Wind Energy Association*. June 2013. Web. January 16, 2014. <http://www.awea.org/Resources/state.aspx?ItemNumber=5213>.

ground, maps of wind power density at 50 and 100 meters, and maps of county level 30 meter average annual wind speed. The predicted wind speed frequency distribution and speed and energy by direction were also produced. The final report and high resolution maps can be downloaded from the Division of Energy's website.[61]

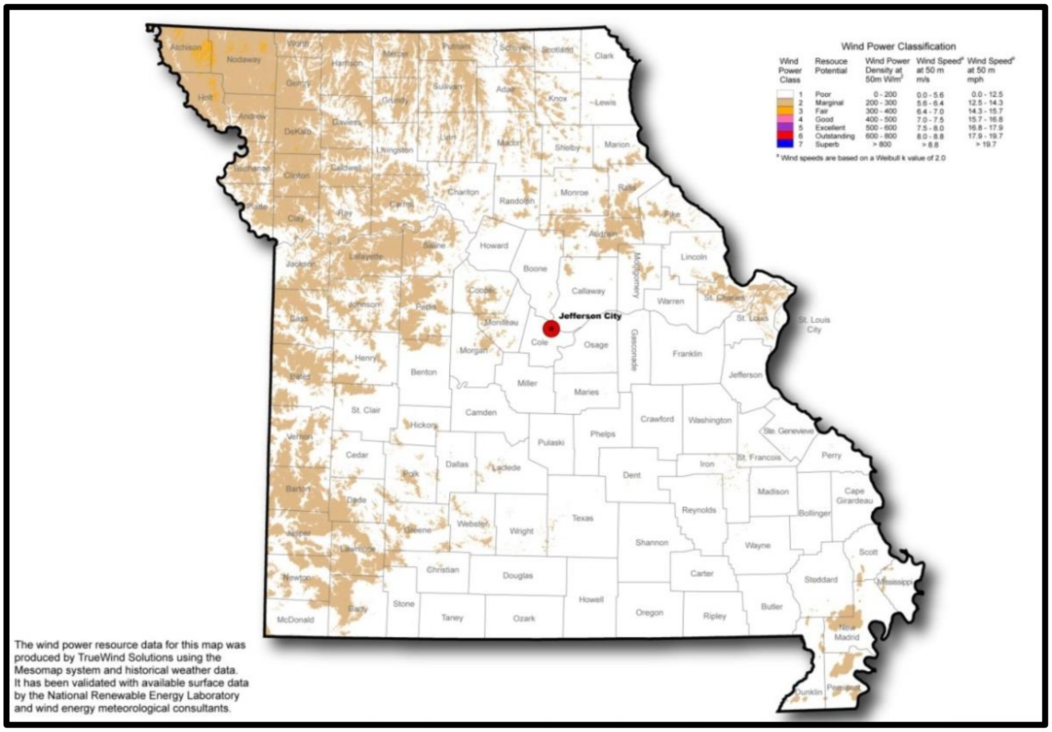

Figure 7-4. 50 Meter Wind Power Resource

The DOE's WPA Program and NREL have published two maps of 50 and 80 meter height wind resources for Missouri. The 80-meter wind resource map (Figure 7-4) shows the predicted mean annual wind speeds, presented at a spatial resolution of about two kilometers that is interpolated to a finer scale for display.[62] Areas with annual average wind speeds around 6.5 meters per second and greater at 80-meter height are generally considered to have a resource suitable for wind development. Utility-scale, land-based wind turbines are typically installed between 80 and 100 meters high. The 50-meter resource map (Figure 7-5) shows estimates of

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[61] "Wind Energy Resources", *Missouri Department of Economic Development, Division of Energy*. 2014. Web. January 16, 2014. <http://ded.mo.gov/division-of-energy/renewables/wind-energy-resources>.
[62] "Missouri 80-Meter Wind Map and Wind Resource Potential", *U.S. Department of Energy, Wind Powering America*. May 2012. Web. September 7, 2012. <http://www.windpoweringamerica.gov/wind_resource_maps.asp?stateab=mo>.

wind power density at 50 meters above the ground and depicts the resource that could be used for utility-scale wind development.[63]

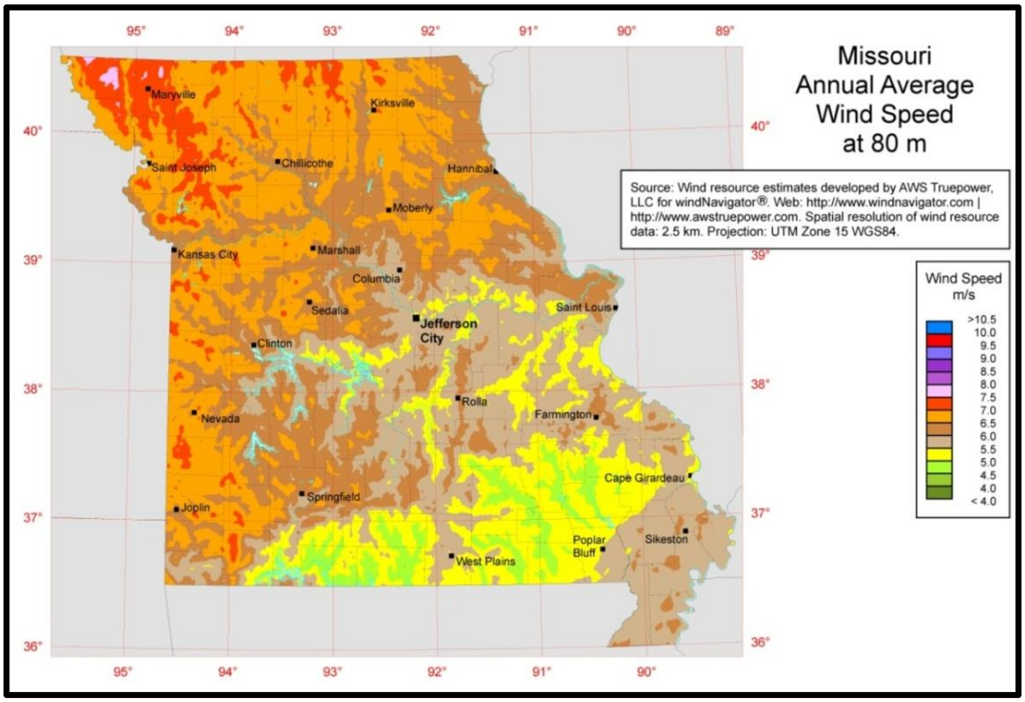

Figure 7-5. Missouri Annual Average Wind Speed at 80 meters

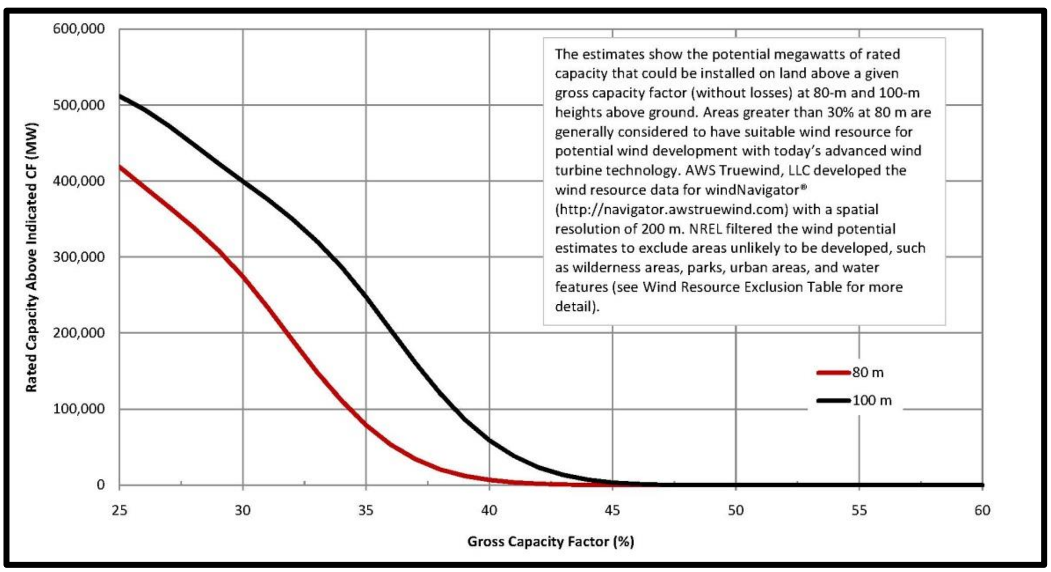

Figure 7-6. Wind Resource Potential Cumulative Rated Capacity and Gross Capacity Factor

[63] "Missouri 50-Meter Wind Map", *U.S. Department of Energy, Wind Powering America*. May 2012. Web. September 7, 2012. <http://www.windpoweringamerica.gov/maps_template.asp?stateab=mo>.

NREL also estimated the wind energy potential in various capacity factor ranges for Missouri using AWS's gross capacity factor data from development of the "available" windy land area after exclusions. The chart in Figure 7-6 shows the wind resource potential above a given gross capacity factor at both 80-meter and 100-meter heights for Missouri.[64] It is estimated that the potential wind power capacity is 274,355 MW for areas more than or equal to 30 percent gross capacity factor at 80 meters, which ranks 14th in the U.S.

These wind maps indicate that the northwestern portion of the state, from the corner of Atchison County down to Kansas City has the greatest abundance of windy land. The mean wind speed on many hills in this region is predicted to be 7.0-7.5 meters/second at 70 meter height. There are pockets of similar wind resources on relatively high elevations in the southwestern part of the state. In southeastern Missouri, dense forest cover and lower elevations substantially reduce the predicted wind speed and wind power. At 80 meter and 100 meter heights, wind resource cumulative potentials improve considerably (Figure 7-6).

[64] "Estimates of Windy Land Area and Wind Energy Potential", *U.S. Department of Energy, National Renewable Energy Lab, AWS Truepower*. April 2011. Web. September 7, 2012. <http://www.windpoweringamerica.gov/docs/wind_potential.xls>.

8. Solar

8.1 Background and History

Missouri has limited production of energy from solar but this is increasing. Operational in March 2013, the Butler Solar Energy Farm is the first utility-scale solar electric installation in Missouri with a capacity of 3.05 MW for use by 35 members of the Missouri Joint Municipal Electric Utility Commission; and in January 2014, Ameren announced plans to build a 5.7 MW solar facility in O'Fallon, Missouri, which could be operational by December 2014. The use of customer-owned solar electric systems in a net metering arrangement with a utility has increased substantially in recent years following passage of the Net Metering and Easy Connection Act in 2007 and the Missouri Renewable Energy Standard in 2008. The Division of Energy has monitored the installations of solar photovoltaic in net metering arrangements across the state, and estimates from data gathered from utilities shows that in 2008 Missouri had less than 100 kW of generating capacity and at the end of 2010 had nearly 750 kW of generating capacity.[65] The Missouri Partnership, an organization that markets Missouri's business advantages to companies, reports an increase of solar installations from 101 kilowatts (kW) in 2009 to over 7.8 MW in 2011.[66] More recent solar industry estimates are 25 MW in 2013.[67]

8.2 Description of Resource

Missouri has moderate solar resources (Figure 8-1) with more than 200 sunny days per year for an average of 4.5 to 5.0 kilowatt hour per square meter per day, according to the U.S. Department of Energy's National Renewable Energy Laboratory's (NREL) solar radiation maps. Missouri's solar resources actually exceed those of Germany, which leads the world in solar energy production on less than three kWh per square meter per day.

Solar resources can be broken into different value representations depending on the solar application and tilt. From NREL's solar radiation maps on the MapSearch site, solar photovoltaics installed at latitude tilt indicate that Missouri's solar resource is consistent across

[65] Correspondence with Ameren Missouri, Empire District Electric Company, Kansas City Power & Light Company, Missouri Public Utility Association, and Associated Electric Cooperative Inc.

[66] "The Market for Renewable Energy is Growing in Missouri", Missouri Partnership. Web. January 6, 2014. <http://www.missouripartnership.com/Industries/Energy-Solutions/CategoryID/13>.

[67] Rebuttal Testimony of Mr. Adam Blake, Chief Executive Officer, Brightergy, LLC, Case No. ET-2014-0059 before the Missouri Public Service Commission, September 16, 2013.

the state at an annual daily average of 4.5 – 5.0 kWh/m^2/day.[68] It is important to note that this resource is an average daily value for the entire year and also that the light intensity panels are rated at what would yield 24 kWh/m^2/day.

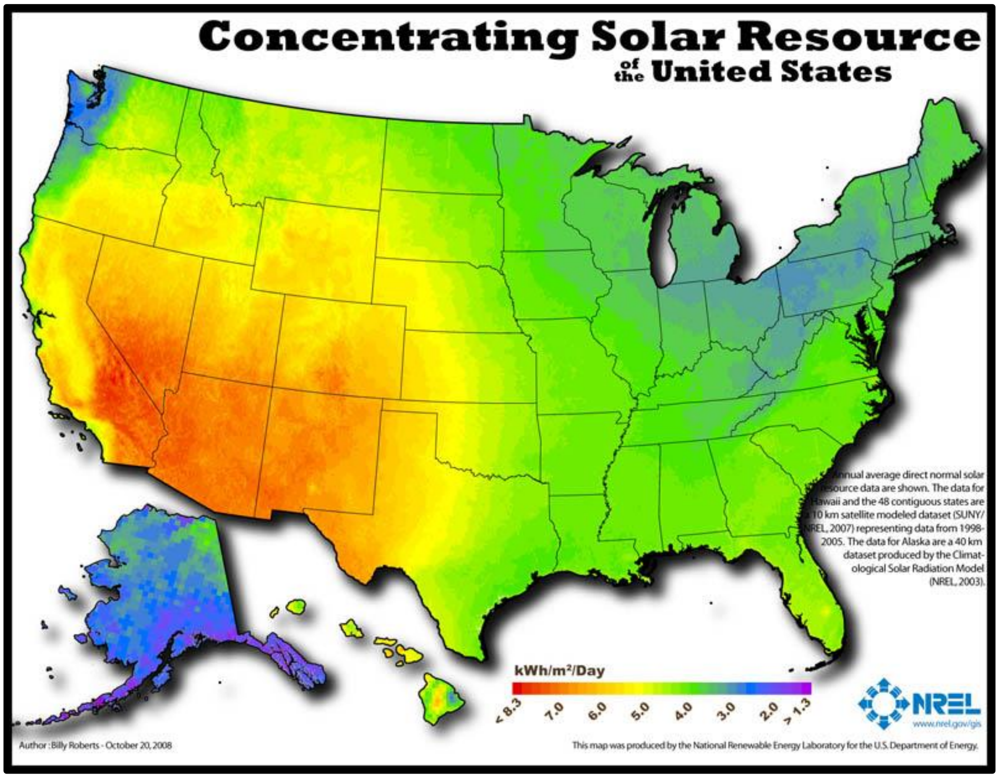

Figure 8-1. Concentrating Solar Resources in the U.S.

In Missouri, December has the lowest solar potential at a daily average of 3.8 kWh/m^2/day and a solar potential range of 2.6- 4.6 kWh/m^2/day for the month. Just as it makes sense that December would be the lowest potential month with the Winter Solstice, June has the highest potential with the Summer Solstice. In Missouri, June has the highest daily average of 6.1 kWh/m^2/day and a solar potential range of 5.1- 6.9 kWh/m^2/day for the month.[69] Therefore, solar panels installed in Missouri at a tilt equal to the location's latitude will produce 60 percent more energy in June than in December.

Just as the time of year influences the solar radiation available, the installation for solar panels can affect the amount of solar resource available. Installing panels flat (0 degrees) will

[68] "National Renewable Energy Research Laboratory MapSearch Beta", *National Renewable Energy Laboratory*. 2012. Web. September 7, 2012. <http://www.nrel.gov/gis/mapsearch>.
[69] "Solar Radiation Data Manual for Flat-Plate and Concentrating Collectors", *National Renewable Energy Laboratory*. 2012. Web. September 7, 2012. <http://rredc.nrel.gov/solar/pubs/redbook/>.

increase solar potential in the summer months when the sun is high in the sky and the panel can get maximum direct sunlight. However, this arrangement allows little production in the winter when the sun is low in the sky and the panel gets little direct light. As the angle of the south facing panel increases, the summer output decreases at the expense of increasing winter output. In Missouri, this tradeoff is effective at least up to latitude plus 15 degrees (55 degrees), but as the angle gets closer to more and more vertical (90 degrees), potential drops across all months as the sun never stays on the horizon for the whole day. Figure 8-2 captures the monthly average daily total radiation from eight years of data for Missouri.

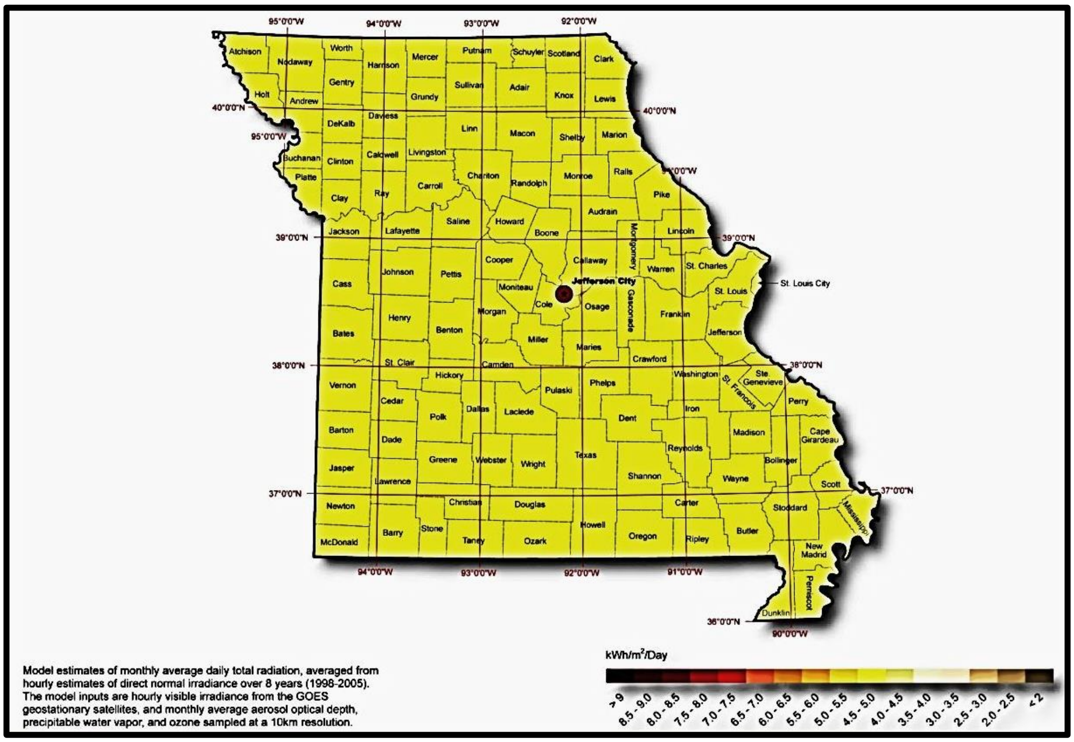

Figure 8-2. Global Solar Radiation at Latitude Tilt (Annual)

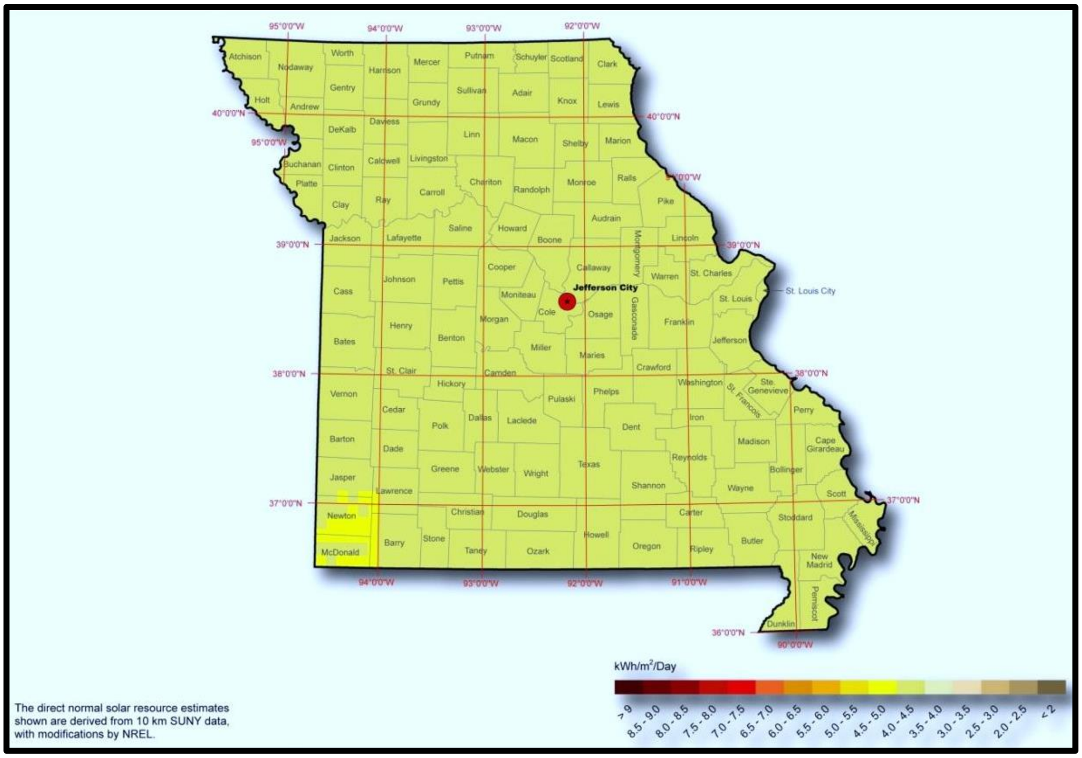

Figure 8-3. Concentrating Solar Power Resources

Some installations can track the sun's azimuth (east-west movement) elevation (height in the sky) or both. A two-axis tracking system that tracks both azimuth and elevation of the sun throughout the day will gather the maximum solar potential for a site by keeping the panel normal (at 90 degrees) to the sun's rays. This maximum would result in December daily average values of 4.6 kWh/m^2/day with a range of 3.0 – 5.9 kWh/m^2/day and June daily average values of 8.8 kWh/m^2/day with a range of 6.8 to 10.3 kWh/m^2/day.

For concentrating solar power, much of Missouri is in a lower insolation class than for photovoltaics as concentrated solar power (CSP) uses only direct sunlight. Solar insolation is a measure of solar radiation energy received on a given surface area in a given time. All of Missouri has insolation values of 4.0 – 4.5 kWh/m^2/day with the exception of small sections of the southwestern counties of Jasper, Newton, Lawrence, Barry and McDonald, which have insolation values of 4.5- 5.0 kWh/m^2/day. These values are not considered great enough for CSP stations. A map of the direct normal solar resources for Missouri is shown in Figure 8-3.

9. Geothermal

9.1 Background and History

Geothermal energy is heat extracted from the Earth. In 2008, the National Renewable Energy Laboratory (NREL) created the national geothermal resource potential map. The map (Figure 9-1) shows locations of identified hydrothermal sites and favorability of deep enhanced geothermal systems (EGS) in the nation (temperatures > 150°C). This map does not include shallow EGS resources located near hydrothermal sites or U.S. Geological Survey (USGS) assessment of undiscovered hydrothermal resources. This map indicates that Missouri is not favorable for utility-scale or industrial geothermal utilization. The recently updated NREL geothermal power generation map (Figure 9- 2) shows that the total installed capacity in the U.S. is 3,187 MW and total planned capacity is about 2,000 MW. While almost all geothermal power plants are located in western states, there are no planned large-scale geothermal projects in the state of Missouri.

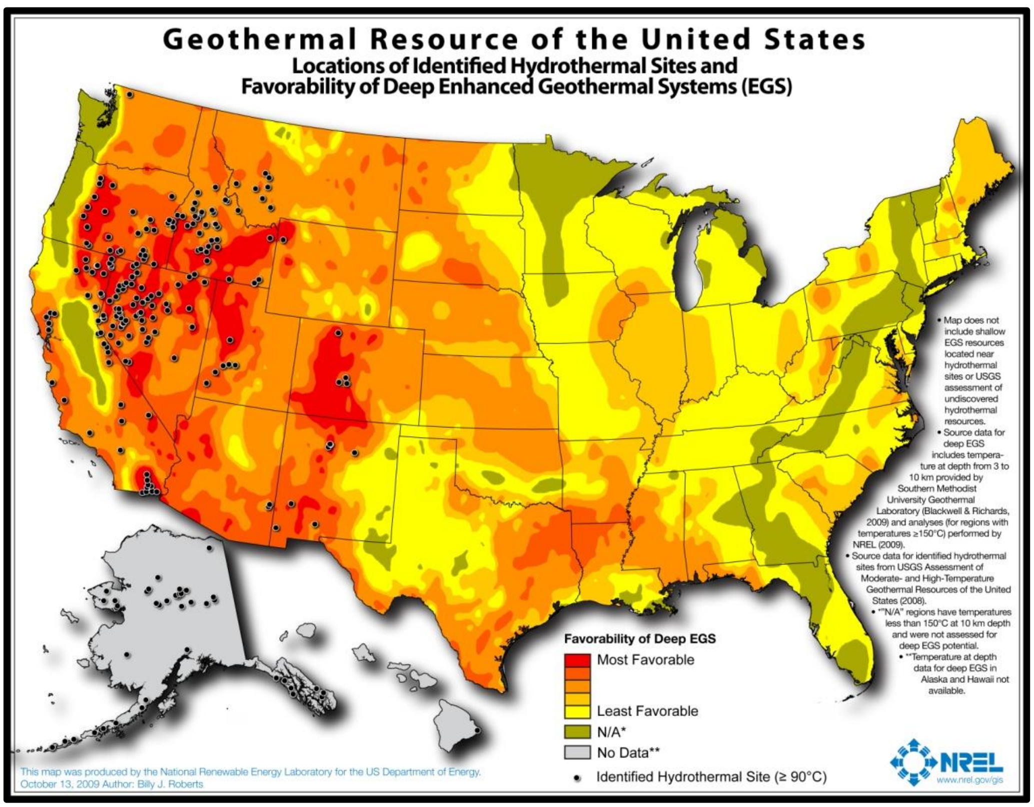

Figure 9-1. National Geothermal Resource Potential Map

Though Missouri does not have hot springs, fumaroles or any of the geothermal features found in some western states, moderate geothermal resources permit commercial applications like greenhouses and heating of fish farms. Using various types of geothermal or ground source heat pump (GSHP) systems, heating and cooling for both commercial buildings and residential homes can be economic. As one of the under-utilized renewable energy resources in Missouri, the increased use of GSHP systems has long-term potential for energy savings. Another benefit of using GSHP systems for heating and cooling for residential purposes is their reliability.

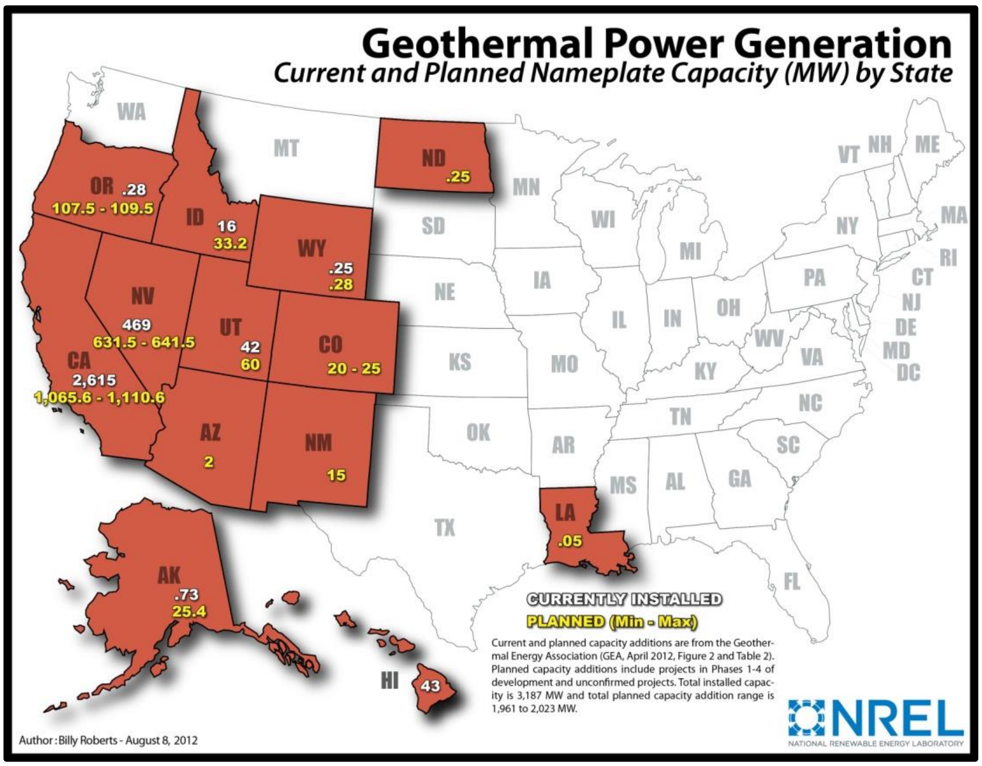

Figure 9-2. National Geothermal Power Generation Map

9.2 Description of Resource

Groundwater temperature data is essential to the proper deployment of GSHP systems including equipment selection and performance improvement. More efficient GSHP systems are easier to achieve when groundwater temperature is known. The Missouri Department of Natural Resources' Missouri Geological Survey conducted a study in 2011 that developed groundwater temperatures for six physiographic regions in Missouri (Figure 9-3). In order to enhance the understanding of GSHP's potential in the state, this study provides a reliable source of groundwater temperatures, which are particularly useful for open loop or standing column well systems installed in bedrock. The majority of the data is from the primary, uppermost aquifer used in each region. The final report titled "Geothermal Map of Missouri" and maps can be downloaded from the Division of Energy's website at the following link: http://ded.mo.gov/division-of-energy/transform/energize-missouri-sep-renewable-energy.

Due to the natural variation in groundwater temperature, selected areas of the state are warm enough to support residential and commercial technical uses.[70] Groundwater temperatures range from mid-50 °F to mid-60 °F. Select portions of the state have groundwater temperatures as low as the upper 40 degree range up to the high 80 degree range. In addition to residential usage, some areas have groundwater temperatures sufficient for industrial and technical uses such as greenhouse and aquaculture facilities. Groundwater for these uses can be as cool as 68°F.

[70] Bone, F., Dove, V., Seeger, C. *Geothermal Map of Missouri*", Missouri Department of Economic Development Division of Energy, February 2012. Web. January 16, 2014. http://ded.mo.gov/division-of-energy/transform/energize-missouri-sep-renewable-energy.

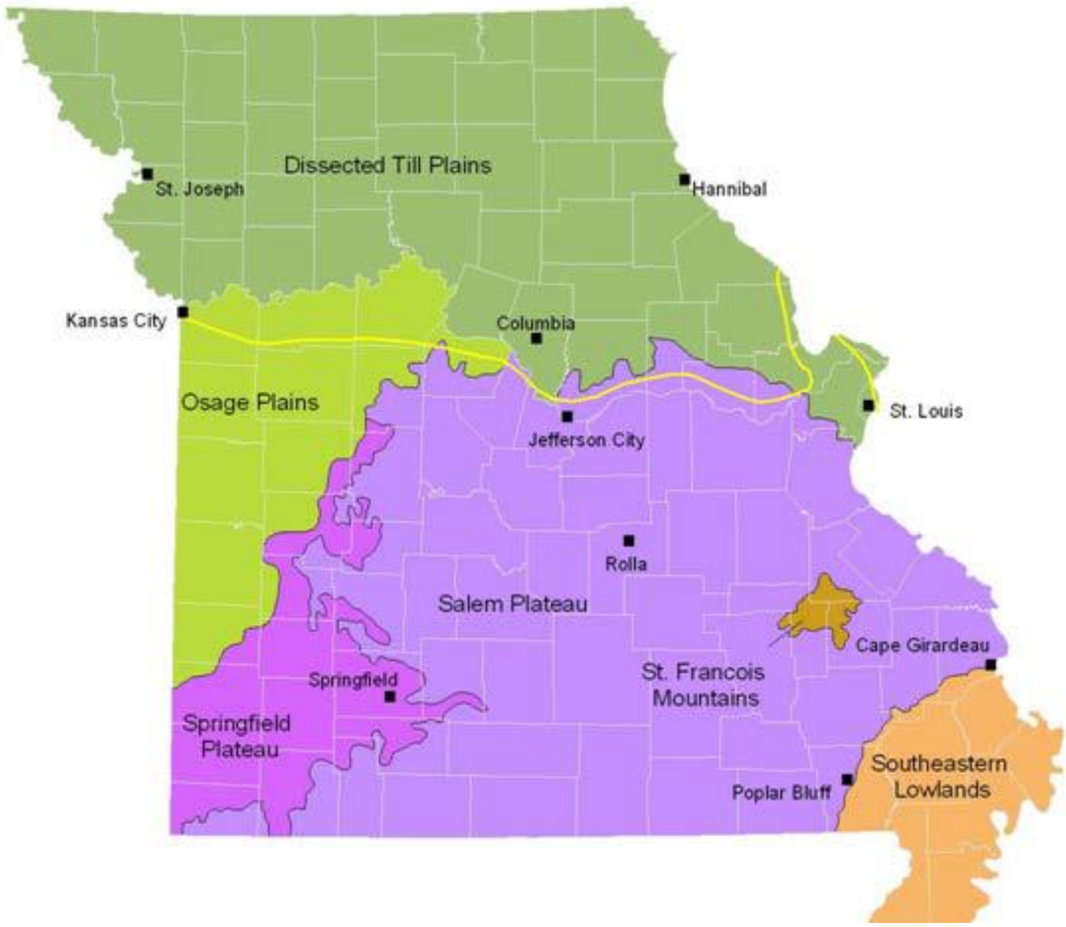

Figure 9-3. Map of Generalized Physiographic Regions of Missouri

A summary of groundwater temperatures for each region is excerpted from the report as follows:

Salem Plateau – Has the most extensive groundwater resources in the state. The St. Francois and Ozark aquifers underlie the province and are separated by the St. Francois confining unit. The Ozark aquifer comprises bedrock units from Potosi Dolomite to Kimmswick Limestone in the Salem Plateau.

St. Francois Mountains – Precambrian granites and rhyolites in part overlain by Cambrian-age sandstone, dolomite and limestone. The igneous rocks have low water yields; however, potential exists for higher temperature water due to concentrations of radioactive isotopes in several granite formations. The St. Francois aquifer is also a producer in this region.

Southeastern Lowlands – Contains the greatest volume of groundwater per unit area. Parts of the St. Francois and Ozark aquifers are used in the northwestern part of the province. However, most usable groundwater is in thick deposits of shallow alluvium and deeper Tertiary- and Cretaceous-age unconsolidated sands. The area has higher water temperatures than other parts of the state.

Springfield Plateau – Mississippian-age limestones comprise the Springfield Plateau aquifer and overlie the St. Francois and Ozark aquifers. The Ozark aquifer in this region comprises Derby-Doerun Dolomite through Cotter Dolomite.

Osage Plains – This province is west of the freshwater-saline water transition zone. The region has Pennsylvanian-age strata underlain by Cambrian, Ordovician and Mississippian units. The area has documented groundwater temperatures of 72^0F and 74^0F (Fuller, 1981).

Dissected Till Plains – Cover northern Missouri and characterized by Pennsylvanian-age sandstones, shales and limestones that are overlain by glacial drift. Mississippian- to Ordovician-age strata are exposed along the Missouri and Mississippi rivers and produce some water. Pennsylvanian strata have generally low permeability and yield small quantities of marginal to poor quality water. Usage of water from glacial drift, including pre-glacial stream valleys, increases to the west.

10. Hydropower

10.1 Background and History

Hydropower can be generated from a variety of different measures to control water resources. Impoundment, diversion and pumped storage can be used in varying sizes to produce hydroelectricity.[71] Missouri currently has more than twenty hydroelectric plants, including both impoundment and pumped storage facilities.[72] Table 10-1 lists the major hydroelectric sites in the state. Several facilities are owned and operated by the United States Army Corp of Engineers (USACE). Union Electric Company (d/b/a Ameren Missouri) owns Bagnell Dam at Lake of the Ozarks which began operations in 1931, and the Taum Sauk pumped storage plant located in Iron County in the St. Francois mountain region which began operations in 1963.

10.2 Description of Resource

The combination of all of the hydropower facilities in the state produced 1,200 gigawatt hours (GWh) in 2011. Between 2010 and 2011, hydroelectric production dropped about 22 percent (Figure 10-1).[73] According to 2011 EIA data, 49 percent of Missouri's electricity generation from renewable resources came from hydropower sources (Figure 10- 2). Missouri's generation capacity from hydroelectric resources is shown in Figure 10-3 along with a few selected Midwest states.

[71] "Types of Hydropower Plants", *U.S. Department of Energy, Water Power Program*. October 2011. Web. January 31, 2013. <http://www1.eere.energy.gov/water/hydro_plant_types.html>.
[72] "Hydro Power", *Missouri Department of Natural Resources, Energy Producing Systems*. *Hydro Power,* N.d. Web. January 31, 2013. <http://ded.mo.gov/energy/education/hydropower.pdf>.
[73] "Missouri Energy Profile", *NASEO*. 2012. Web. January 31 2013. <http://ded.mo.gov/energy/docs/Missouri_Energy_Profile_9_6_2012a.pdf>.

Table 10-1. Major Hydroelectric Facilities in Missouri[74]

Operator	Plant Name	Hydro Technology	Current Nameplate Rating (MW)	Year in Service
Union Electric Co.	Osage	HYC	208	1931
Union Electric Co.	Taum Sauk	PS	440	1963
USACE	Table Rock	HYC	200	1959
USACE	Clarence Cannon	HYC+PS	58	1984
USACE	Harry Truman	PS	161.4	1979
USACE	Stockton	HYC	45.2	1973
Show-Me Power Electric Coop	Niangua	HYC	3	1930
Empire District Electric Co	Ozark Beach	HYC	16	1930

HYC: hydroelectric conventional PS: pumped storage

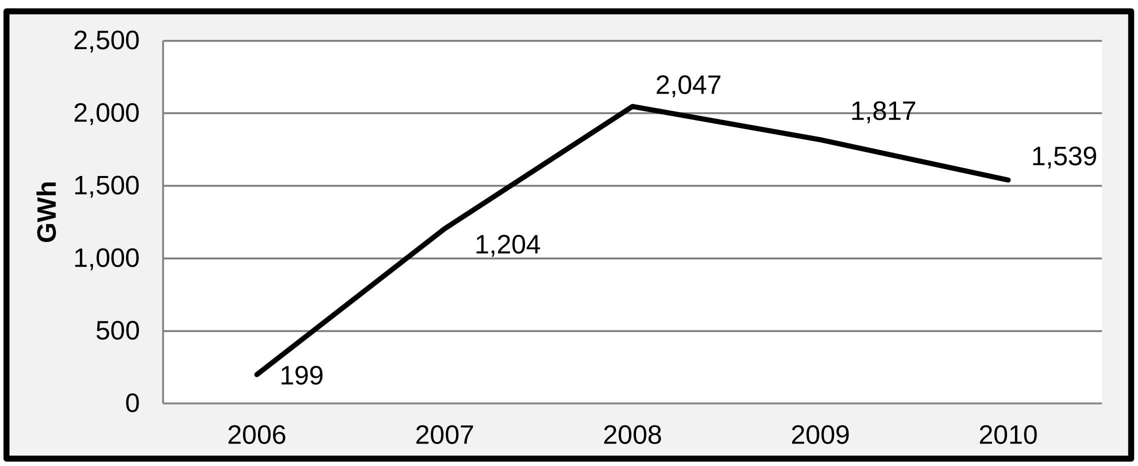

Figure 10-1. Net Electricity Generation from Conventional Hydropower in Missouri

[74] Nameplate rating data source: Osage, Table Rock, Clarence Cannon and Harry Truman from EIA-923 and EIA-860 reports (December, 2013); Taum Sauk from Ameren Missouri's website (http://www.ameren.com/sites/aue/Media/Pages/TaumSaukfactsandfigures.aspx) and Missouri Public Service Commission; Stockton, Niangua and Ozark Beach from Oak Ridge National Laboratory's HydroGIS (http://nhaap.ornl.gov/content/hydrogis-0).

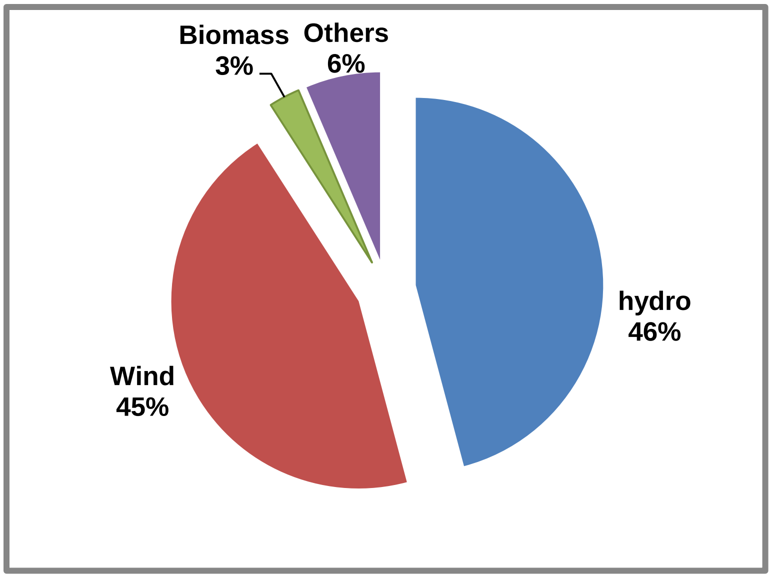

Figure 10-2. Renewable Electricity Generation by Energy Source, 2011

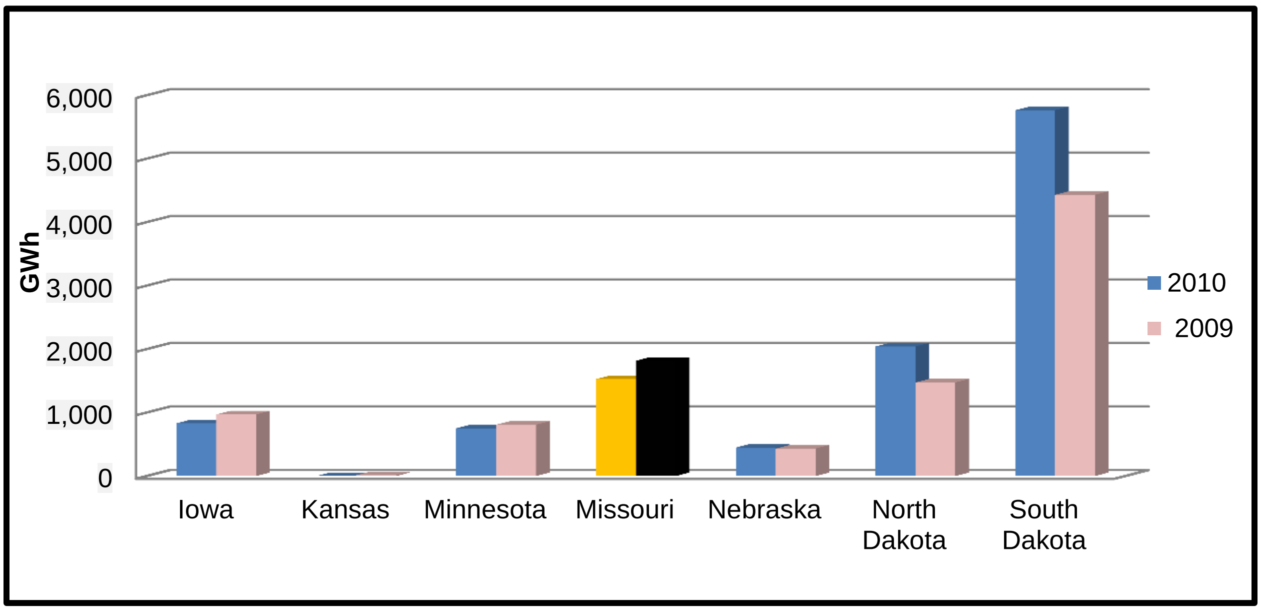

Figure 10-3. Net Generation from Hydroelectric Power in Selected States

According to a study by the U.S. Department of Energy (DOE), Missouri has the potential to develop 29 additional sites for electricity generation (Figure 10-4).[75] However, the

[75] "Assessment of Energy Potential at Non-Powered Dams", *U.S. Department of Energy, Wind & Water Power Program*. April 2012. Web. January 31, 2013. <http://www1.eere.energy.gov/water/pdfs/npd_report.pdf>.

location of some of the proposed sites may be inappropriate due to environmental and other concerns. Existing dams could also be retrofitted with turbines to expand the capacity to generate electricity. Missouri is composed of four hydrologic regions: Missouri, Upper Mississippi, Lower Mississippi and the Arkansas-White-Red.[76] Each of these regions has varied regional generation-weighted capacities. The DOE Idaho National Laboratory assessed the hydropower capacity in Missouri in 1997. The study found that 12 existing hydropower facilities were without power at that time and an additional 11 hydropower projects could potentially be developed within the state to contribute a total of 580,956 kilowatt hours, or 0.58 gigawatt hours (GWh), of hydropower.[77] The pre-existing dam structures identified in the 1997 DOE study that are not powered are shown in Figure 10-5.

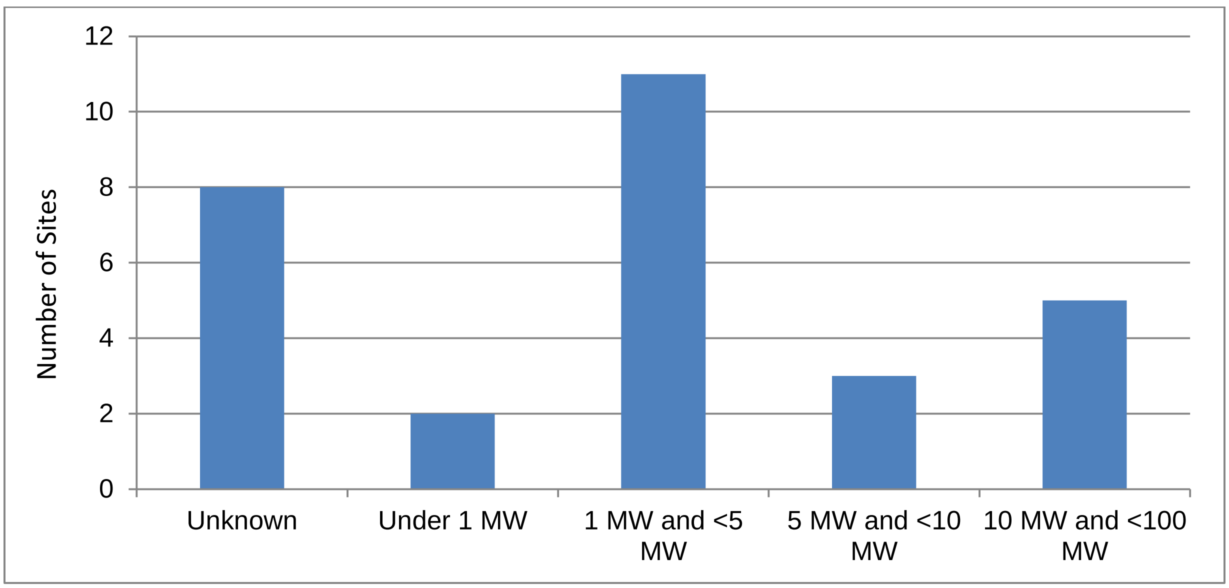

Figure 10-4. Number of Sites with Various Capacity Potentials in Missouri

[76] "Assessment of Energy Potential at Non-Powered Dams", *U.S. Department of Energy, Wind & Water Power Program*. April 2012. Web. January 31, 2013. <http://www1.eere.energy.gov/water/pdfs/npd_report.pdf>.
[77] "Missouri Hydropower Capacity Summary", *Idaho National Laboratory*. December 1997. Web. January 31, 2013. <http://hydropower.inel.gov/resourceassessment/app_a/index_states.shtml?mo>.

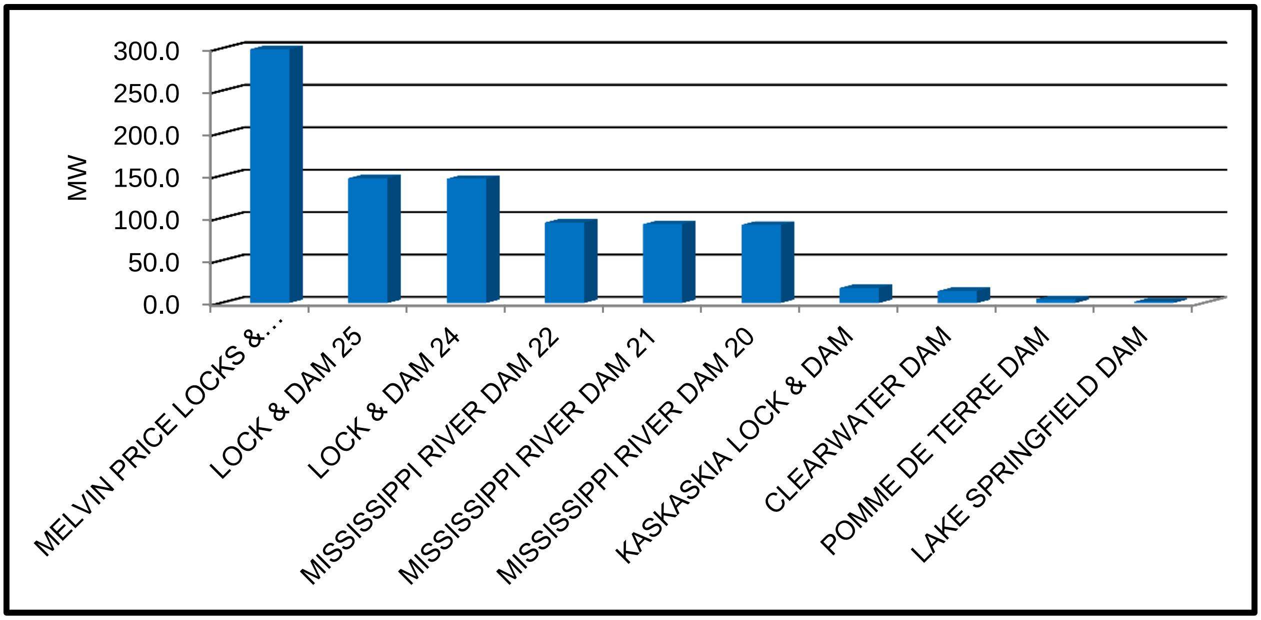

Figure 10-5. Missouri Existing Unpowered Dam Structures -- Technical Potential Hydropower Capacity (> 1MW)

11. Demand Side Management: Energy Efficiency and Demand Response

11.1 Background and History

"Demand Side Management" (DSM) describes efforts to provide utility customers with the tools they need to control their energy use. When referring to DSM, practitioners make a distinction between "energy efficiency" programs that support the purchase of high efficiency measures (light bulbs, appliances, air conditioners, heating systems, etc.), and "demand response" programs, which offer users an incentive to reduce their electricity use in response to extreme system loads by shifting the time period that electricity is used.

In Missouri, most DSM programs are sponsored by utilities, whether investor-owned utilities, rural electric cooperatives or municipal utilities, rather than being sponsored by the state or by an independent program implementer. Utility-sponsored DSM programs in Missouri began in 2005 and continue to the present.

11.2 Resource Overview

Missouri's DSM program savings have grown rapidly over the past seven years. Figure 11-1 shows the overall growth in Missouri's DSM savings since 2005, according to the U.S. Department of Energy's Energy Information Administration (EIA).[78] Reported savings from DSM programs grew from 1,029 MWh in 2005 to 383,096 MWh in 2011. Virtually all of these savings came from the energy efficiency programs. Most of the growth in DSM program savings between 2005 and 2011 came from programs sponsored by investor-owned utilities. In 2005, the EIA reported no DSM savings from investor-owned utilities. In 2012, savings from investor-owned utilities represented 98 percent of the DSM savings statewide.

The rapid growth of investor-owned utility DSM programs is an outcome of the state's energy policy, in particular, the electric integrated resource planning process, which has consistently identified DSM savings as the lowest cost resource for meeting utility generation needs. Utilities have found that sponsoring DSM programs to meet expected energy demand is

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[78] "Annual Electric Power Industry Report, 2005-2011", *United States Department of Energy, Energy Information Agency*, *Form 861*.20 September 2012. Web. February 6, 2013. <http://www.eia.gov/electricity/data/eia861/index.html>.

lower cost than building traditional power plants to generate additional electricity. Recently, investor-owned utilities have sought to meet their energy demands through both DSM programs and developing power plants that use renewable fuels, for example, that burn methane collected from landfills and from combined heat and power plants that utilize waste heat from industrial processes to generate electricity.

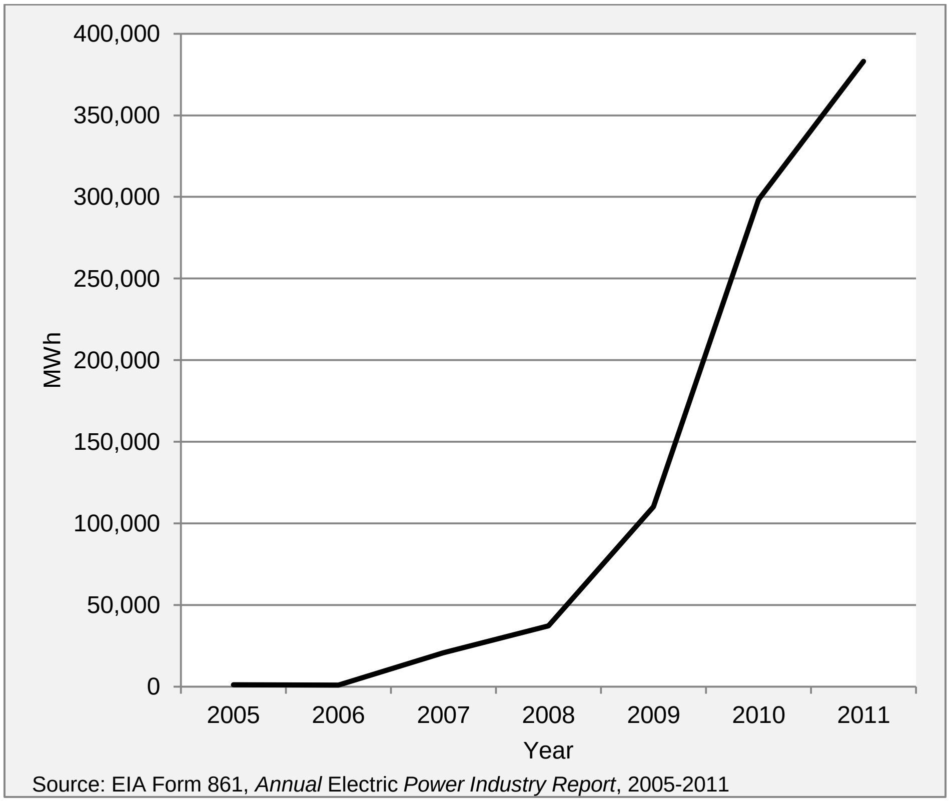

Figure 11-1. Missouri DSM Program Savings from All Sources, 2005-2011

According to the American Council for an Energy Efficient Economy (ACEEE) in 2010, Missouri electric DSM programs have saved approximately 0.34 percent of electricity sales. Missouri utilities spent $47.7 million dollars on energy efficiency programs, a figure equal to 0.67 percent of statewide utility revenues. Missouri natural gas utilities spent $7.2 million on DSM programs, an amount equal to $5.80 per residential customer. [79] While Missouri has seen a marked growth in savings from DSM programs over the past seven years, other states have been

[79] "The 2012 State Energy Efficiency Scorecard, Report E12c, Table 12", *American Council for an Energy Efficient Economy*. 2012. Web. February 6, 2013. <http://aceee.org/research-report/e12c>.

increasing their investments and savings in DSM programs as well. Figure 11-2, which shows statewide savings from DSM programs in 2010 and 2011 using EIA data, places Missouri as 20th out of the 51 states and the District of Columbia. Missouri's overall state ranking on the 2012 ACEEE scorecard, which is based on states' energy profiles in 2010, was 43rd. The ACEEE ranking considers many energy policy areas beyond utility DSM programs. When looking only at Missouri's electric DSM programs, Missouri ranked 29th in terms of energy savings and 33rd in terms of DSM program spending.

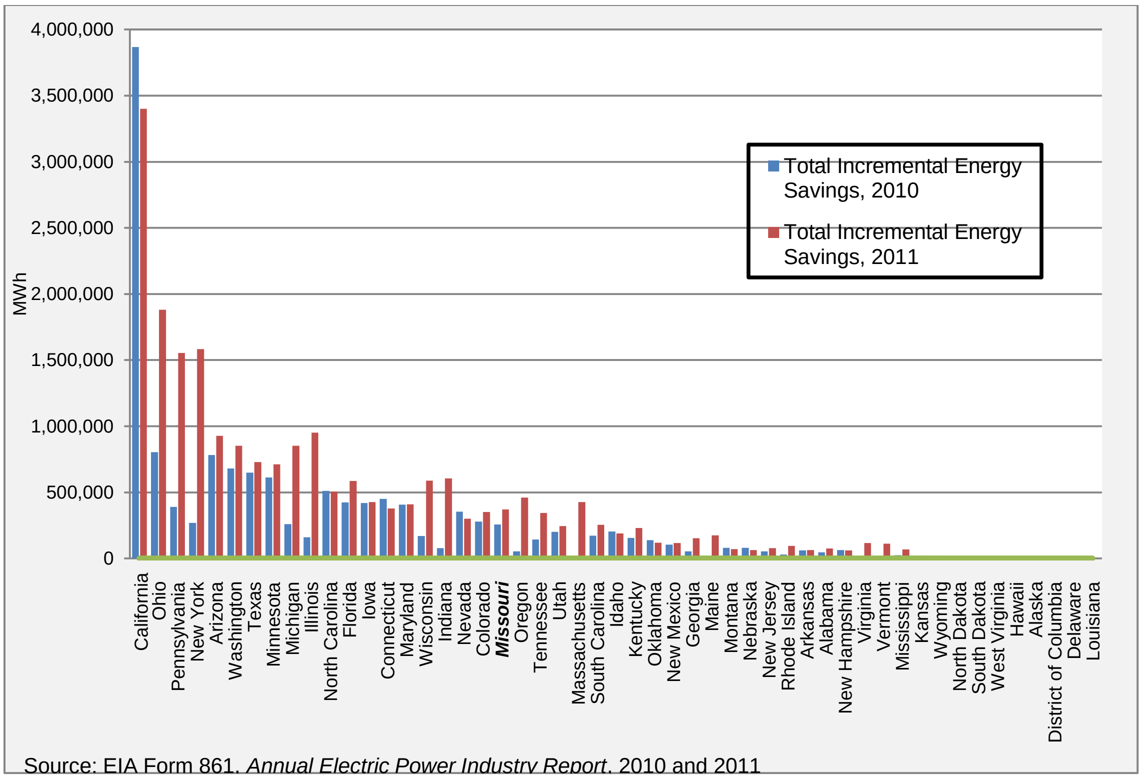

Figure 11-2. Total Savings from DSM Programs in 2010 and 2011

Figure 11-3 shows the per-capita savings of electricity, in KWh, from all DSM programs in 2010. The EIA data ranked Missouri 18th in terms of electricity savings. Figures 11-2 and 11-3, as well as the ACEEE ranking, suggest that Missouri's DSM performance can increase.

11.3 Development of State Policies that Support DSM

During the 2011 calendar year, Missouri's investor-owned utilities, the Missouri Public Service Commission, with input from the Office of Public Council, the Department of Natural Resources' Division of Energy[80] and other interested groups, finalized the rules implementing the Missouri Energy Efficiency Investment Act (MEEIA), a 2009 law that allows investor-owned electric utilities to recover their DSM program costs, recover losses due to reduction in electricity sales attributable to DSM programs and receive incentives for meeting a savings goal. The MEEIA law established the state policy goal of "achieving all cost-effective demand-side resources" in Missouri.

[80] The Division of Energy transferred from the Missouri Department of Natural Resources to the Missouri Department of Economic Development effective August 28, 2013 per Executive Order #13-03.

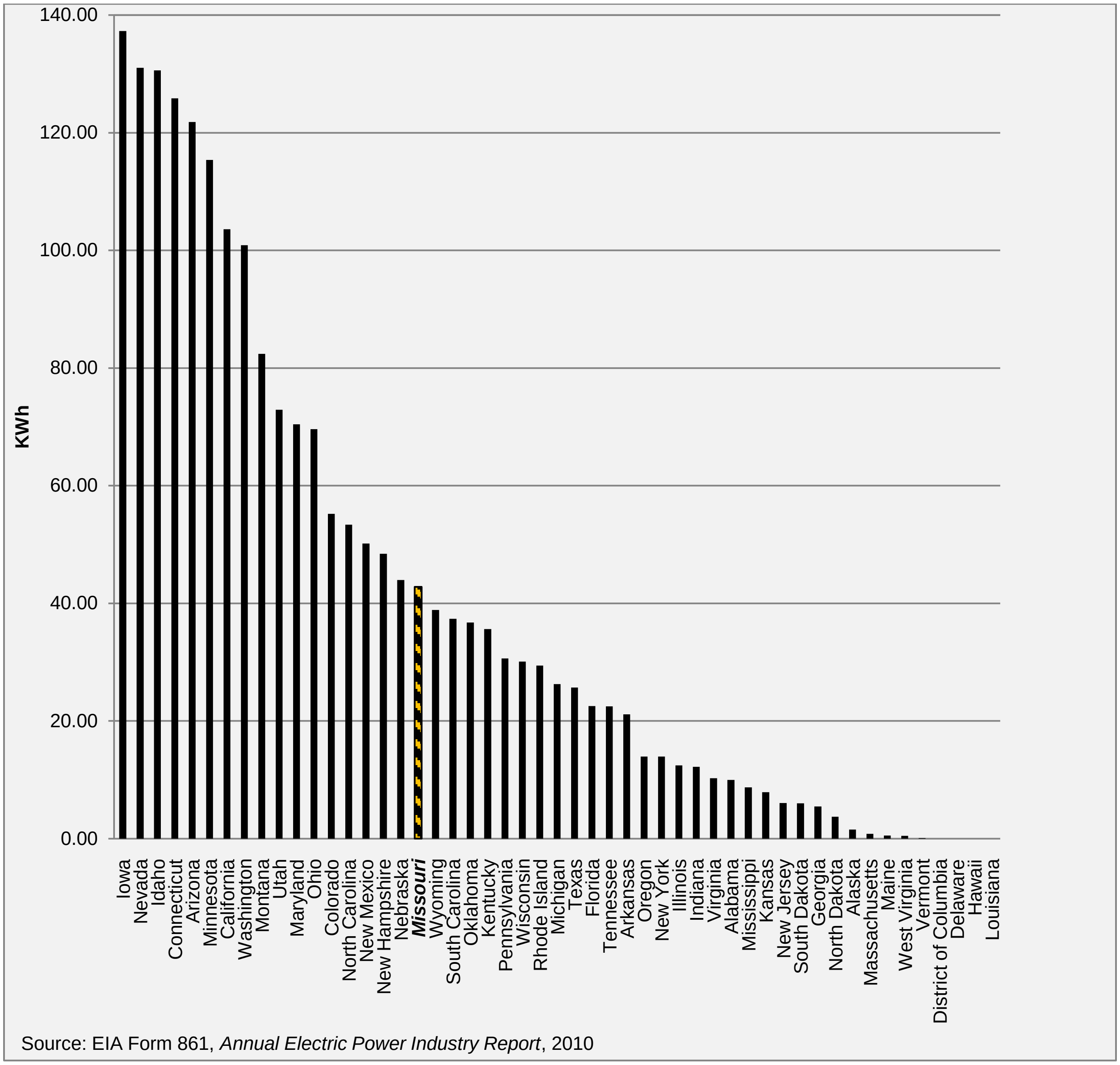

Figure 11-3. Kilowatt Hours Saved Per Capita from DSM programs

Two of Missouri's four investor-owned utilities filed MEEIA plans in 2012. These plans are expected to save over 943,000 megawatt hours (MWh) of electricity between 2013 and 2015 at a cost of approximately $184 million dollars.[81]

[81] See Missouri Public Service Commission cases EO-2012-0009 and EO-2012-0142 http://psc.mo.gov/General/EFIS.

11.4 How Much Energy Can Be Saved? Results from Two DSM Potential Studies

While Missouri has seen rapid growth in its energy savings over the past seven years, comparisons with other states give the impression that Missouri could increase its savings substantially. However, one question to consider is how much energy could Missouri save through DSM programs, renewable generation and supportive state policies; and at what cost? Missouri state energy policy specifies a goal of achieving "all cost-effective demand-side resources," which means that the benefits of Missouri DSM programs must be at least equal to their cost. In an attempt to estimate how much savings can be realized and at what cost, utilities and the state conduct "energy efficiency potential studies." Investor-owned electric utilities are required by the Missouri Public Service Commission to conduct potential studies every four years. These studies necessarily focus on savings from electric DSM programs targeted to a utility's service territory.

In 2011, the ACEEE conducted a statewide analysis of savings potential employing a much broader scope than any individual utility study. By considering the results of two of these studies, a utility-specific potential study conducted by Ameren Missouri in 2010[82] and the broader study conducted by ACEEE, it is possible to understand the range of potential savings from DSM, building codes and other energy efficiency policies in Missouri. The estimated savings level from each study, along with the incremental savings from DSM for the state as a whole in 2011, is displayed in Table 11-1.

Table 11-1. Estimates of DSM Savings by 2020 in MWh

Estimated Savings, ACEEE 2020	9,164,000
Estimated Savings, Ameren RAP, 2020	2,627,000
DSM Savings, EIA Form 861, 2011	370,263

Ameren's *2010 DSM Market Potential Study* published in January 2010, estimated savings from the adoption of energy efficiency measures by its customers under the market conditions that customers are likely to face. The estimated level of savings by 2020 of 2,627,000 MWh reflects savings from a proposed portfolio of DSM programs developed by Ameren

[82] AmerenUE Demand Side Management (DSM) Market Potential Study, 4 Volumes, Global Energy Partners, LLC. Walnut Creek, CA. 2010. 1287-1.

referred to as realistic achievable potential (RAP). The programs in this study formed the core of its MEEIA portfolio.

In August 2011, the ACEEE published an analysis of the energy savings potential in Missouri.[83] This analysis considered improvements in energy efficiency broadly, including not only utility-funded programs but also changes in building codes, establishment of a state energy efficiency resource standard, development of combined heat and power (CHP) resources and a particular focus on energy use in the agricultural sector. Their estimates suggest that, if all possible sources were exploited to capture all cost-effective energy savings, Missouri could save approximately 9,164 Gigawatt hours (GWh) (or 9,164,000 MWh) of electricity and 187 million therms of natural gas by 2020. ACEEE estimates that these program changes and savings opportunities could create 9,492 new jobs in Missouri by 2025.

These two studies are not strictly comparable. The Ameren Missouri study is based on likely electric DSM program savings in its service territory. The ACEEE study is much broader, considering savings opportunities for all sectors on a statewide basis. However, both studies estimate that a higher level of savings from DSM programs is possible. Ameren Missouri estimates that its customers can save approximately 2.6 million MWh by 2020, while ACEEE estimates a statewide savings figure of 9.1 million MWh. In contrast, the EIA data indicates that Missouri saved 370,000 MWh in 2011. While much of the discussion surrounding DSM savings focuses on energy and environmental outcomes, DSM programs also support Missouri's economy. Missouri's experience with utility energy efficiency programs has shown that these programs support local business directly, by creating jobs in the building trades, and indirectly, by making businesses and homes more efficient. Over the next three years, Missouri electric utilities are expected to increase their spending on energy efficiency programs by a factor of four, and are expected to increase their energy savings by a factor of three. Analyses conducted by the ACEEE suggests that total savings between 2011 and 2020 could increase nearly ten times over the expected savings from the current MEEIA DSM programs and that this effort could produce 9,492 new jobs in Missouri by 2025.

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[83] "Missouri's Energy Efficiency Potential: Opportunities for Economic Growth and Energy Sustainability," *American Council for an Energy Efficient Economy*, 2011. Report E114. <http://ded.mo.gov/energy/docs/aceestudy.pdf>.

11.5 Conclusion

Missouri's recent experience with demand side management programs suggests that they have been successful in saving substantial amounts of energy. DSM savings have shown rapid growth since 2005. With the implementation of MEEIA DSM programs in the beginning of 2013, the current expectation is that DSM savings will continue to grow. While this is good news both environmentally and economically, it appears that more can be done. The future of DSM programs and energy efficiency has the potential of substantially changing Missouri's energy usage patterns.