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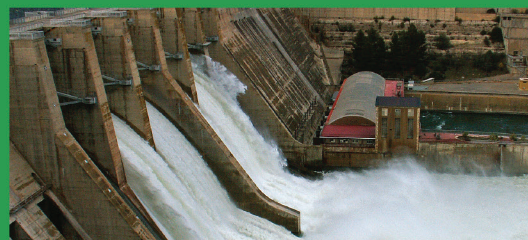


2013 INDIANA RENEWABLE ENERGY RESOURCES STUDY


Prepared for:
Indiana Utility Regulatory Commission and Regulatory Flexibility Committee of the Indiana General Assembly Indianapolis, Indiana

State Utility Forecasting Group | Energy Center at Discovery Park | Purdue University | West Lafayette, Indiana

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Acronyms and Abbreviations

ARRA	American recovery and reinvestment act
AEP	American Electric Power
AMP	American Municipal Power
AWEA	American Wind Energy Association
Btu	British thermal unit
CAFO	concentrated animal feeding operations
CHP	combined heat and power plant
CO_2	Carbon dioxide
CPV	Concentrating photovoltaic
CREB	Clean renewable energy bonds
CSP	Concentrating solar power
DC	District of Columbia
DOE	U.S. Department of Energy
DSIRE	Database of state incentives for renewables and efficiency
EDP	Energias de Portugal energy corporation
EERE	Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy
EIA	Energy Information Administration, U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
EPAct	2005 Energy Policy Act
FERC	Federal Energy Regulatory Commission
FHA	Federal Housing Authority
FY	Financial year
GW	Gigawatt
GWh	Gigawatthour
IEA	International Energy Agency
IMPA	Indiana Municipal Power Agency

INL	Idaho National Laboratory, U.S. Department of Energy
IPL	Indianapolis Power and Light Company
IREC	Interstate Renewable Energy Council
ISDA	Indiana State Department of Agriculture
ITC	Business energy investment tax credit
IURC	Indiana Utility Regulatory Commission
kW	Kilowatt
kWh	Kilowatthour
LLC	Limited liability company
LMOP	Landfill Methane Outreach Program, Energy Information Administration, U.S. Department of Energy
m/s	Meters per second
MACRS	Modified accelerated cost-recovery system
MGY	Million gallons per year
mmBtu	Million British thermal unit
mmscfd	Million standard cubic feet per day
MMTCE	Million metric tons of carbon equivalent
mph	Miles per hour
MSW	Municipal solid waste
MTBE	Methyl tertiary butyl ether – a gasoline oxygenating additive
MW	Megawatt
MW_{DC}	Megawatt direct current
MW_{th}	Thermal megawatt
MWh	Megawatthour
NIPSCO	Northern Indiana Public Service Company
NO_x	Nitrogen oxide
NREL	National Renewable Energy Laboratory, U.S. Department of Energy
O&M	Operation and maintenance
OED	Indiana Office of Energy Development
ORNL	Oak Ridge National Laboratory, U.S. Department of Energy

POLYSYS	Policy analysis system
PTC	Production tax credit
PV	Photovoltaic
REAP	Rural Energy for America Program, U.S. Department of Agriculture
RPS	Renewable portfolio standard
QECB	Qualified energy conservation bonds
SEDS	State Energy Data System, Energy Information Administration, U.S. Department of Energy
SEGS	Solar Electric Generation System
SEIA	Solar Energy Industries Association
SOx	Sulfur oxides
SUFG	State Utility Forecasting Group
USDA	U.S. Department of Agriculture
VA	U.S. Department of Veterans Affairs
VEETC	Volumetric ethanol tax credit
W	Watts
W/m^2	Watts per square meter
WPCP	Water pollution control plant
WVPA	Wabash Valley Power Association
WWTF	wastewater treatment facility
WWTP	wastewater treatment plant

Foreword

This report represents the eleventh annual study of renewable resources in Indiana performed by the State Utility Forecasting Group. It was prepared to fulfill SUFG's obligation under Indiana Code 8-1-8.8 (added in 2002) to "conduct an annual study on the use, availability, and economics of using renewable energy resources in Indiana." The code was further amended in 2011, clarifying the topics to be covered in the report. In accordance with this change, fuel cells are no longer included and energy from algae is incorporated in the section on organic waste biomass.

The report consists of seven sections. Section one provides an overview of the renewable energy industry in the United States and in Indiana. It includes a discussion of trends in penetration of renewable energy into the energy supply, both nationally and in Indiana. The other six sections are each devoted to a specific renewable resource: energy from wind, dedicated crops grown for energy production, organic biomass waste, solar energy, photovoltaic cells, and hydropower. They are arranged to maintain the format in the previous reports as follows:

- Introduction: This section gives an overview of the technology and briefly explains how the technology works.
- Economics of the renewable resource technology: This section covers the capital and operating costs of the technology.
- State of the renewable resource technology nationally: This section reviews the general level of usage of the technology throughout the country and the potential for increased usage.
- Renewable resource technology in Indiana: This section examines the existing and potential future usage for the technology in Indiana in terms of economics and availability of the resource.
- Incentives for the renewable resource technology: This section contains incentives currently in place to promote the development of the technology and recommendations that have been made in regards to how to encourage the use of the renewable resource.
- References: This section contains references that can be used for a more detailed examination of the particular renewable resource.

This report was prepared by the State Utility Forecasting Group. The information contained in it should not be construed as advocating or reflecting any other organization's views or policy position. For further information, contact SUFG at:

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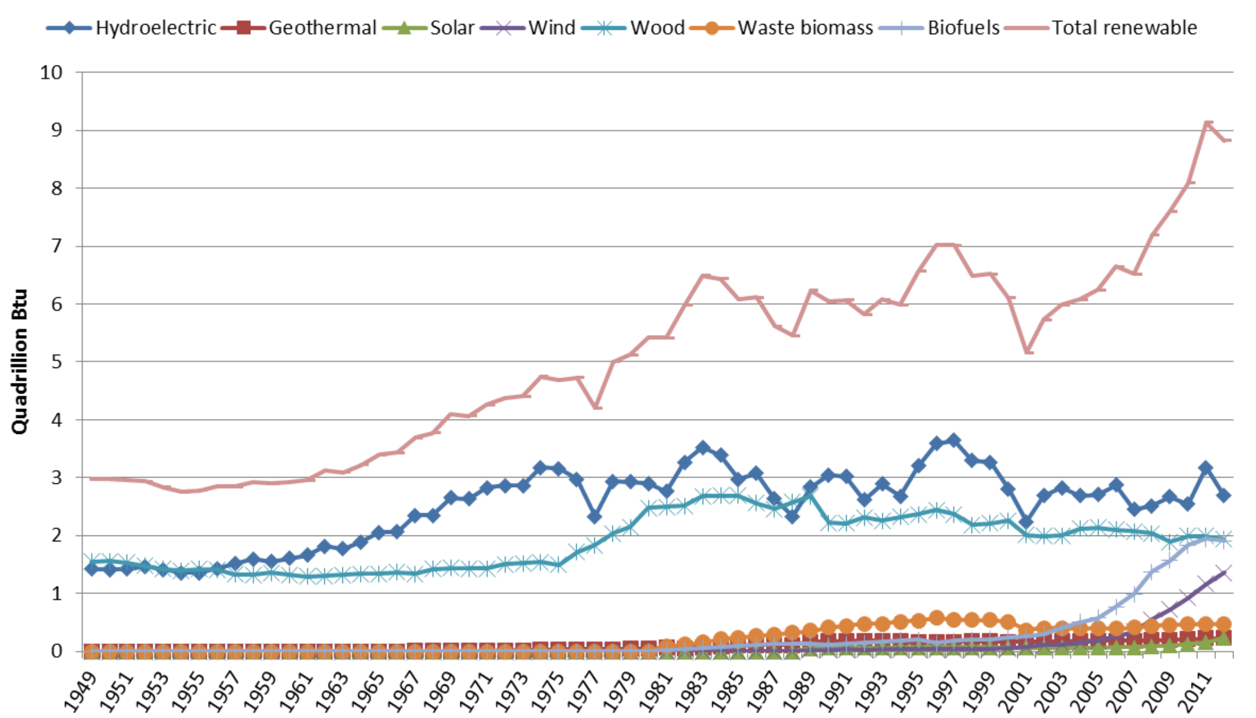
1. Overview

This first section of the 2013 Indiana Renewable Energy Resources Report presents an overview of the trends in renewable energy consumption in the U.S. and in Indiana.

1.1 Trends in renewable energy consumption in the United States

Figure 1-1 shows the amounts of renewable energy in quadrillion British thermal units (Btu) consumed in the U.S. from 1949 to 2012. Until the early 2000s hydroelectricity and woody biomass were the dominant sources of renewable energy consumed in the U.S. The last decade has seen a rapid increase in biofuels (mainly corn-based ethanol) and wind as sources of renewable energy. The rapid increase in corn-ethanol has been driven by two factors: it serves as a replacement of the oxygenating additive MTBE in gasoline which started being phased out in 2000, and the Federal Renewable Fuel Standard, which was first authorized in the 2005 Energy Policy Act and then expanded in 2007, created mandates for the production of biofuels. This rapid increase in corn-ethanol has since slowed down and even turned into a decline in 2012 in line with declining U.S. gasoline demand. The rapid increase in wind energy started with the introduction of the Federal Production Tax Credit in 1992 (PTC), and continued with the proliferation of renewable portfolio standards in a number of states. The PTC is set to expire at the end of 2013.



<u>Figure 1-1:</u> <u>Renewable energy consumption in the U.S. (1949-2012)</u> (Data source: EIA [1, 2])

Despite the growth shown in Figure 1-1, renewable energy's share of the total energy consumed in the U.S. remains modest at less than 10 percent. Fossil fuels supply over 80 percent of the energy consumed, while nuclear energy supplies the remainder. Figure 1-2 shows the sources of total energy consumed in the U.S. from 1949 to 2012.

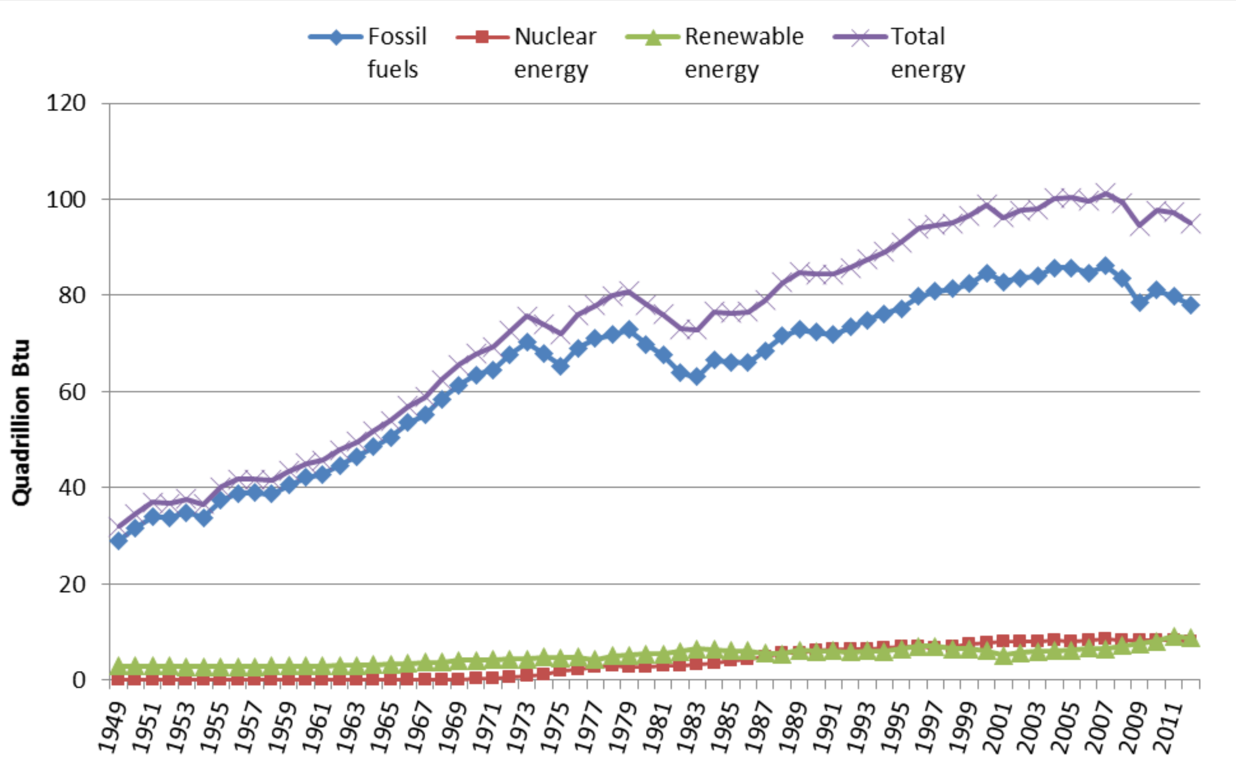


Figure 1-2: U.S. energy consumption by source (1949-2012) (Data source: EIA [3, 4])

Figure 1-3 shows the contribution of the various energy sources to total energy consumed in the U.S. in 2012. Petroleum continued to be the dominant energy source supplying 37 percent, followed by natural gas at 27 percent and coal at 18 percent. Among the renewable resources, biomass (including wood, biofuels, municipal solid waste, landfill gas and others) comprised nearly half of the total renewable energy, followed by hydroelectricity at 30 percent. Wind power's contribution rose to 15 percent from 13 percent in 2011, the geothermal and solar shares rose from 2 percent to 3 percent each.

When one considers renewable resources in electricity generation (Figure 1-4), hydroelectricity played a dominant role in 2010, exceeding all other renewable resources combined. Hydroelectricity made up 56 percent of the renewable electricity generated. Wind energy took second place at 22 percent of the renewable electricity and woody biomass takes third place at 7 percent.

Waste biomass contributed 4 percent, geothermal 3 percent and solar 1 percent. As expected, pumped hydroelectricity's net energy contribution was negative.[1]

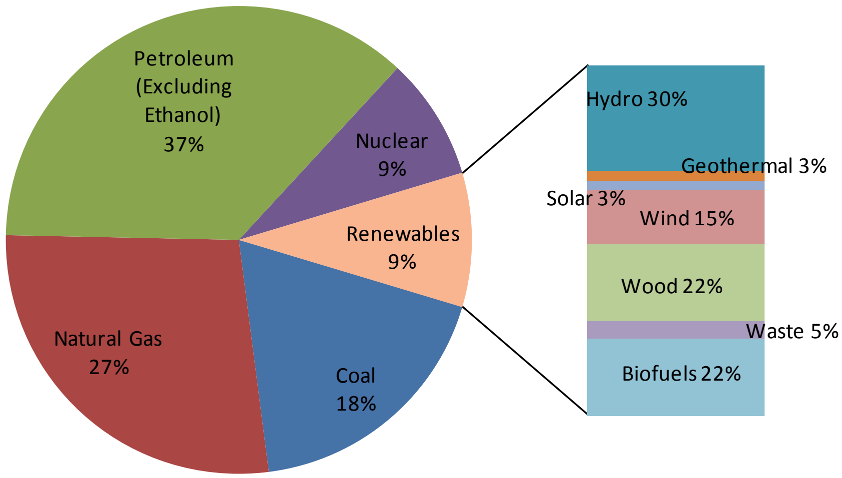


Figure 1-3: U.S. total energy consumption by energy source in 2012 (Data source: EIA [2, 5])

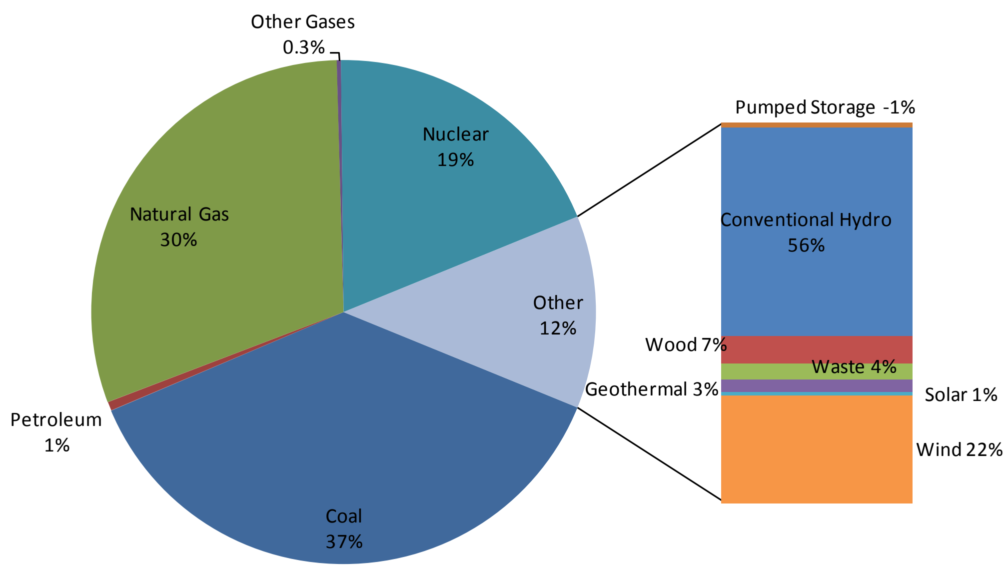
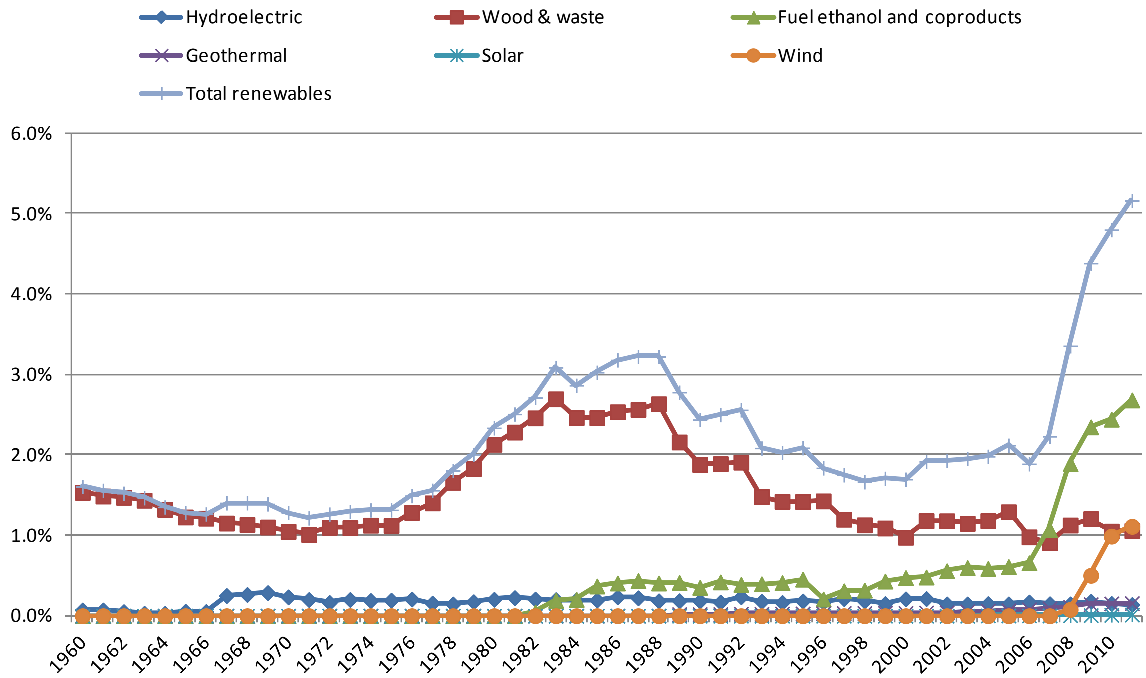


Figure 1-4: Net U.S. electricity generation by energy source in 2011 (Data source: EIA [6])

[1] Pumped hydroelectric facilities use electricity from the grid during periods of low demand and price to pump water from a lower reservoir to a higher one. That water is then available to generate electricity during high demand and price periods. Due to evaporation and inefficiencies in the pumping and generating processes, less energy is generated than is used. However, the value of the lost energy is more than compensated because low cost, off-peak electricity is converted to high cost, on-peak electricity.

1.2 Trends in renewable energy consumption in Indiana

Figure 1-5 shows renewable energy consumption in Indiana from 1960 to 2011. In the 1980s, renewable resources contributed over 3 percent of total energy consumed in Indiana. In the 1990s the share fell to below 2 percent, before the recent increase in ethanol and wind increased it to over 4.9 percent. Before the entry of ethanol and wind in the 2000s woody biomass had been the main source of renewable energy in Indiana, comprising over 80 percent of the total renewable energy.



<u>**Figure 1-5:** Renewables share of Indiana total energy consumption (1960-2011)</u> (Data source: EIA [7])

Figure 1-6 shows the contribution of renewable energy to Indiana's electricity generation from 1990 to 2010. The arrival of utility-scale wind energy projects in 2007 caused a rapid increase in renewable energy's share of Indiana's electricity generation. The share changed from a low of 0.5 percent in 2006 to 3 percent in 2010. Wind energy's share of the annual generation was 1.5 percent in 2009 and 2.6 percent in 2010 [8]. Hydroelectricity, which until 2007 was the dominant source of renewable electricity, maintained its share at approximately 0.4 percent of total generation.

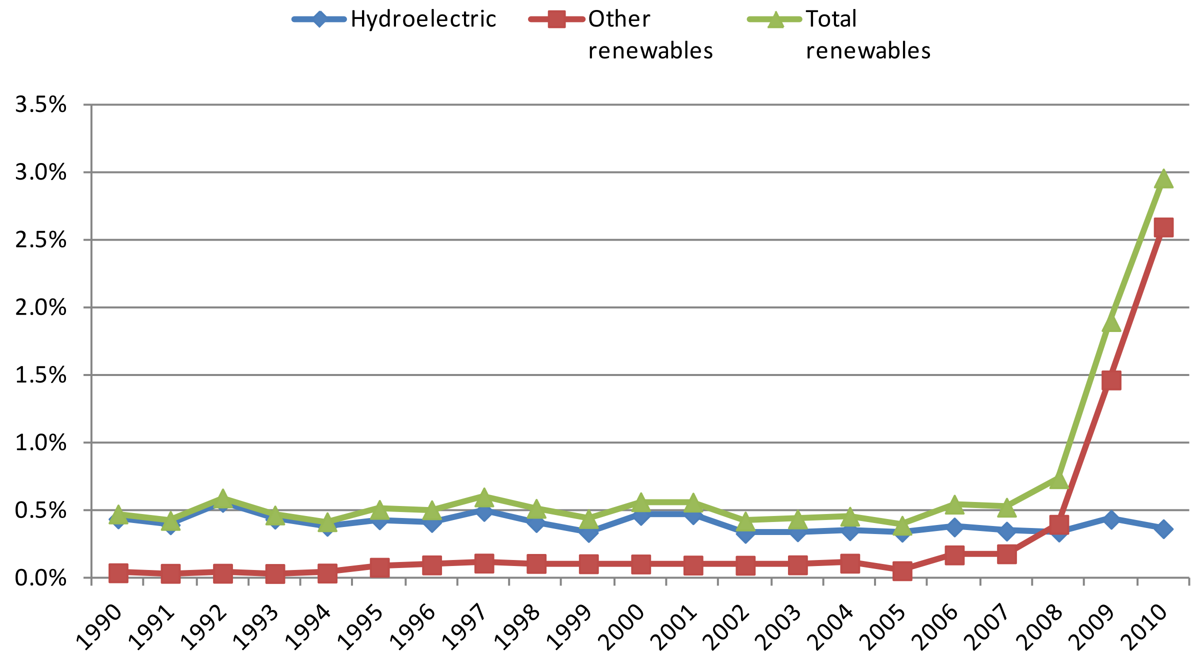


Figure 1-6: Renewables share of Indiana net electricity generation (1990-2010) (Data source: EIA [9])

In keeping with the national trend, the rapid growth in wind energy capacity in Indiana has slowed down substantially with only one wind farm, the 200 MW Wildcat wind farm in Madison and Tipton counties, being commissioned in the last two years. Figure 1-7 shows the annual and cumulative installed wind energy capacity in Indiana. Indiana utilities have a total 946 MW contracted on power purchase agreements, 536 MW from wind farms in Indiana and 410 MW from out of state wind farms in Illinois, Iowa, Minnesota and South Dakota.

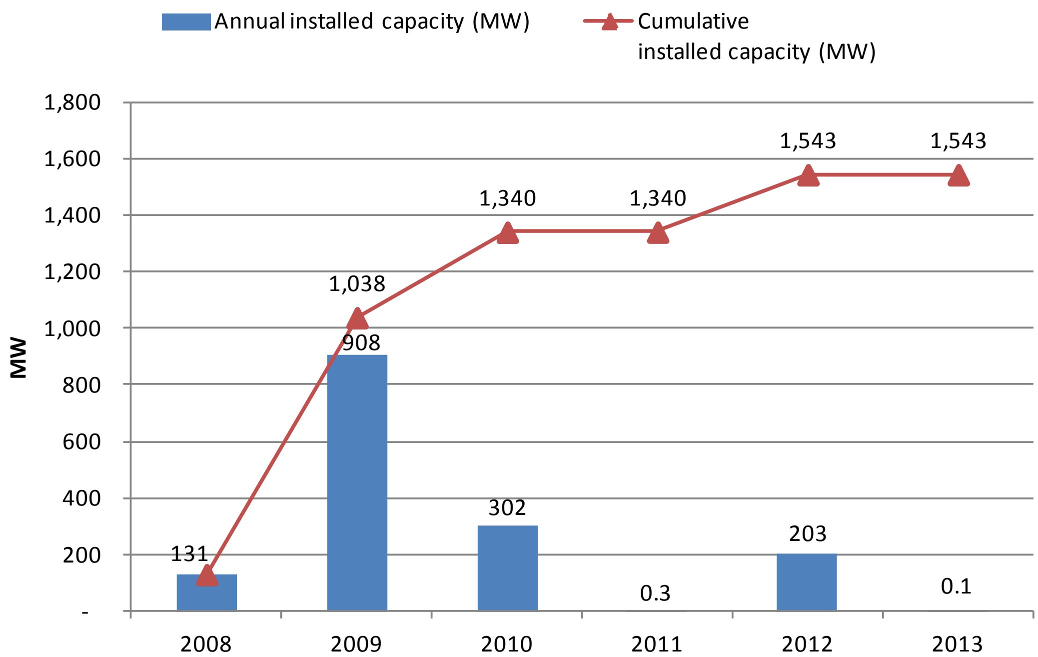


Figure 1-7: Wind energy installed capacity in Indiana (Data sources: IURC, DOE [10-13]).

Another renewable resource whose installed capacity has experienced rapid growth in the last five years is solar photovoltaic. Figure 1-8 shows the annual and cumulative PV capacity installations as reported to the National Renewable Energy Laboratory's *Open PV Project* database. This capacity is expected to more than double when the 10 MW solar farm at the Indianapolis International Airport opens in late 2013.

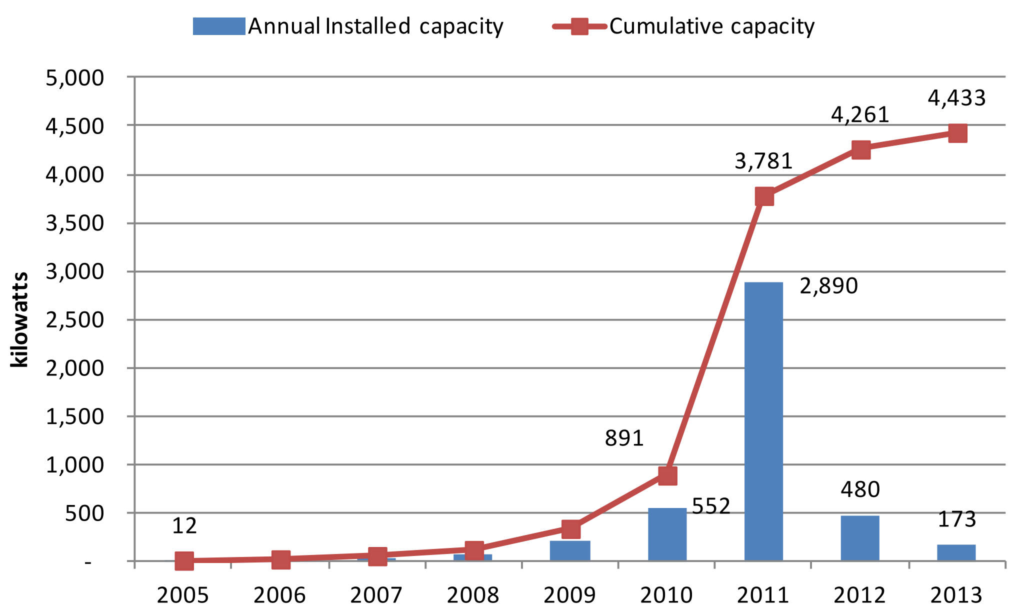


Figure 1-8: Indiana installed PV capacity in NREL *Open PV Project* database (Data source NREL [14]

1.3 References

1. Energy Information Administration (EIA). 2012 Annual Energy Review Table 10.1. http://www.eia.gov/totalenergy/data/annual/#renewable
2. EIA. May 2013 Monthly Energy Review Table 10.1 http://www.eia.gov/totalenergy/data/monthly/#renewable http://205.254.135.7/totalenergy/data/monthly/#renewable
3. EIA. 2012 Annual Energy Review Table 1.1. http://www.eia.gov/totalenergy/data/annual/#summary
4. EIA. May 2013 Monthly Energy Review Table 1.1. http://205.254.135.7/totalenergy/data/monthly/#summary
5. EIA. May 2013 Monthly Energy Review Table 1.3 http://www.eia.gov/totalenergy/data/monthly/#summary
6. EIA. Renewable. May 2013 Monthly Energy Review, Table 7.2a. http://www.eia.gov/totalenergy/data/monthly/#electricity
7. EIA. State Energy Data System (SEDS), Table CT2. Primary Energy Consumption Estimates, Selected Years, 1960-2011, Indiana. http://www.eia.gov/state/seds/data.cfm?incfile=/state/seds/sep_use/total/use_tot_INcb.html&sid=IN
8. Department of Energy Office of Energy Efficiency and Renewable Energy (EERE). 2010 Wind technologies market report. http://www1.eere.energy.gov/wind/pdfs/2011_wind_technologies_market_report.pdf
9. EIA. Indiana Electricity Profile 2010, Table 5, Release date: January 2012. http://www.eia.gov/electricity/state/indiana/
10. George Stevens. Indiana Utility Regulatory Commission.
11. Performance Services Corporation. http://www.performanceservices.com/services/wind_power/Community_wind_project
12. DOE, Wind Powering America Program.School wind project locations. http://www.windpoweringamerica.gov/schools/projects.asp
13. Cascade Renewable Energy. CityBus Headquarters Wind Project. http://www.cascaderenewableenergy.com/projects/citybus-wind
14. National Renewable Energy Laboratory. The open PV Project. http://openpv.nrel.gov/

2. Energy from Wind

2.1 Introduction

Wind turbines convert the kinetic energy in wind into mechanical energy and then into electricity by turning a generator. There are two main types of wind turbines, vertical and horizontal axis. The horizontal axis turbine with three blades facing into the wind is the most common configuration in modern wind turbines. Figure 2-1 shows the basic parts of a modern wind turbine used for electricity generation.

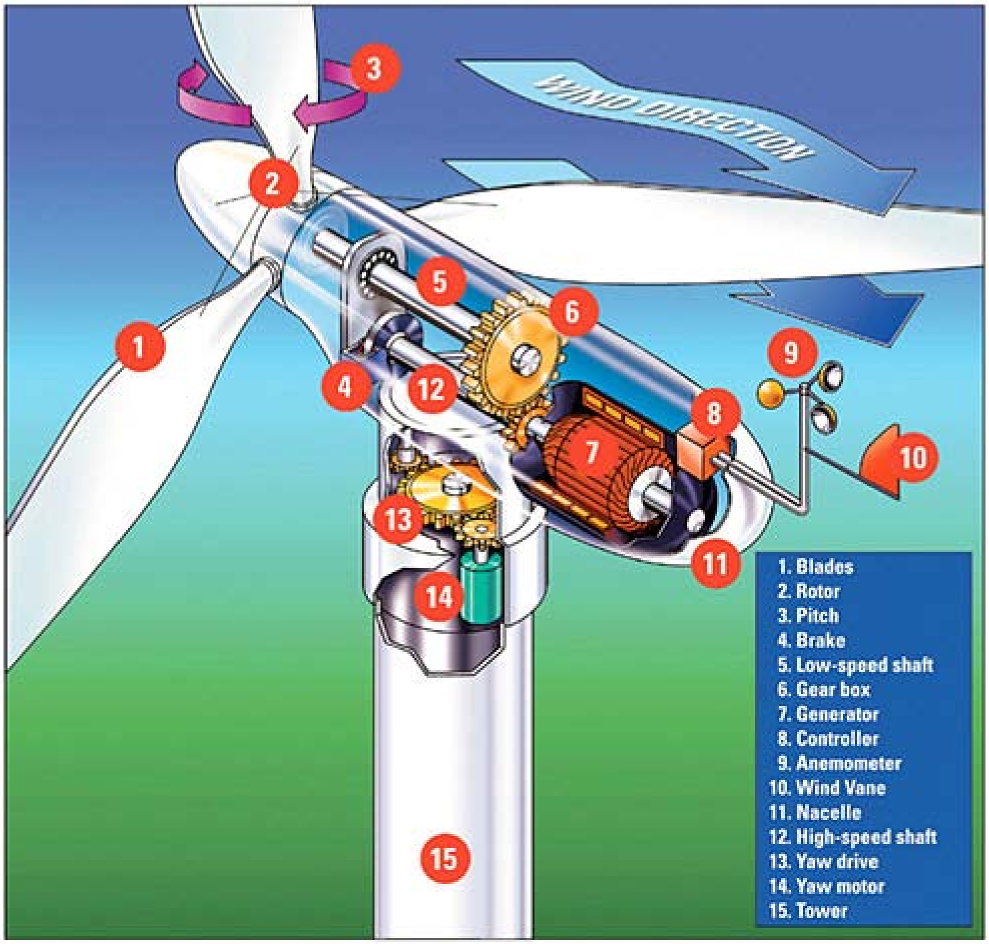


Figure 2-1: Horizontal wind turbine configuration (Source: Alternative Energy News [1])

Utility-scale wind farms in the U.S. began in California in the 1980s, with individual wind turbines on the order of 50 – 100 kilowatt (kW) of rated capacity. Turbine capacity and wind farm sizes have grown steadily to the point where the 2 megawatt (MW) turbine and wind farms with hundreds of MW of capacity are common [2].

Although wind farms' capacities have grown to be comparable to fossil fueled generators, the total electricity that can be produced from wind farm annually is typically much less than the electricity that is available from a fossil-fueled power plant with the same maximum capacity. A baseload coal or nuclear power plant in the U.S. will typically have an annual capacity factor[2] of over 80 percent while the capacity factors of wind farms are estimated to range between 20 and 40 percent, depending on the average annual wind speed at their location [3].

Wind speeds are important in determining a turbine's performance. Generally, annual average wind speeds of greater than 7 miles per hour (mph), or 3 meters per second (m/s), are required for small electric wind turbines not connected to the grid, whereas utility-scale wind plants require a minimum wind speed of 11 mph (5 m/s). The power available to drive wind turbines is proportional to the cube of the speed of the wind. This implies that a doubling in wind speed leads to an eight-fold increase in power output. A measurement called the wind power density is used to classify sites into "wind power classes" [4]. Wind power density is measured in watts per square meter (W/m^2) and is calculated from annual observed wind speeds and the density of air. Table 2-1 lists the wind class categories currently used.

	10 m (33 ft) Elevation		**50 m (164 ft) Elevation**	
Wind Power Class	Wind Power Density (W/m^2)	Speed m/s (mph)	Wind Power Density (W/m^2)	Speed m/s (mph)
1	0–100	0- 4.4 (9.8)	0-200	0-5.6 (12.5)
2	100 – 150	4.4 – 5.1 (9.8 – 11.5)	200 – 300	5.6 – 6.4 (12.5 – 14.3)
3	150 – 200	5.1 – 5.6 (11.5 – 12.5)	300 – 400	6.4 – 7.0 (14.3 – 15.7)
4	200 – 250	5.6 – 6.0 (12.5 – 13.4)	400 – 500	7.0 – 7.5 (15.7 – 16.8)
5	250 – 300	6.0 – 6.4 (13.4 – 14.3)	500 – 600	7.5 – 8.0 (16.8 – 17.9)
6	300 – 400	6.4 – 7.0 (14.3 – 15.7)	600 – 800	8.0 – 8.8 (17.9 – 19.7)
7	> 400	> 7.0 (15.7)	> 800	> 8.8 (19.7)

Table 2-1: Wind resource classification (Data source: NREL [5])

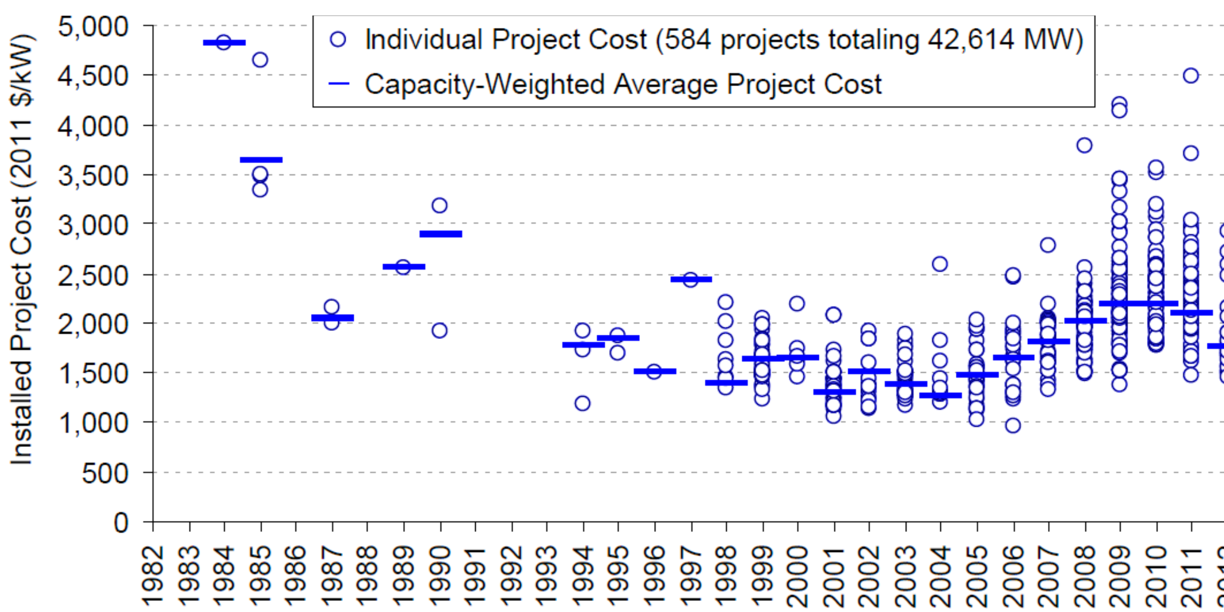
In addition to being a virtually inexhaustible renewable resource, wind energy has the advantage of being modular; that is a wind farm's size can be adjusted by simply adjusting the number of turbines on the farm.

[2] $\text{Annual capacity factor} = \frac{\text{Actual amount of energy produced in a year}}{\text{Energy that would have been produced if plant operated at full rated capacity all year}}$

A major disadvantage of wind is that the amount of energy available from the generator at any given time is dependent on the intensity of the wind resource at the time. This reduces the wind generator's value both at the operational level and also at the system capacity planning level where the system planner needs information about how much energy they can depend on from a generator at a future planning date, i.e., when the wind intensity cannot be perfectly predicted. Another disadvantage of wind energy is that good wind sites tend to be located far from main load centers and transmission lines. Concerns have also been raised about the death of birds and bats flying into wind turbines, the possibility of turbines causing radar interference, and potential adverse effects of the shadow flicker on people living in close proximity.

2.2 Economics of wind energy

In 2011, the installed cost of wind energy projects began to decline, breaking the upward trend that started in the early 2000s and continued through 2010. Capacity-weighted average installed costs peaked in 2009 and 2010 at $2,144/kW and $2,155/kW, respectively, and declined to $2,100/kW in 2011 [6]. Figure 2-2 shows the trends in the installed projects' costs from 1982 to 2012.



Note: 2012 data represent preliminary cost estimates for a sample of 20 projects totaling 2.6 GW that have either already been or will be built in 2012, and for which substantive cost estimates were available.

Source: Berkeley Lab (some data points suppressed to protect confidentiality)

Figure 2-2: Installed wind project costs over time (Source: EERE [6])

The expected further decline in wind farm project costs is already being reflected by a preliminary sample of 2012 wind energy projects.

The decline of the installed costs of wind energy projects reflects the reduction in turbine prices observed in the beginning months of 2011. Figure 2-3 shows wind turbine costs over time as calculated for the projects included in the Lawrence Berkeley National Laboratory dataset used in the *2011 Wind Technologies Market Report* [6]. As illustrated in the diagram, turbine prices peaked in 2008 and have steadily decreased since. This decline reflects similar declines in energy and commodity prices, and a shift in the supply-demand balance for turbines towards a buyer's market. These price reductions are expected to drive down total project costs and wind power prices.

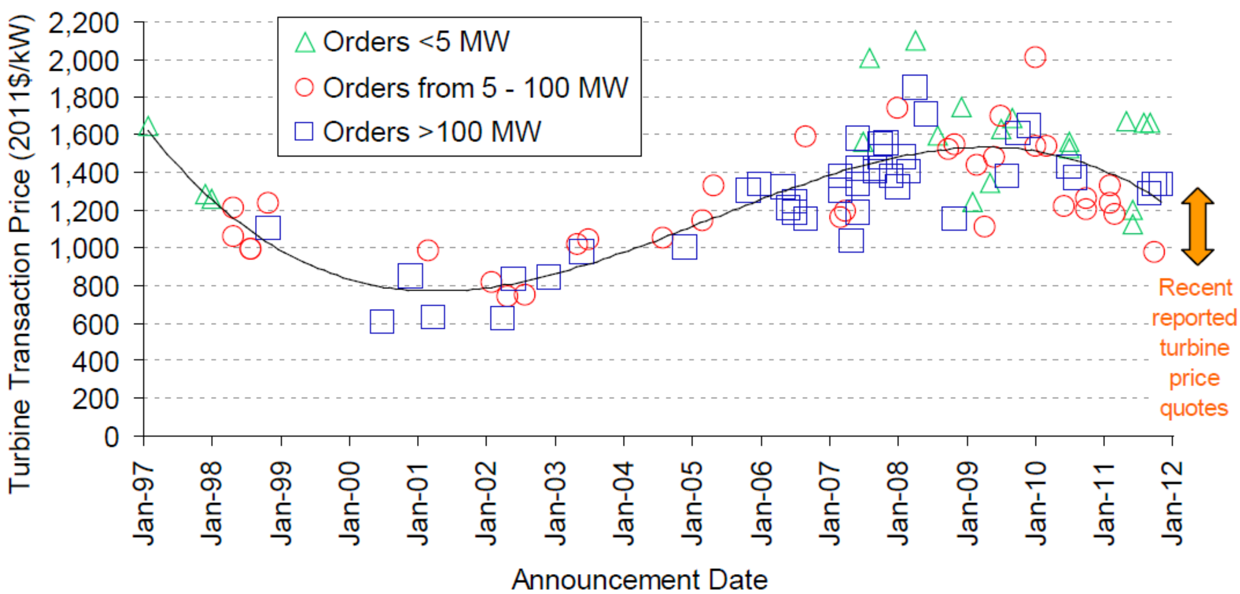


Figure 2-3: Reported U.S. wind turbine prices over time (Source: EERE [6])

Operation and maintenance (O&M) costs can vary substantially among projects. Figure 2-4 shows O&M costs using data compiled by Lawrence Berkeley National Laboratory for 133 wind projects installed between 1982 and 2010 with a total capacity of 7,965 MW. It suggests that projects installed recently have incurred lower average O&M costs. Specifically, capacity-weighted average O&M costs for the 24 sampled projects constructed in the 1980s were \$33/MWh, which dropped to \$22/MWh for the 37 projects installed in the 1990s, and to \$10/MWh for the 65 projects installed since 2000 [6].

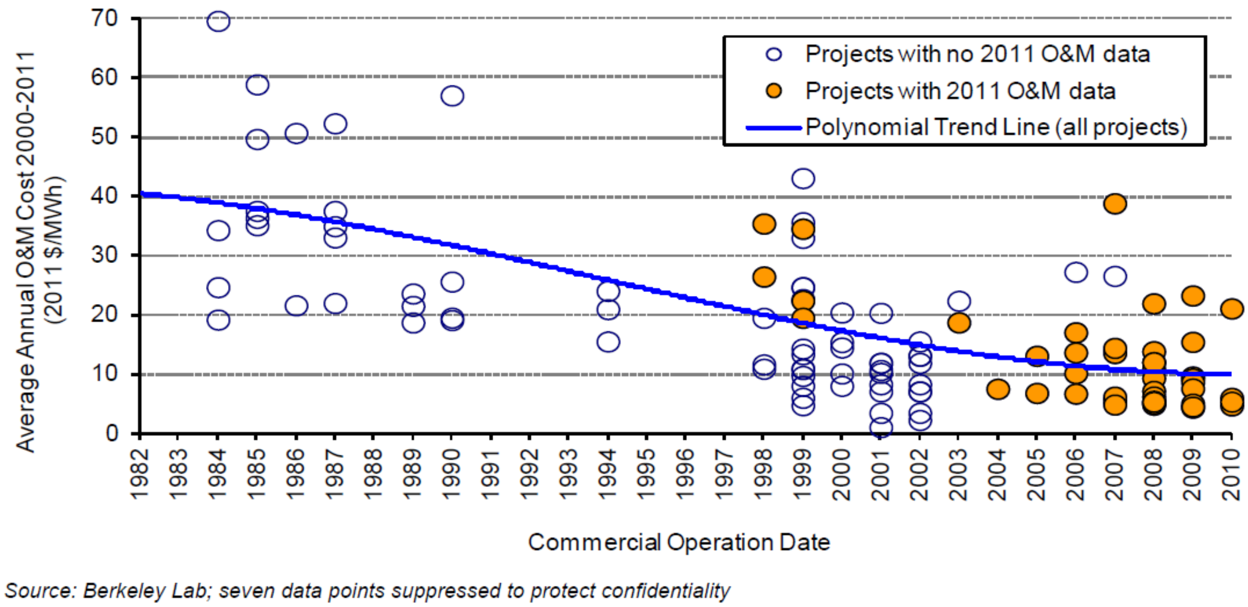
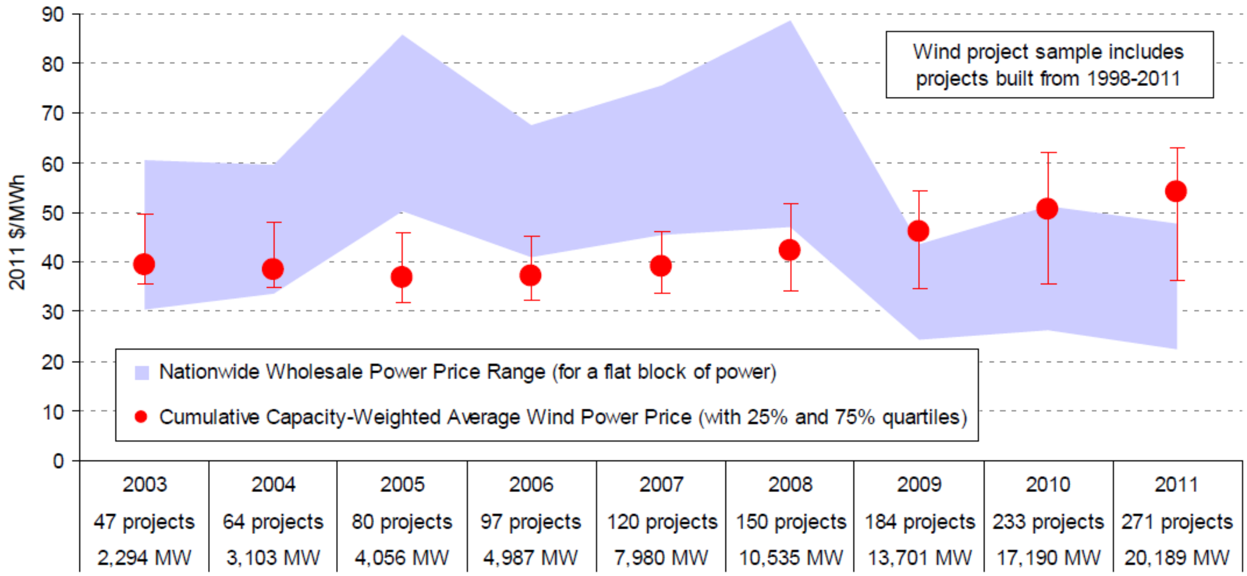


Figure 2-4: Reported U.S. wind turbine O&M costs over time (Source: EERE [6])

Figure 2-5 shows the range of average annual wholesale electricity prices for a flat block of power and the cumulative capacity-weighted average price received by wind power projects in each year from 2003 to 2011. On a cumulative basis, average wind power prices compared favorably to wholesale electricity prices from 2003 through 2008. However, increasing wind power prices combined with a sharp drop in wholesale electricity prices in 2009 (driven by lower natural gas prices and reduced electricity demand), decreased the competitiveness of wind power. In 2011, average wind energy prices surpassed the wholesale power price range. Low wholesale electricity prices continued to challenge the relative economics of wind power in 2011 [6]. The wind energy prices in the Berkeley data set reflect the price sold by wind project owners under multi-year power purchase agreements. The wind project owners are able to take a price lower than the wholesale market price because they have access to the federal production tax credit, currently valued at $23/MWh for ten years of operation.

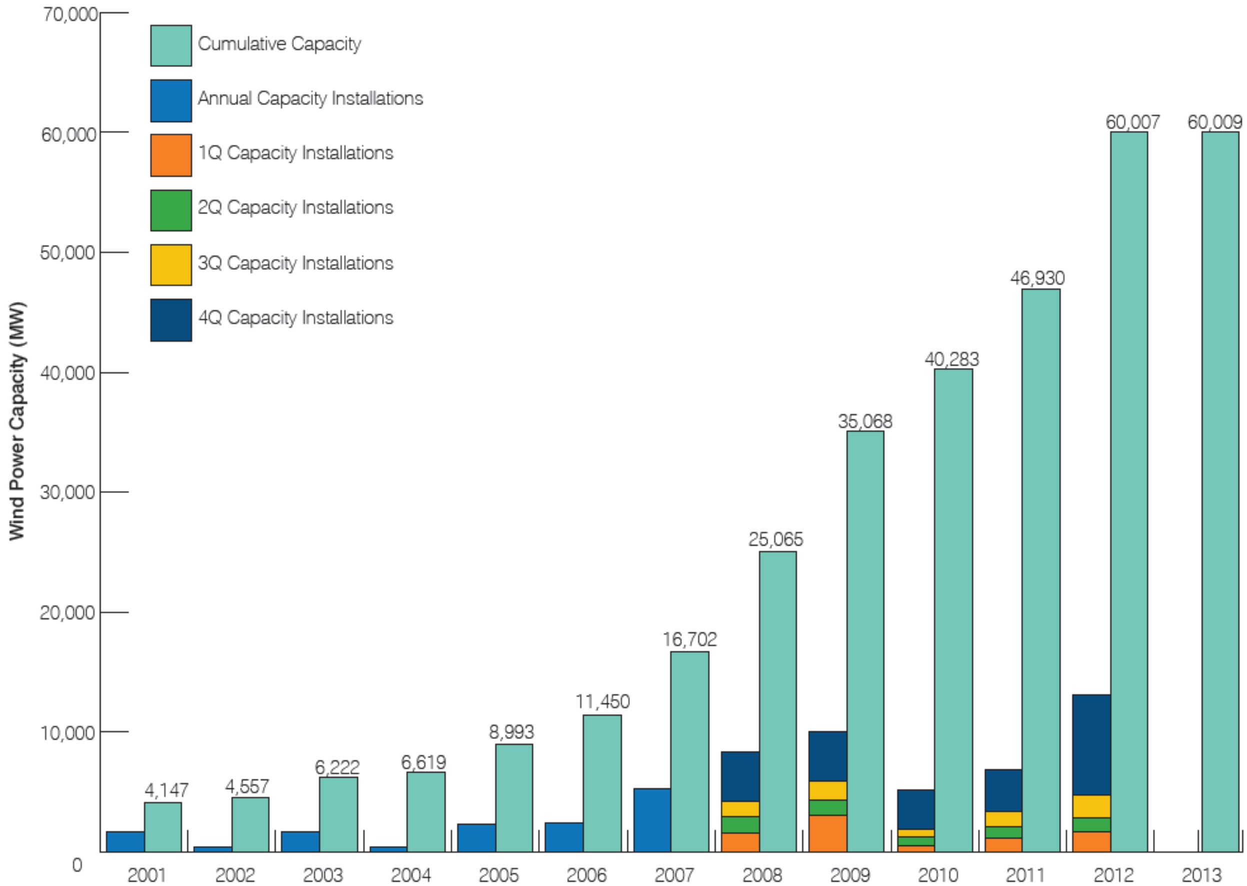


Source: Berkeley Lab, FERC, Ventyx, ICE

Figure 2-5: Average cumulative wind and wholesale electricity prices (Source: EERE [6])

2.3 State of wind energy nationally

Although wind capacity annual installations dropped from 2009 to 2010, annual installed capacity resurged from 6,647 MW in 2011 to 13,077 MW in 2012. According to the American Wind Energy Association (AWEA), the total cumulative installed capacity at the end of April 2013 was 60,009 MW. Despite large capacity additions in the fourth quarter of 2012, only 2 MW of capacity has been installed in the first quarter of 2013 [7]. Figure 2-6 shows the capacity installation from 2001 to the first quarter of 2013. The combined effect of the reduced electricity demand growth due to the recession and the abundance of natural gas from shale formations have kept wholesale electricity prices at a level with which it is difficult for wind to compete.



<u>Figure 2-6:</u> <u>U.S. wind capacity growth</u> (Source: AWEA [7])

Federal and state incentives and state renewable portfolio standards continued to play key roles in the growth in the wind industry. The provisions in the 2009 American Recovery and Reinvestment Act to allow investors to convert the federal production tax credit into a treasury cash grant has been a significant source of capital for the wind industry, offsetting the capital shortage caused by the 2008 financial crisis. Figure 2-7 is a map showing the states that have enacted some form of renewable portfolio standard or set a non-binding goal.

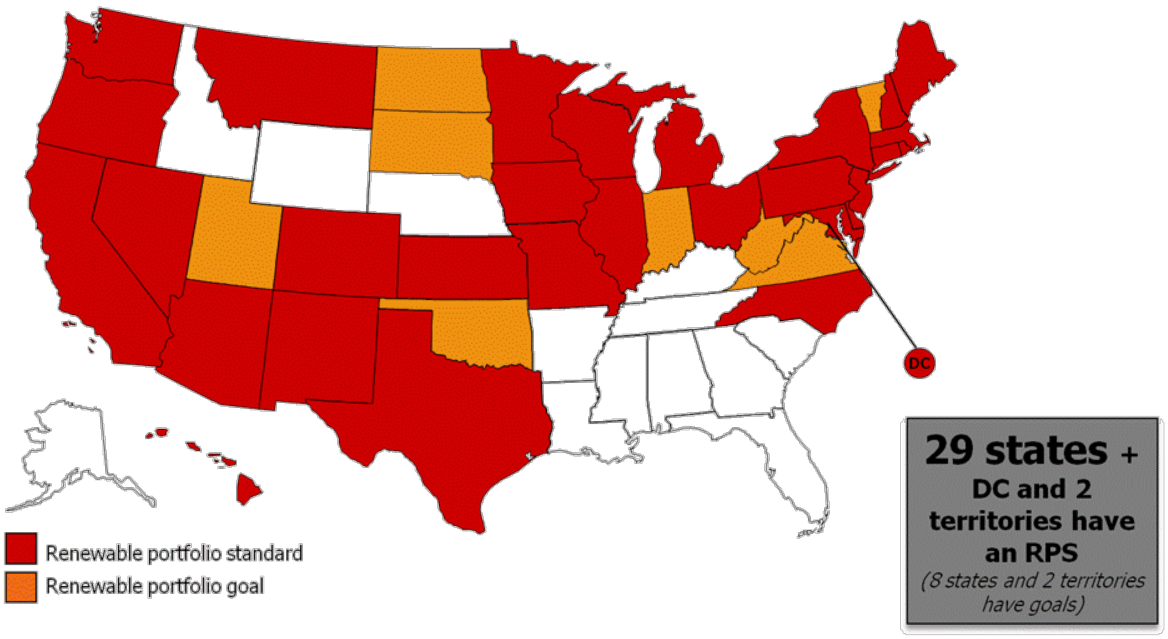


Figure 2-7: Renewable portfolio standards across the U.S. (Source: DSIRE [8])

Figure 2-8 shows the cumulative capacity of wind energy installed in states as of the end of 2012. Texas continued to lead with a total capacity of 12,212 MW installed followed by California with 5,549 MW of cumulative capacity installed. Indiana ranked 13th overall with 1,543 MW of cumulative installed capacity at the end of 2012. In terms of wind capacity added in 2012, Texas led with 1,818 MW followed by California with 1,632 MW added and Iowa with 815 MW added. Indiana added 203 MW of wind energy capacity and ranked 18th in terms of capacity added in 2012 [9].

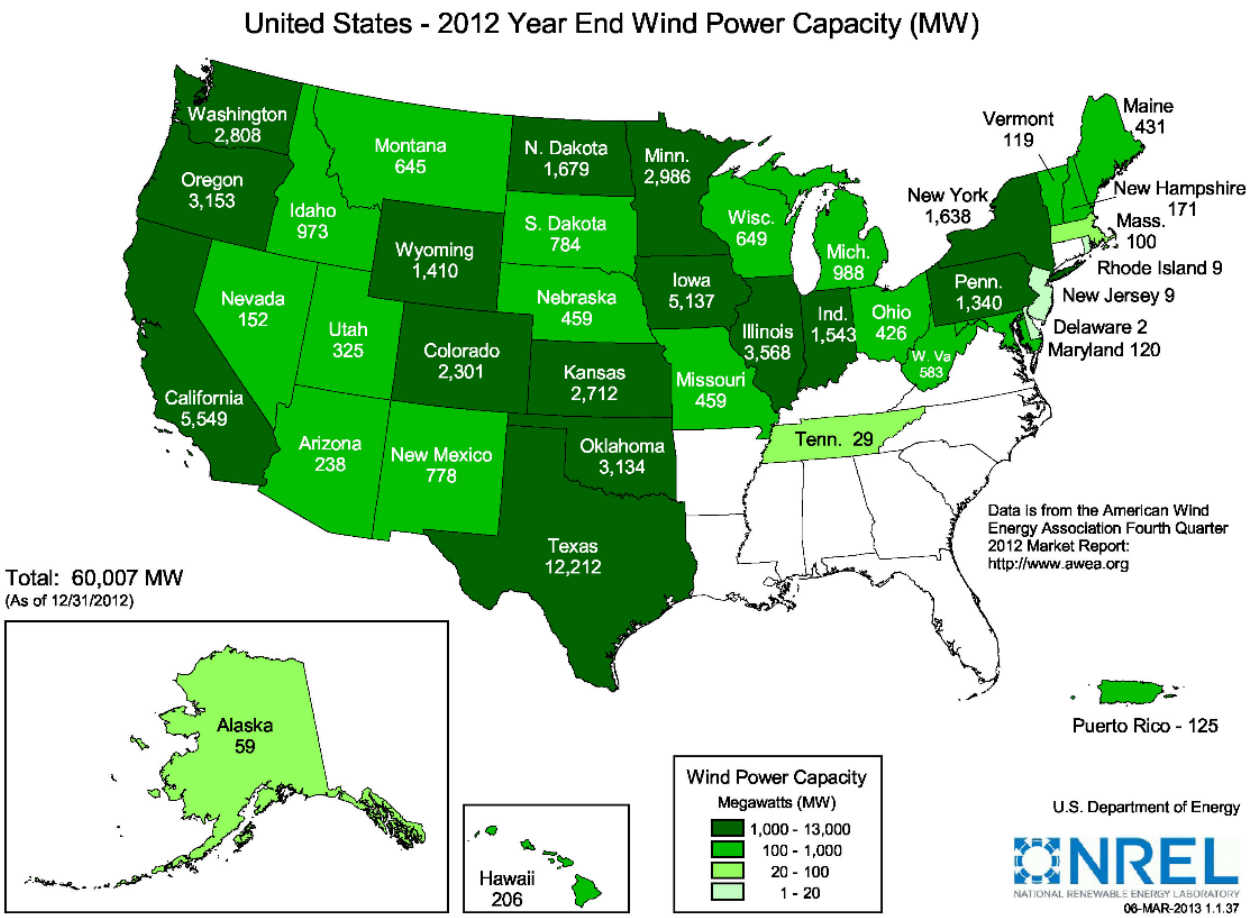


Figure 2-8: Wind power capacity by state at the end of 2012 (MW) (Source: U.S. DOE [10])

With regard to the penetration of wind energy as a percent of the total electricity generated in 2011, the leading five states in wind energy penetration in 2011 are South Dakota –22.3 percent; Iowa – 18.8 percent; North Dakota – 14.7 percent; Minnesota – 12.7 percent; and Wyoming – 10.1 percent. Table 2-2 shows the top twenty states in capacity added in 2011, total cumulative capacity, actual and estimated penetration of wind energy in 2011. Indiana's wind penetration ranks 20th nationally at 2.7 percent of total in-state electricity generation, which was slightly below the U.S. average of 2.9 percent.

Capacity (MW)				Percentage of In-State Generation			
Annual (2011)		Cumulative (end of 2011)		Actual (2011)*		Estimated (end of 2011)**	
California	921	Texas	10,394	South Dakota	22.3%	South Dakota	22.1%
Illinois	692	Iowa	4,322	Iowa	18.8%	Iowa	20.0%
Iowa	647	California	3,917	North Dakota	14.7%	Minnesota	14.9%
Minnesota	542	Illinois	2,742	Minnesota	12.7%	North Dakota	14.1%
Oklahoma	525	Minnesota	2,718	Wyoming	10.1%	Colorado	10.7%
Colorado	506	Washington	2,573	Colorado	9.2%	Oregon	10.5%
Oregon	409	Oregon	2,513	Kansas	8.2%	Idaho	9.7%
Washington	367	Oklahoma	2,007	Idaho	8.2%	Kansas	9.2%
Texas	297	Colorado	1,805	Oregon	8.2%	Oklahoma	9.1%
Idaho	265	North Dakota	1,445	Oklahoma	7.1%	Wyoming	8.8%
Michigan	213	Wyoming	1,412	Texas	6.9%	Texas	7.3%
Kansas	200	New York	1,403	New Mexico	5.4%	Maine	6.5%
Wisconsin	162	Indiana	1,340	Washington	5.3%	New Mexico	5.8%
West Virginia	134	Kansas	1,274	Maine	4.5%	Washington	5.5%
Maine	131	Pennsylvania	789	Montana	4.2%	California	4.7%
New York	129	South Dakota	784	California	4.0%	Montana	3.8%
Nebraska	125	New Mexico	750	Illinois	3.1%	Illinois	3.7%
Utah	102	Wisconsin	631	Hawaii	3.1%	Hawaii	3.7%
Ohio	102	Idaho	618	Nebraska	2.9%	Indiana	3.0%
South Dakota	75	West Virginia	564	Indiana	2.7%	Nebraska	2.9%
Rest of U.S.	274	*Rest of U.S.*	2,915	*Rest of U.S.*	0.4%	*Rest of U.S.*	0.5%
TOTAL	**6,816**	**TOTAL**	**46,916**	**TOTAL**	**2.9%**	**TOTAL**	**3.2%**

* Based on 2011 wind and total generation by state from EIA's *Electric Power Monthly*.

** Based on a projection of wind electricity generation from end-of-2011 wind power capacity, divided by total in-state electricity generation in 2011.

Source: AWEA project database, EIA, Berkeley Lab estimates

Table 2-2: <u>U.S. wind power rankings: Top 20 states</u> (Source: EERE [6])

The U.S. has significant wind energy potential. National Renewable Energy Laboratory (NREL) estimates that the potential rated capacity that could be installed on available windy land areas across U.S. is 10,956,912 MW, and the annual wind energy that could be generated from these potential installed capacities is 38,552,706 GWh. This is approximately 9 times the amount of electricity generated in the U.S. in 2011 from all energy sources. Figure 2-9 shows the distribution of the wind resource.

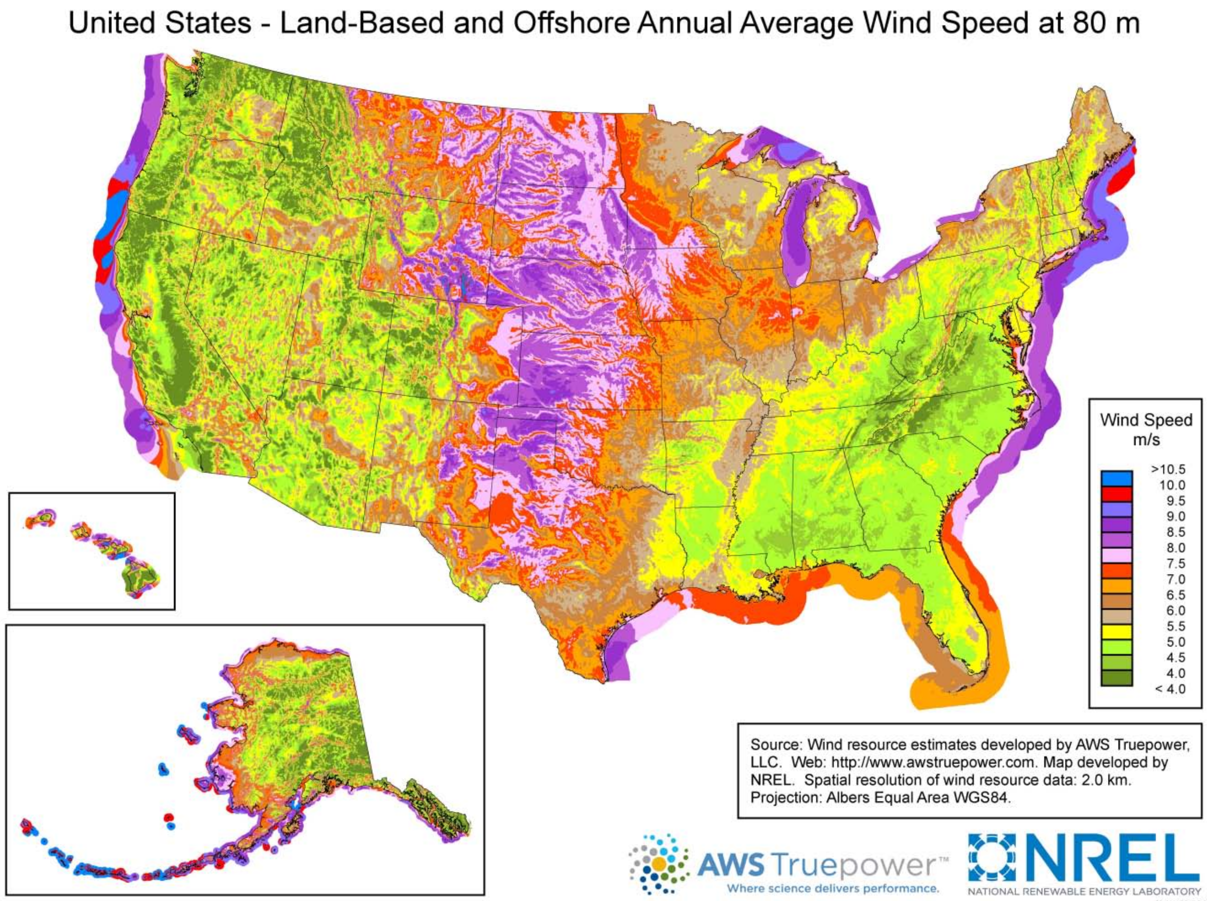


Figure 2-9: <u>80-meter U.S. wind resource map</u> (Source: NREL [11])

As can be seen in Figure 2-9 there is an abundance of wind energy resource along the U.S. coast lines and in the Great Lakes. In addition to offshore wind being typically of higher speed than on land, they also tend to be steadier with less ground interference. So far there has been no offshore wind energy project established in the U.S. The proposed Cape Wind project, the closest to construction among proposed projects, has only recently obtained the necessary federal and state pre-construction permits in a process that has taken over ten years. In addition to resistance from local communities as demonstrated by the vigorous opposition to Cape Wind, the other factors hindering the development of offshore wind energy include its relatively higher cost, the technical challenges associated with installing wind turbines in a marine environment, and challenges associated with connecting the electricity to the on-shore power grid.

The federal government, in a combined effort between DOE and the U.S. Department of the Interior, has launched an effort to lower these barriers and expedite the deployment of substantial offshore wind generation capacity. This effort is explained in a document titled *A National Offshore Wind Strategy: Creating an Offshore Wind Energy Industry in the United States* released in February 2012 [12].

2.4 Wind energy in Indiana

Like the rest of the U.S., Indiana experienced rapid growth of wind generation capacity in 2008 and 2009. The 907 MW annual capacity addition in 2009 fell to additions of 300 MW in 2010 and virtually no capacity additions in 2011 outside small, stand-alone community wind turbines. Figure 2-10 shows the annual and cumulative capacity additions in Indiana. The 203 MW shown for 2012 reflects the completion of the 200 MW Wildcat wind farm in Madison and Tipton counties and three 1 MW projects at schools in Howard, Pulaski and Newton Counties. The 0.1 MW installed in 2013 reflects the completion of the 2 turbine project at Taylor University.

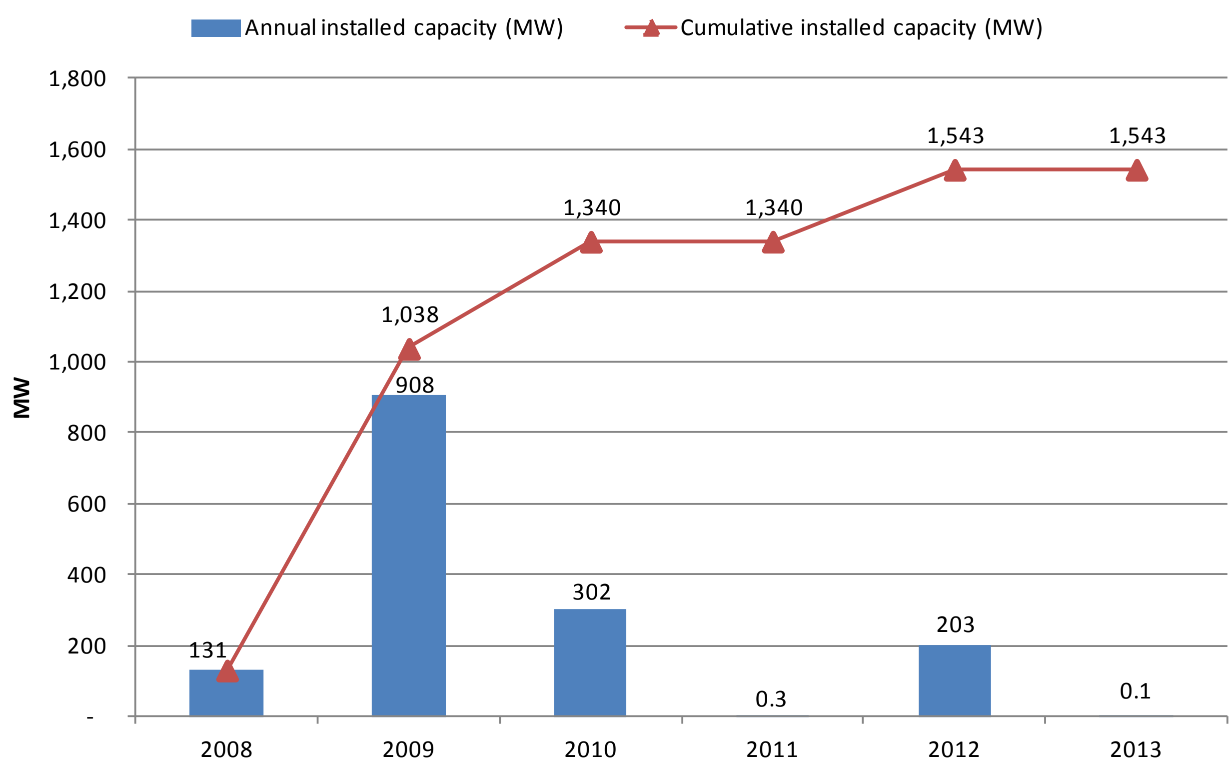


Figure 2-10: Annual wind energy capacity installation in Indiana (Data source: IURC, DOE [13-16]

Table 2-3 shows a list of utility scale wind farms in Indiana. It includes the ten operational wind farms with a combined capacity of 1,537 MW. Four additional wind farms with a combined capacity of 568 MW have been approved by the Indiana Utility Regulatory Commission, while one wind farm, the 200MW second phase of the Wildcat wind farm, was in the application process at the writing of this report.

Project Name	Counties	Capacity (MW)	Developer	Date Completed	Wind Purchaser
Benton County Wind Farm	Benton	131	Orion	2008	Duke (101 MW) Vectren (30 MW)
Fowler Ridge I Wind Farm	Benton	301	BP/Dominion	2009	I&M (100 MW), Dominion (201 MW)
Fowler Ridge II-A Wind Farm	Benton	200	BP/Sempra	2009	AEP (50x3 MW), Vectren (50 MW)
Fowler Ridge III Wind Farm	Benton	99	BP/Sempra	2009	AEP Appalachian (99 MW)
Hoosier Wind Farm	Benton	106	enXco	2009	IPL (106 MW)
Meadow Lake Wind Farm I	White	200	Horizon (EDP)	2009	Wholesale market COMED (50 MW)
Meadow Lake Wind Farm II	White	99	Horizon (EDP)	2010	Wholesale market COMED (25 MW) Ameren (25 MW)
Meadow Lake Wind Farm III	White	104	Horizon (EDP)	2010	Wholesale market Ameren (25 MW)
Meadow Lake Wind Farm IV	White	99	Horizon (EDP)	2010	Wholesale market Ameren (25 MW)
Wildcat Wind Farm I	Madison/ Tipton	200	E.ON	2012	Wholesale market I&M (100 MW)
Approved by Indiana Utility Regulatory Commission (IURC)					
Meadow Lake Wind Farm V	White	101	Horizon (EDP)	Construction currently suspended	
Spartan Wind Farm	Newton	198	Duke Generation Services	Construction not started	
Bluff Point	Jay/ Randolph	119	NextEra	Construction not started	
Fowler Ridge IV Wind Farm	Benton	150	BP/Sempra	Construction not started	
Application in Process at IURC					
Wildcat Wind Farm II	Grant/ Howard	200	E.ON	Application before IURC	

Table 2-3: Status of wind generation projects in Indiana (Data source: IURC [16])

In addition to the utility scale wind farms, community wind projects have been gaining popularity, especially in schools. Table 2-4 is a list of the community wind projects of which SUFG was aware at the writing of this report.

Project Name	County	Capacity (MW)	Developer	Date Completed
Randolph Eastern School Corporation/Union City	Randolph	2	Performance Services	2009
Tippecanoe Valley Schools	Kosciusko	0.9	Performance Services	2010
Lafayette CityBus Headquarters	Tippecanoe	0.3	Cascade Renewable Energy	2011
North Newton School Corporation	Newton	0.9	Performance Services	2012
West Central School Corporation	Pulaski	0.9	Performance Services	2012
Northwestern School Corporation	Howard	0.9	Performance Services	2012
Taylor University	Upland/Grant	0.1	ECI Wind and Solar	2013

Table 2-4: Community wind projects in Indiana (Data source: [13-15])

Indiana utilities have a total 946 MW contracted on power purchase agreements, 526 MW from wind farms in Indiana and 410 MW from out of state wind farms in Illinois, Iowa, Minnesota and South Dakota. Table 2-5 shows the capacity contracted to Indiana utilities.

Utility	Project	State	Power Purchase Agreement (MW)
Duke Energy	Benton County Wind Farm	Indiana	101
Vectren	Benton County Wind Farm	Indiana	30
Vectren	Fowler Ridge Wind Farm II	Indiana	50
Indiana Michigan	Fowler Ridge Wind Farm	Indiana	150
Indiana Michigan	Wildcat Wind Farm	Indiana	100
IPL	Hoosier Wind Farm	Indiana	106
IPL	Lakefield Wind Project	Minnesota	206
NIPSCO	Buffalo Ridge Wind FArm	South Dakota	50
NIPSCO	Barton Windpower	Iowa	50
WVPA	AgriWind	Illinois	8
WVPA	Storey County Wind Farm	Illinois	21
IMPA	Hancock County Wind Farm	Iowa	50
Hoosier Energy	Storey County Wind Farm	Illinois	25

Table 2-5: Wind energy purchase agreements by Indiana utilities (Data source: IURC, AEP, IPL [16-18])

Figure 2-11 shows the distribution of wind energy resources at 100 meters and the location of major transmission lines, the two main factors influencing the location of utility scale wind farms while Figure 2-12 shows the distribution of the wind resource at 50m, a height at which smaller scale community wind projects operate.

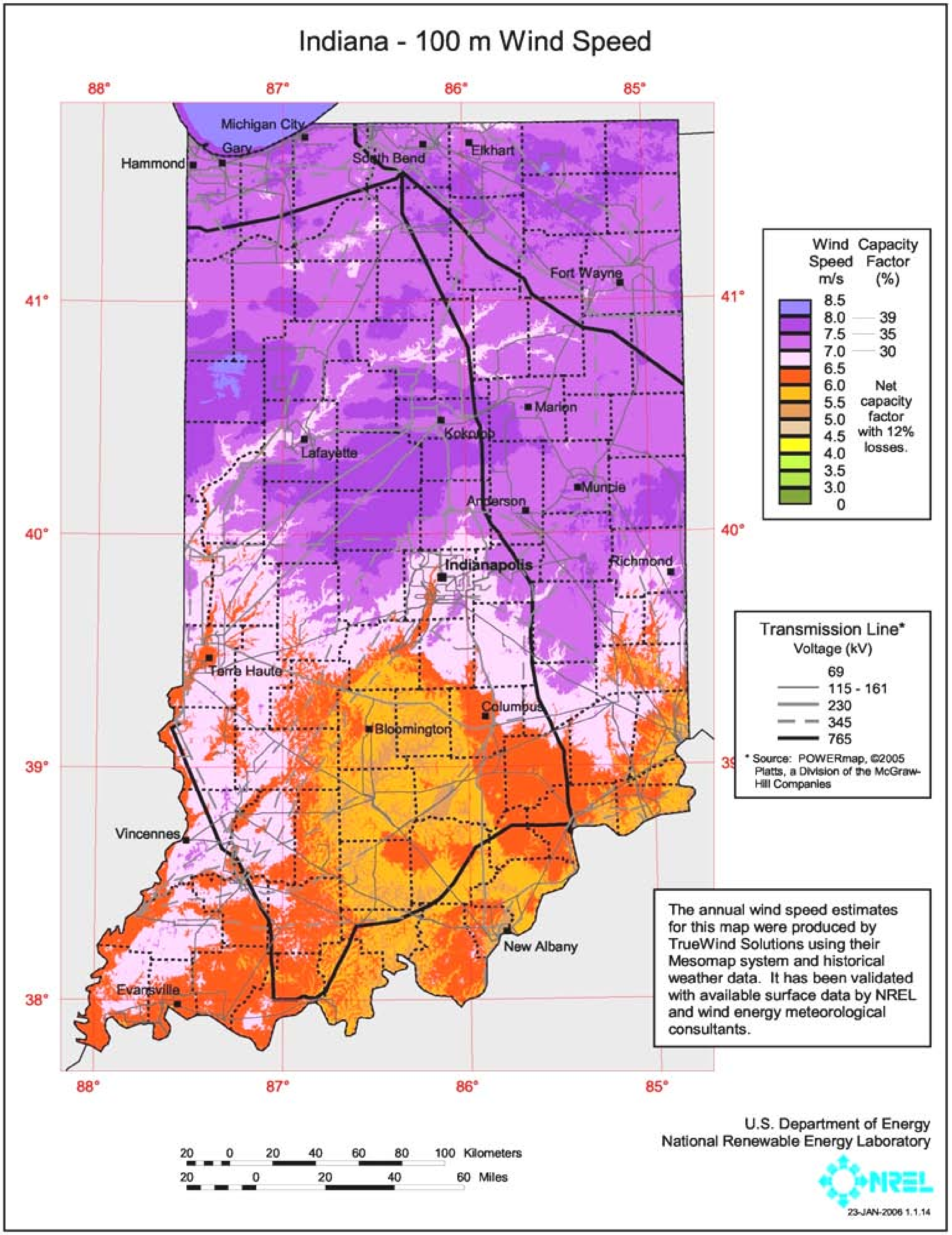


Figure 2-11: Indiana wind speed at 100 meters height (Source: OED/NREL [19])

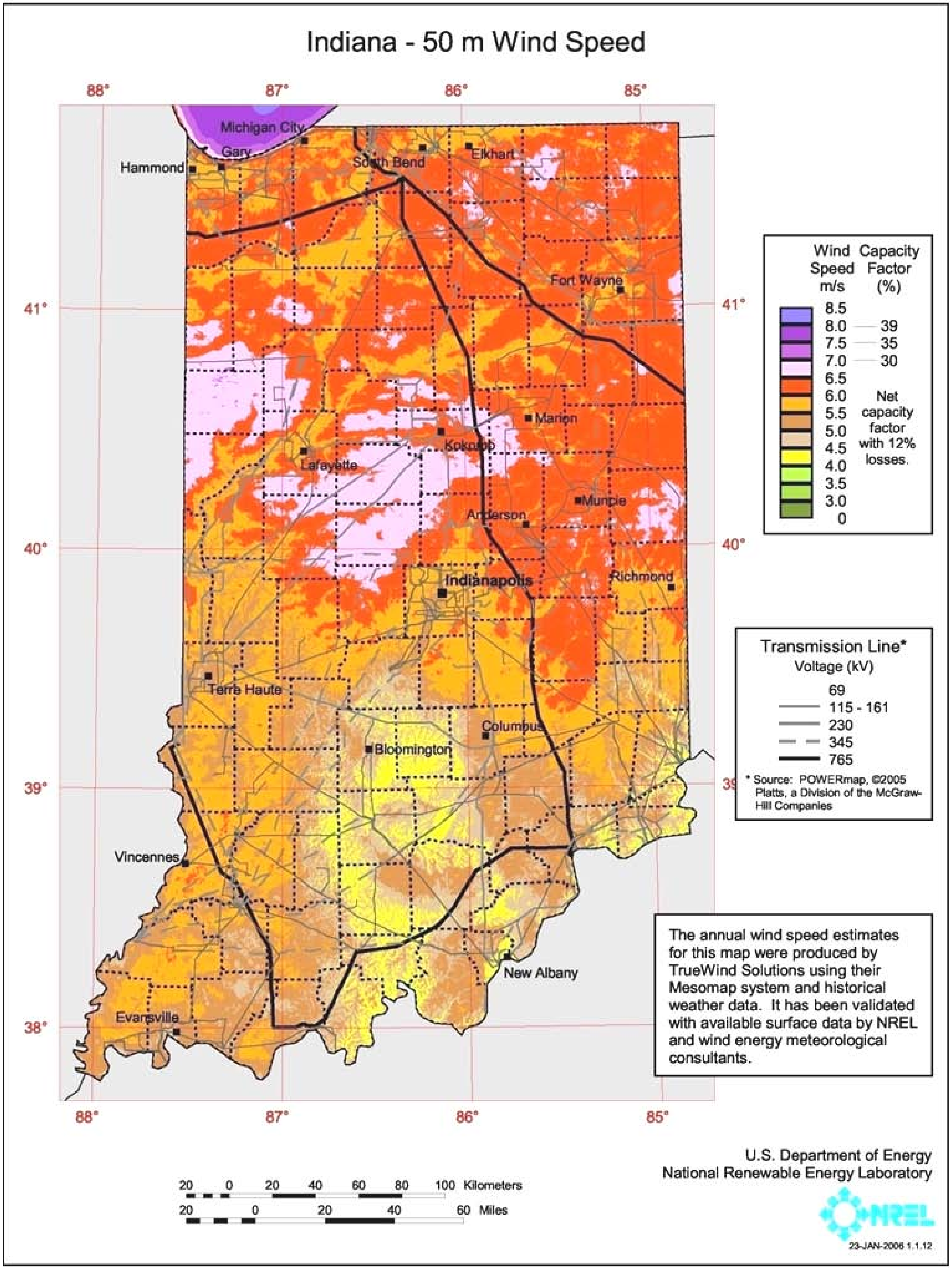


Figure 2-12: Indiana wind speed at 50 meters height (Source: OED/NREL [19])

2.5 Incentives for wind energy

The following federal and state incentives are available for wind energy projects.

Federal Incentives

- Renewable Electricity Production Tax Credit (PTC) credits wind energy producers with 2.3 cents/kWh during the first ten years of operation. The PTC was modified in the February 2009 American Recovery and Reinvestment Act (ARRA) to allow producers who would qualify for the PTC to opt to take the federal business energy investment tax credit (ITC). The PTC is available for projects with a begin-construction deadline of December 31, 2013 [8].
- Business Energy Investment Tax Credit (ITC) credits up to 30 percent of expenditures, with no maximum credit, on qualifying wind energy installations (small wind turbines placed in service after December 31, 2008). Eligible small wind property includes wind turbines up to 100 kW in capacity with an in-service deadline of December 31, 2016. Large scale wind energy systems qualify for the 30 percent credit if construction begins before December 31, 2013, under the provisions made in the 2009 Recovery Act [8].
- U.S. DOE Loan Guarantee Program (Section 1703, Title IV of Energy Policy Act (EPAct) of 2005 provides loan guarantees for large scale innovative renewable energy projects. The program is authorized for $10 billion and focuses on projects costing over $25 million. A supplementary loan guarantee program authorized by the American Recovery and Reinvestment Act of 2009 under Section 1705 of EPAct expired in 2011 [8].
- Modified Accelerated Cost-Recovery System (MACRS) + Bonus Depreciation allows businesses to recover investments in qualified renewable energy technologies through depreciation deductions. A provision for a 50 percent first year bonus depreciation was added by the Stimulus Act of 2008. This provision expires at the end of 2013 [8].
- Qualified Energy Conservation Bonds (QECBs) are qualified tax credit bonds that are allocated to each state based upon the state's percentage of the U.S. population. The states are then required to allocate a certain percentage to "large local governments." Qualified energy conservation projects include renewable energy production projects [8].
- Residential Energy Conservation Subsidy Exclusion established by Section 136 of the IRS Code, makes direct and indirect energy conservation subsidies provided by public utilities nontaxable. Eligible technologies include PV, solar water heating and solar space heating [8].
- Rural Energy for America Program (REAP) promotes energy efficiency and renewable energy for agricultural producers and rural small businesses through the use of grants and loan guarantees for energy efficiency improvements and renewable energy systems. The program covers up to 25 percent of costs [8].

- High Energy Cost Grant Program administered by USDA is aimed at improving the electricity supply infrastructure in rural areas having home energy costs exceeding 275 percent of the national average. Eligible infrastructure includes renewable resources generation. USDA has allocated $21 million for the 2011 funding cycle [8].
- Energy Efficiency Mortgage program provides mortgages that can be used by homeowners to finance a variety of energy efficiency measures, including renewable energy technologies, in a new or existing home. The federal government supports these loans by insuring them through FHA or VA programs. This allows borrowers who might otherwise be denied loans to pursue energy efficient improvements, and it secures lenders against loan default, providing them confidence in lending to customers whom they would deny without the federal insurance [8].
- Residential Renewable Energy Tax Credit allows taxpayers to claim 30 percent of their qualifying expenditures on installation of renewable energy technologies including solar electric systems, solar water heaters, wind turbines and geothermal heat pumps [8].
- Green Power Purchasing Goal requires a minimum amount of the electric energy consumed by the federal government during any fiscal year to be from renewable sources. From 2013 forward this goal is 7.5 percent. The amount of renewable-energy credit is doubled for electricity produced and used on-site at a federal facility, produced on federal lands and used at a federal facility, or produced on Native American land [8].

Indiana Incentives

- Net Metering Rule allows utility customers with renewable resource facilities having a maximum capacity of 1 MW to receive a credit for net excess generation in the next billing cycle [8].
- Renewable Energy Property Tax Exemption provides property tax exemptions for solar thermal, PV, wind, hydroelectric and geothermal systems [8].
- Emissions Credits allow electricity generators that do not emit nitrogen oxides (NO_x) and that displace utility generation eligible to receive NO_x emissions credits under the Indiana Clean Energy Credit Program [20].
- Community Conservation Challenge Grant provides $25,000-$250,000 in grants for community energy conservation projects located in Indiana using commercially-available technologies. Projects include improving energy efficiency, renewable energy, reduction in energy demand or fuel consumption, and energy recycling. Projects must be public and have at least one community partner [8, 21].
- Sales and Use Tax Exemption for Electrical Generating Equipment exempts transactions involving manufacturing machinery, tools, and equipment used for the production of tangible personal property from state gross retail tax. This includes renewable generation equipment [8].

- Clean Energy Portfolio Goal sets a voluntary goal of obtaining 4 percent between 2013 and 2018, 7 percent between 2019 and 2024, and 10 percent by 2025, of electricity from clean energy sources based on 2010 retail sales. Participation in the goal makes utilities eligible for incentives that can be used to pay for the compliance projects [22].
- Indianapolis Power & Light - Small-Scale Renewable Energy Incentive Program provides incentive payments of $1 per watt of wind generation and $2 per watt of photovoltaic generation with a maximum incentive payment of $4,000 for systems between 1 and 49.9 kW for wind and 1 and 19 kW for photovoltaic [8, 23].
- Northern Indiana Public Service Company offers feed-in tariff incentive rates for electricity generated from renewable resources for up to 15 years. The payments for electricity from wind generating facilities are $0.17/kWh for facilities with a capacity less than or equal to 100 kW and $0.10/kW for facilities with capacities between 101 and 2,000 kW. The renewable tariff is experimental and slated to run until December 31, 2013. The generating unit size allowed under the tariff is between 5 and 5,000 kW while the total allowed system-wide capacity is 30 MW. Five hundred kilowatts of the system-wide cap are reserved for wind projects of capacity less than 10 kW, and 500 kW for solar projects of capacity less than 10 kW [8, 24].

2.6 References

1. Alternative Energy News. http://www.alternative-energy-news.info/technology/wind-power/wind-turbines/
2. Wind Powering America. NREL. Wind energy update, January 2012. http://www.windpoweringamerica.gov/pdfs/wpa/wpa_update.pdf
3. Renewable Energy Research Laboratory. University of Massachusetts at Amherst. Wind power: Capacity factor, intermittency, and what happens when the wind doesn't blow? http://www.umass.edu/windenergy/publications/published/communityWindFactSheets/RERL_Fact_Sheet_2a_Capacity_Factor.pdf
4. Renewable Resource Data Center. NREL. Wind energy resource atlas of the United States. http://rredc.nrel.gov/wind/pubs/atlas/appendix_A.html#wind
5. Renewable Resource Data Center. NREL. Wind energy resource atlas of the United States, Table 1-1. http://rredc.nrel.gov/wind/pubs/atlas/tables/1-1T.html
6. Department of Energy Office of Energy Efficiency and Renewable Energy (EERE). 2011 Wind technologies market report. http://www1.eere.energy.gov/wind/pdfs/2011_wind_technologies_market_report.pdf
7. AWEA. U.S. Wind industry first quarter 2013 market report. http://www.awea.org/learnabout/publications/reports/AWEA-US-Wind-Industry-Market-Reports.cfm; http://www.awea.org/learnabout/publications/reports/upload/AWEA-US-Wind-Industry-1Q-2013-Market-Report_Executive-Summary.pdf
8. Database of State Incentives for Renewables & Efficiency (DSIRE). http://www.dsireusa.org/
9. U.S. Department of Energy, Wind Powering America. Installed Wind Capacity 2012. http://www.windpoweringamerica.gov/wind_installed_capacity.asp

10. U.S. DOE. Wind Powering America. Installed Wind Capacity. http://www.windpoweringamerica.gov/wind_installed_capacity.asp
11. NREL. Wind maps. http://www.nrel.gov/gis/wind.html
12. EERE. A national offshore wind strategy: creating an offshore wind industry in the United States. http://www1.eere.energy.gov/wind/pdfs/national_offshore_wind_strategy.pdf
13. Cascade Renewable Energy. CityBus Headquarters Wind Project. http://www.cascaderenewableenergy.com/projects/citybus-wind
14. Performance Services Corporation. http://www.performanceservices.com/services/wind_power/Community_wind_project
15. DOE, Wind Powering America Program. School wind project locations. http://www.windpoweringamerica.gov/schools/projects.asp
16. George Stevens. Indiana Utility Regulatory Commission.
17. American Electric Power. http://www.aep.com/environment/climatechange/docs/WindEnergyPowerPurchaseAgreements.pdf
18. Indianapolis Power & Light. http://www.iplpower.com/content.aspx?id=719
19. Indiana Office of Energy Development. Indiana wind maps & reports. http://www.in.gov/oed/2425.htm
20. Indiana Department of Environmental Management. Clean Energy Credit. http://www.in.gov/idem/4134.htm
21. Indiana Office of Energy Development. Community Conservation Challenge. http://energy.gov/savings/community-conservation-challenge
22. Indiana's CHOICE Program. http://www.in.gov/oed/2649.htm
23. Indianapolis Power and Light Company. Small Scale Renewable Energy Incentive Program. http://www.iplpower.com/Residential/Home_Energy_Savings/Renewable_Energy_Incentive_Program.aspx
24. Northern Indiana Public Service Company. http://www.nipsco.com/en/about-us/Rates-Tariffs/electric-service-tariff-122711.aspx

3. Dedicated Energy Crops

3.1 Introduction

This section discusses biomass in the form of crops grown exclusively for use as a source of energy. Biomass in the form of organic wastes and residues as sources of energy is presented in the section that follows (Section 4).

Unlike the use of organic wastes as an energy source, the dedicated energy crop industry in the U.S. is still in its infancy. A substantial federally-driven research and development effort is under way as part of the national effort to reduce dependence on imported oil. This research effort is detailed in the DOE report titled *U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry* [1]. One of the main factors that make biomass an attractive renewable resource is its ability to be used as a feedstock for both electricity generation and transportation fuels. The crops being considered and developed as dedicated energy crops can be grouped into three main categories – perennial grasses, woody crops and annual crops.

<u>Perennial grasses</u> include switchgrass, big bluestem, Indian grass, miscanthus and sugarcane. Switchgrass, big bluestem, and Indian grass are perennial grasses that are native to North America. They are already grown in a wide range of habitats and climates for pasture, hay production, soil and water conservation, and for wildlife habitat. With proper management they can remain productive for as long as ten years. Figure 3-1 shows switchgrass on a farm in Tennessee.

The Giant Miscanthus hybrid was developed in Japan and introduced to the U.S. as a landscape plant. The main attraction of Giant Miscanthus as an energy crop is its high level of biomass production. While a great deal of research has been done establishing its potential as an energy crop, there are still barriers to overcome before it can enter large scale commercial production. They include the development of low-cost reliable propagation methods since it is a seedless sterile hybrid. In addition there is still work to be done to identify types suited to given regions of the country.

Figure 3-1: Switchgrass (Source: University of Tennessee [2])

Sugarcane is attractive as an energy crop primarily due to its ability to store sugar (sucrose) in its stem. In addition, sugarcane ethanol is used as a fuel and is recognized to cut greenhouse gas emissions more than any other biofuel. However, sugarcane is a tropical crop and significant research work is still to be done to develop varieties that do well in temperate climates.

Woody crops being developed as energy crops include poplars, willows, eucalyptus and southern pines. Poplars are well established trees native to North America. There are already commercial plantations of hybrid poplars (cottonwood) for the production of fiber, biofuels and for environmental remediation. High rates of biomass productivity, ease of propagation and management are cited as factors that make poplar attractive as an energy crop. The characteristics that make willows desirable as energy crops include high yields, ease of propagation and high energy content. Eucalyptus is being developed for the southern United States where it is grown for lumber. It has been grown commercially for lumber in Florida since the 1960s.

Southern pines are already one of the main contributors to bioenergy in the United States. Their barks and the paper processing byproduct *black liquor* are used to produce energy in pulp and paper mills.

Their ability to grow rapidly in a wide range of sites have made the southern pine the most important and widely cultivated timber species in the U.S., mainly for lumber and pulpwood.

The one annual crop being developed as an energy crop is sorghum. According to the DOE Biomass Program, although perennial crops are considered better than annual crops for energy production sustainability purposes, an annual crop serves well as a bridge for a new bioenergy processing facility as it awaits the establishment and full productivity of perennial crops. The factors that make sorghum attractive as an energy crop include its composition and high yield potential, drought resistance, water use efficiency, established production systems, and potential for genetic improvement [1].

Biomass, including energy crops, can be converted into energy in the following ways:

- In direct combustion the biomass is burned directly in a boiler to produce steam that can then be used to drive a turbine to generate electricity. Combustion can be done either in a dedicated biomass-only boiler or cofired with other fuels such as coal. Cofiring of biomass in coal boilers has the advantage of lowering the emission of sulfur oxides (SOx), nitrogen oxides (NOx) and net lifecycle carbon. However, the widespread application of cofiring with coal has been hindered by the occurrence of alkali deposits that cause slag and corrosion in boiler heat transfer surfaces in the coal boilers [3].

- In biochemical conversion processes the biomass material is broken down into sugars using either enzymes or chemical processes. These sugars are then fermented to make ethanol [4].

- In thermochemical conversion heat is used to break down the biomass material into intermediate products (synthetic gas) which can then be converted into fuels using heat, pressure and catalysts. Two common thermochemical processes are gasification and pyrolysis. Gasification is a high temperature conversion of solids into a flammable mixture of gases. Pyrolysis is a process of thermal decomposition of biomass at high temperatures in the absence of oxygen into charcoal, bio-oil and synthetic gas [5].

To take full advantage of the strengths of the different biomass-to-energy conversion processes, the DOE Biomass Program is funding the construction of integrated biorefineries that combine all processes in one plant and produce multiple products. By producing multiple products, the integrated biorefineries, like refineries in the petroleum industry, will be able to take advantage of the differences in feedstocks and intermediate products to maximize the value obtained from the biomass feedstock.

There are currently 25 DOE funded integrated biorefinery related projects spread across the United States working to develop the various bio-processing technologies needed.

Twelve of these are small scale pilot projects with a capacity of one dry ton of biomass per day. These pilot plants screen and validate promising bio-processing technologies. Six of the biorefineries are demonstration plants where the technologies validated at the pilot plants are scaled up to produce at the scale of at least 50 dry tons of feedstock a day. In the five commercial-scale projects currently under construction the bio-processing technologies are scaled up to process at least 700 dry tons of feedstock a day. Table 3-1 is list of integrated biorefinery projects [6].

Project	Location	Scale	Conversion Technology
Abengoa	Hugoton, KS	Commercial	Biochemical
BlueFire Renewables Inc.	Fulton, MS	Commercial	Biochemical
Mascoma	Kinross, MI	Commercial	Biochemical
Abengoa	Hugoton, KS	Commercial	Biochemical
POET/DSM Advanced Biofuels, LLC	Emmetsburg, IA	Commercial	Biochemical
Verenium	Jennings, LA	Demo	Biochemical
Enerkem	Pontotoc, MS	Demo	Thermo - Gasification
INEOS Bio/New Planet Bioenergy	Vero Beach, FL	Demo	Hybrid
Myriant	Lake Providence, LA	Demo	Biochemical
Red Shield Acquisition, LLC (RSA)	Old Town, ME	Demo	Biochemical
Sapphire Energy, Inc.	Columbus, NM	Demo	Algae
Algenol Biofuels, Inc	Fort Myers, FL	Pilot	Algae
American Process, Inc. (API)	Alpena, MI	Pilot	Biochemical
Amyris, Inc.	Emeryville, CA	Pilot	Biochemical
Archer Daniels Midland (ADM)	Decatur, IL	Pilot	Biochemical
Haldor Topsoe, Inc.	Des Plaines, IL	Pilot	Thermo - Gasification
ICM, Inc.	St. Joseph, MO	Pilot	Biochemical
Logos/Edeniq Technologies	Visalia, CA	Pilot	Biochemical
Renewable Energy Institute International (REII)	Toledo, OH	Pilot	Thermo - Gasification
Rentech ClearFuels	Commerce City, CO	Pilot	Thermo - Gasification
Solazyme, Inc.	Peoria, IL	Pilot	Algae
UOP, LLC	Kapolei, HI	Pilot	Thermo - Pyrolysis
ZeaChem, Inc.	Boardman, OR	Pilot	Thermo - Pyrolysis
Gas Technology Institute (GTI)	Des Plaines, IL	Design Only	Thermo - Pyrolysis
Elevance	Newton, IA	Design Only	Chemical

Table 3-1: DOE funded integrated biorefinery projects (Source: DOE [6])

3.2 Economics of energy crops

For large scale production of dedicated energy crops to occur, the price and profitability of the energy crops will have to be competitive with the current crops and other cropland uses. DOE, in the *Billion-Ton Update* report, used the U.S. agricultural sector simulation model (POLYSYS) to estimate the quantities of the various energy crops that would be produced at various prices. The POLYSYS model is a detailed model of the U.S. agricultural sector that includes crop supply at the county level, national crop demand and prices, national livestock demand and prices, and agricultural income.

Three types of energy crops are modeled in the POLYSYS simulation for the results presented in the *Billion-Ton Update* report – a perennial grass, an annual energy crop and two types of short rotation woody crops, one that is rotated by coppicing[3] (e.g. willows) and one by other non-coppicing methods (e.g. poplars). The perennial grass and the non-coppicing woody crop were modeled for 10 year rotations and the coppicing wood for 20 year rotations with cuttings every 4 years.

Figure 3-2 shows the quantities of the three energy crops expected to be produced at farmgate prices $40, $50 and $60 per dry ton in 2017, 2022 and 2030. Figure 3-3 shows the supply curves for total quantity of energy crop, i.e. all energy crops combined, expected to be produced in 2017, 2022, and 2030. According to the *Billion-Ton Update* report the projected total biomass production (energy crops, agricultural and forest residues, and dual use crops) at $60 per dry ton is adequate to meet both the mandate of the Renewable Fuel Standard (36 billion gallons of biofuels by 2022) and the "billion-ton" goal of replacing 30 percent of U.S. petroleum consumption by 2030.

[3] Coppicing is a method of woody crop management that takes advantage of the property that some plants such as willows have where new growth occurs from the stump or roots when the plant is cut down.

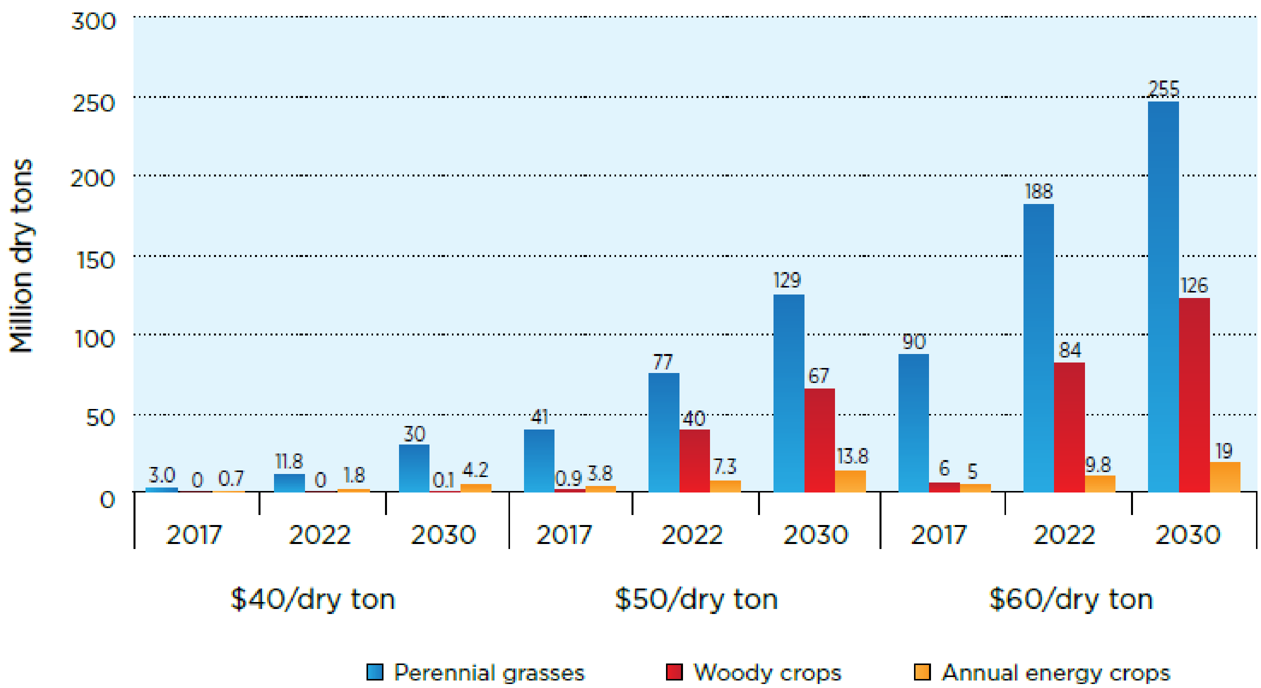


Figure 3-2: Potential production of energy crops at various years and farmgate prices (Source: DOE [1])

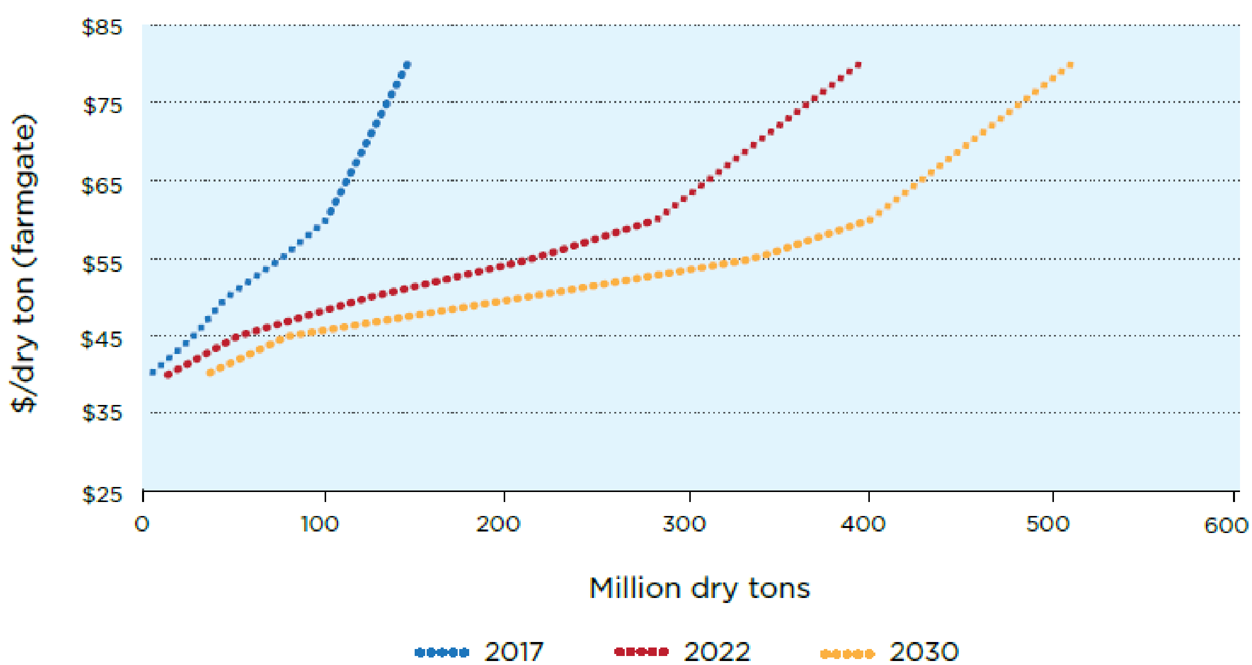


Figure 3-3: Supply curves for all energy crops at selected years (Source: DOE [1])

Corn and soybean use for biofuel production

Although corn and soybeans do not meet the strict definition of dedicated energy crops, they are included in this section in recognition of their being the largest source of renewable energy in Indiana. The ethanol and diesel biofuels experienced a rapid expansion in the mid-2000s. Before 2007 Indiana's ethanol production capacity consisted of one plant with a capacity of 100 million gallons per year (MGY). Since then twelve corn-ethanol plants with a combined capacity of 768 MGY have been constructed, bringing the total corn-ethanol capacity to 868 MGY. Towards the end of the 2000s the production of corn ethanol started outpacing the demand due to the weakened demand for gasoline associated with the recession. This has resulted in the idling and shutting down of ethanol plants in Indiana and all across the U.S. Among those plants in Indiana idled or shut down are the lone pre-2007 New Energy Corporation plant in South Bend (100 MGY). The other two are the Valero Energy plant in Linden (100 MGY) and the Aventine Renewable plant in Mount Vernon (220 MGY). The capacity of the remaining ten active corn ethanol plants is 768 MGY. Table 3-2 shows the location and capacities of ethanol plants in Indiana.

Table 3-3 shows the location and capacities of the three Indiana biodiesel plants. One of them, the E-biofuels plant in Middletown is currently not producing, leaving a total 91 MGY biodiesel capacity currently operational in Indiana in two plants.

The following factors account for the biofuel plant construction in the U.S. since 2005.

- The use of corn-ethanol as an oxygenating additive in gasoline in place of the chemical MTBE. The shift from MTBE was due to its being associated with ground water pollution. The replacement of MTBE was mandated both by states and the 2005 Energy Policy Act [7].
- The enactment of the renewable fuel standard under the 2005 Energy Policy Act that required that 7.5 billion gallons of renewable fuel must be blended into gasoline by 2012. This has since been expanded to a requirement of 36 billion gallons of renewable fuel by 2022 (15 billion gallons from corn-ethanol and the balance from advanced biofuels) [8].
- The enactment of the volumetric ethanol excise tax credit (VEETC) in 2004 improved the cost competitiveness of corn-ethanol with gasoline and provided long-term protection for corn-ethanol producers against price volatility in the transportation fuel market. The VEETC allowed for a 45 cents/gallon tax credit to be given to individuals who produce the mixture of gasoline and ethanol. This tax credit expired at the end of 2011.

Company	Year	Town/County	Current Capacity (MGY*)
New Energy Corp (no longer producing)	1985	South Bend/St. Joseph	100 (potential when producing)
Central Indiana Ethanol	2007	Marion/Grant	40
Iroquois Bio-Energy Co.	2007	Rensselaer/Jasper	40
POET Biorefining	2007	Portland/Jay	65
The Andersons	2007	Clymers/Cass	110
Valero Energy (no longer producing)	2007	Linden/Montgomery	100 (potential when producing)
POET Biorefining	2011	Cloverdale/Putman	90
Cardinal Ethanol	2008	Harrisville/Randolph	100
Indiana Bio-Energy	2008	Bluffton/Wells	110
POET Energy	2008	Alexandria/Madison	60
POET Energy	2008	North Manchester/Wabash	65
Abengoa Bioenergy Indiana	2009	Mt. Vernon/Posey	88
Aventine Renewable (no longer producing)	2011	Mt. Vernon/Posey	220 (potential when producing)

*MGY denotes million gallons per year.

Table 3-2: Ethanol plants in Indiana (Source: Indiana State Department of Agriculture (ISDA) [9])

Biodiesel plant Name	Year	Town/County	Estimated Capacity (MGY)
E-biofuels (not producing)	2007	Middletown/Henry	10
Integrity Biofuels	2006	Morristown/Shelby	5
Louis Dreyfus	2007	Claypool/Kosciusko	88

Table 3-3: Biodiesel plants in Indiana (Data source: ISDA [9])

3.3 State of energy crops nationally

As discussed previously, the energy crop industry is still in its infancy with a substantial research and development effort under way to establish a sustainable supply of biomass to satisfy the Renewable Fuel Standard mandate of 36 billion gallons of biofuels for the transportation industry per year by 2022 and also increase electricity generation from biomass.

As part of this research, DOE has partnered with universities, national laboratories and the U.S. Department of Agriculture to establish a *Regional Biomass Feedstock Partnership* to conduct research, development and outreach at the regional level to address the barriers associated with the effort to establish a sustainable bioenergy industry. Figure 3-4 shows the biomass feedstock field trial locations established by the *Regional Biomass Feedstock Partnership*.

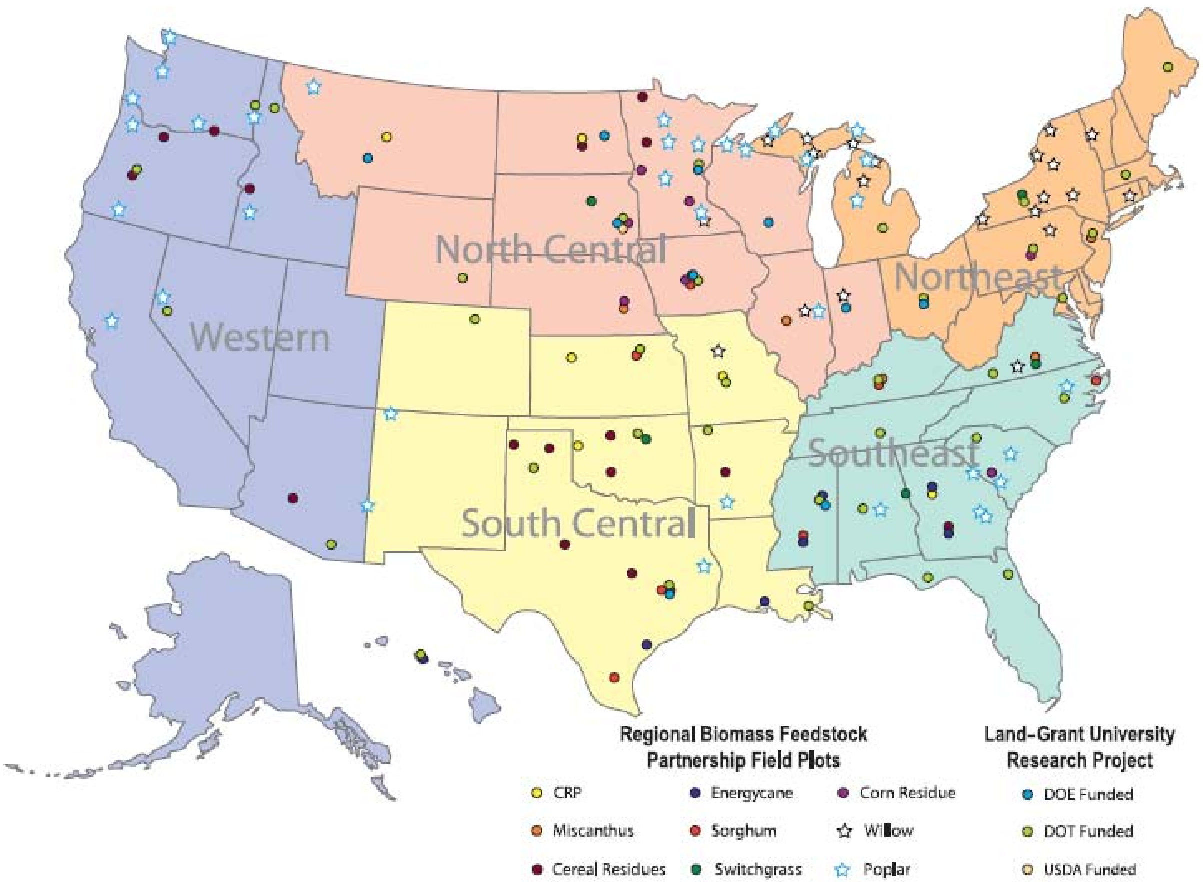


Figure 3-4: 2011 energy crop test stations (Source DOE [10])

In addition to the field test sites the *Regional Biomass Feedstock Partnership* is also involved in education and outreach efforts to farmers and other stakeholders to prepare them for a future where energy crops are a substantial portion of the agricultural industry. The lead institutions for the five regions in the program are: South Dakota State University in the North Central region, Oregon State University in the Western region, Oklahoma State University in the South Central region, Cornell University in the Northeast, and University of Tennessee in the Southeast region [11].

3.4 Energy crops in Indiana

The results from the DOE *Billion-Ton* model show Indiana and other corn-belt states such as Iowa and Illinois being major producers of agricultural crop residues such as corn stover and only a limited amount of energy crops. Figure 3-5 shows the projected pattern of biomass feedstock production by the year 2030 at biomass farmgate price of $60 per dry ton.

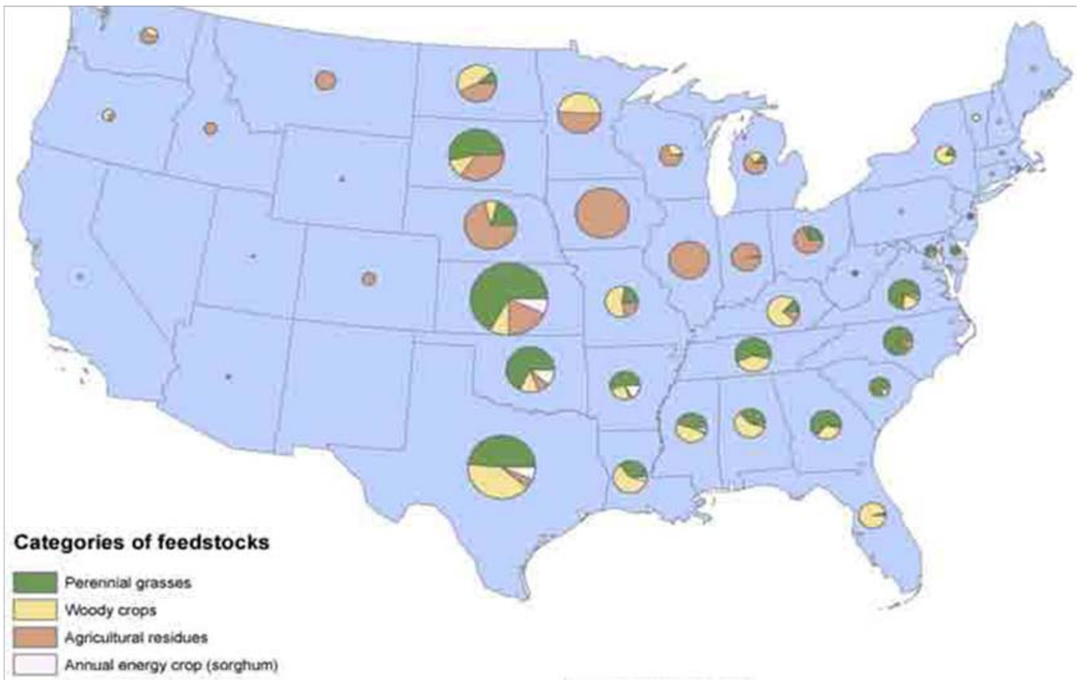


Figure 3-5: Estimated shares of energy crops and agricultural residues supplied at $60 per dry ton in 2030 (Source: DOE [1])

Figure 3-6 shows the quantities of energy crops projected to be produced in Indiana in 2030 at a biomass farmgate price of $50, $60, $70 and $80 per dry ton. At a biomass price of $60 per dry ton, Indiana's projected production of all energy crops combined is 1.5 million dry tons. In comparison, the amount of agricultural residue biomass produced at $60 per dry ton in 2030 is projected to be 9 million dry tons. As can be seen in the figure, perennial grasses are the preferred energy crop in Indiana, followed by woody crops. At prices above $70 per dry ton some annual crops (e.g., sorghum) enter into the crop mix.

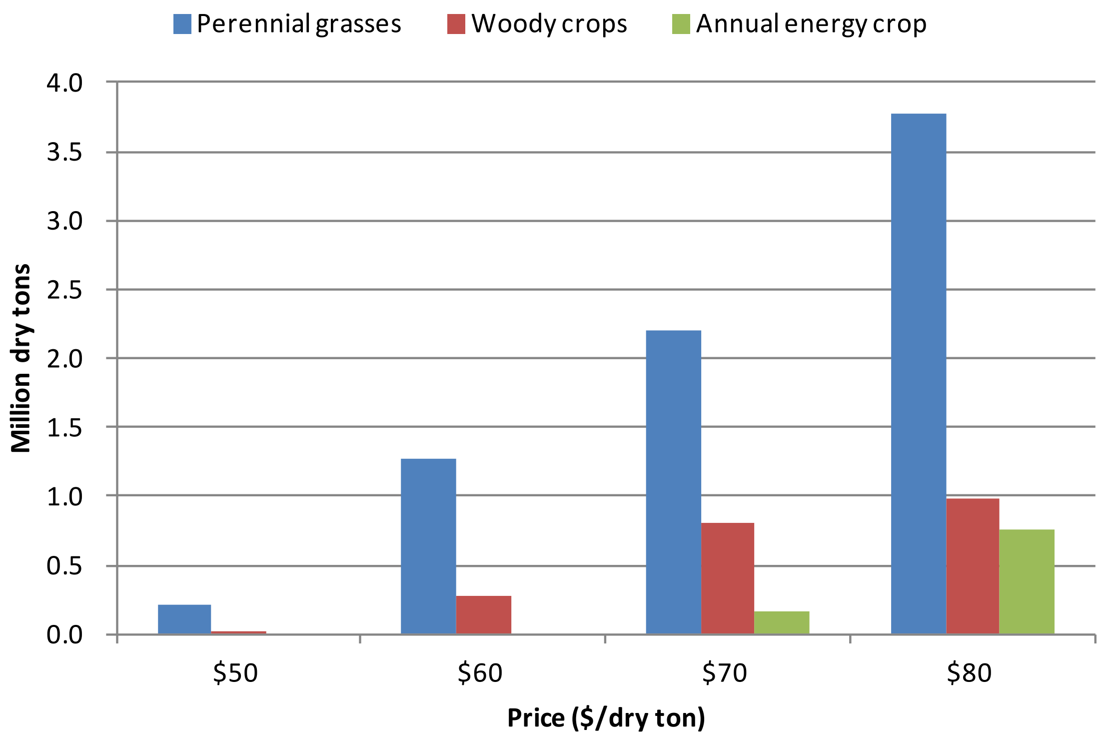


Figure 3-6: Projected production of energy crops in Indiana in 2030 (Data source: DOE [12])

In an April 2008 working paper, Brechbill and Tyner of Purdue's Agricultural Economics Department did an extensive study of the estimated cost of producing switchgrass and harvesting corn stover for the energy industry. Table 3-4 shows the average cost of producing switchgrass given in this study. The table includes the farmer's choice to either: purchase and own the harvesting equipment or hire the services of a specialized custom operator.

	500 acre farm	**1,000 acre farm**	**1,500 Acre farm**	**2,000 acre farm**
Custom hired equipment	$53.23	$53.23	$53.23	$53.23
Owned equipment	$54.54	$52.43	$51.73	$51.38

Table 3-4: Average cost ($/ton) for producing switchgrass in Indiana (Data source: Brechbill & Tyner [13])

Mr. Allen, in his December 2011 Master Thesis, estimated the cost of producing and transporting biomass from woody crops to be between $43 and $52 per dry ton [14].

3.5 Incentives for energy crops

The following incentives have been available to assist in the use of energy crops.

Federal Incentives

- Renewable Electricity Production Tax Credit (PTC) provides a 2.3 cents/kWh tax credit for closed-loop biomass and 1.1 cents/kWh for open-loop biomass, landfill gas municipal solid waste energy technologies. Dedicated energy crops fall under the closed loop biomass category. As part of the February 2009 American Recovery and Reinvestment Act the PTC was modified to provide the option for qualified producers to take the federal business energy investment tax credit. The PTC is available for projects with a begin-construction deadline of December 31, 2013 [15].
- Business Energy Investment Tax Credit (ITC) credits up to 30 percent of expenditures on qualified renewable energy systems [15].
- Modified Accelerated Cost-Recovery System (MACRS) + Bonus Depreciation allows businesses to recover investments in qualified renewable energy technologies through depreciation deductions. A provision for a 50 percent first year bonus depreciation was added by the Stimulus Act of 2008. This provision expires at the end of 2013 [15].
- Qualified Energy Conservation Bonds (QECBs) are qualified tax credit bonds that are allocated to each state based upon the state's percentage of the U.S. population. The states are then required to allocate a certain percentage to "large local governments." In February 2009, these funds were expanded to $3.2 billion [15].
- Rural Energy for America Program (REAP) promotes energy efficiency and renewable energy for agricultural producers and rural small businesses through the use of grants and loan guarantees for energy efficiency improvements and renewable energy systems. The program covers up to 25 percent of costs [15]
- High Energy Cost Grant Program administered by the U.S. Department of Agriculture (USDA) is aimed at improving the electricity supply infrastructure in rural areas having home energy costs exceeding 275 percent of the national average. Eligible infrastructure includes renewable resources generation. The USDA has allocated $21 million for the 2011 funding cycle. The individual grants range from $75,000 to $5 million [15].
- Green Power Purchasing Goal requires a minimum amount of the electric energy consumed by the federal government during any fiscal year to be from renewable sources. From 2013 forward this goal is 7.5 percent. The amount of renewable-energy credit is doubled for electricity produced and used on-site at a federal facility, produced on federal lands and used at a federal facility, or produced on Native American land [15].

Indiana Incentives

- Net Metering Rule allows utility customers with renewable resource facilities with a maximum capacity of 1 MW to receive a credit for net excess generation in the next billing cycle [15].
- Emissions Credits make electricity generators that do not emit NO_x and that displace utility generation eligible to receive NO_x emissions credits under the Indiana Clean Energy Credit Program [16]. These credits can be sold on the national market.
- Clean Energy Portfolio Goal sets a voluntary goal of obtaining 4 percent between 2013 and 2018, 7 percent between 2019 and 2024, and 10 percent by 2025, of electricity from clean energy sources based on 2010 retail sales. Participation in the goal makes utilities eligible for incentives that can be used to pay for the compliance projects [15].
- Northern Indiana Public Service Company offers feed-in tariff incentive rates for electricity generated from renewable resources on 15 year contracts. Payment for biomass facilities is $0.106/kWh. The tariff is experimental and slated to run until December 31, 2013. The generating unit size allowed under the tariff is between 5 and 5,000 kW while the total allowed system-wide cap is 30 MW. Five hundred kW of the total system-wide cap are reserved for solar projects of capacity less than 10 kW, and 500 kW for wind projects of capacity less than 10 kW [15, 17].

3.6 References

1. U.S. Department of Energy (DOE) 2011. U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry. R.D. Perlack and B.J. Stokes (Leads), ORNL/TM-2011/224. Oak Ridge National Laboratory, Oak Ridge, TN. 227p . http://www1.eere.energy.gov/biomass/pdfs/billion_ton_update.pdf
2. University of Tennessee Institute of Agriculture. http://www.agriculture.utk.edu/news/releases/2009/0911DOEaward.html
3. Ileleji, Klein. Purdue Agricultural and Biological Engineering Department. Technologies for generating power from biomass. Presentation at the Indiana Biomass Working Group, March 2010.
4. DOE. Biomass Program. Processing and conversion http://www1.eere.energy.gov/biomass/processing_conversion.html
5. NREL. Thermochemical technology overview http://www1.eere.energy.gov/biomass/thermochemical_processes.html
6. EERE. Biomass Program Integrated biorefineries overview. http://www1.eere.energy.gov/biomass/pdfs/ibr_portfolio_overview.pdf
7. EIA. U.S. ethanol production and the Renewable Fuel Standard RIN bank. http://www.eia.gov/todayinenergy/detail.cfm?id=11551
8. EPA. Renewable Fuel Standard. May 2010. http://www.epa.gov/otaq/fuels/renewablefuels/index.htm

9. Indiana State Department of Agriculture. Fact Sheet: Biofuels plants in Indiana. http://www.in.gov/isda/biofuels/factsheet.pdf
10. Sun Grant Initiative. http://www.sungrant.org/Feedstock+Partnerships/Research+Plots/
11. Sun Grant Initiative. Feedstock partnerships. http://www.sungrant.org/Regional+Centers/
12. DOE. Bioenergy Knowledge Discovery Framework. https://www.bioenergykdf.net/
13. Brechbill, Sarah and Tyner, Wallace. Department of Agricultural Economics, Purdue University. The economics of biomass collection, transportation, and supply to Indiana cellulosic and electric utility facilities. Working paper #08-03, April 2008. http://www.agecon.purdue.edu/papers
14. Benjamin W. Allen. An economic and emissions analysis of electricity generation using bimass feedstock in co-fired and direct fired facilities. Master of Science Thesis, Purdue University August 2011.
15. Database of State Incentives for Renewables & Efficiency (DSIRE). http://www.dsireusa.org/
16. Indiana Department of Environmental Management. Indiana Clean Energy Credit Program. http://www.in.gov/idem/4134.htm
17. Northern Indiana Public Service Company. http://www.nipsco.com/en/our-services/connecting-to-the-grid.aspx

4. Organic Waste Biomass

4.1 Introduction

The previous section (Section 3) presented the use of organic biomass in the form of dedicated energy crops. In this section the use of biomass in the form of organic wastes and residues as a source of renewable energy is discussed. The organic waste biomass in this section is separated into two main categories: that which is in use currently as an energy source and that which is being considered for use in the future as an energy source in an effort to increase the proportion of renewable energy in the nation's energy mix. The types of organic waste biomass already in use as energy sources include:

- Residues from the forestry and wood products industry, including material left from logging, residues from the paper and pulp industry and residues from primary wood milling;
- Municipal solid waste (MSW), which is the organic portion of the post-consumer waste collected in community garbage collection services;
- Gas extracted from landfills, which is naturally occurring gas resulting from decomposition of landfill material;
- Livestock manure, mainly from large swine and dairy farms where it is used to produce gas in biodigesters; and
- Municipal wastewater, or sewage, which is used to produce gas in biodigesters.

Organic waste biomass resources that are not yet in large-scale use as energy sources but are being considered for future use include:

- Agricultural crop residues, such as stalks, leaves and other material left in the fields when conventional crops such as corn are harvested; and
- Aquatic plants, such as algae that have high oil content that can be converted to biodiesel.

Residues from the forestry and wood products industry and municipal solid waste are typically used to produce electricity and heat. These feedstocks are burned directly in a boiler to produce steam that is used to drive a turbine to generate electricity and/or steam that is used directly for heat.

The other sources of organic waste based energy that are currently in use all take advantage of the production of biogas that contains a significant percentage of methane as the waste breaks down through either natural or managed decay processes. This is the case for landfill gas, livestock manure or municipal waste water that is processed through an anaerobic digester.

Anaerobic digestion of biomass waste consists of a breakdown of organic wastes by microorganisms in an oxygen deficient environment that produces biogas that can be burned as an energy source. The biogas is then burned in a boiler to produce steam that is used to drive a turbine and generate electricity. An additional benefit to generation of electricity from biogas is that it prevents the methane from being emitted into the atmosphere. Because methane is 21 times more potent than carbon dioxide as a heat trapping greenhouse gas, its conversion to energy provides an added environmental benefit [1].

Biomass, including agricultural crop residues, is expected to play a significant role in the energy supply portfolio in the U.S. in the future. One of the characteristics that makes biomass a very attractive source of renewable energy is its ability to be converted both to electricity and to liquid fuels for the transportation industry. Studies have shown that substantial energy resources in the form of biomass from crop residues could be harvested under appropriate economic conditions.

Large scale farming of algae is another area being considered as a potential source of bioenergy. Algae are simple organisms, ranging from microscopic-sized algae to seaweeds that grow to over 100 feet. Like other plants, they utilize energy from the sun through photosynthesis to convert carbon dioxide from the air into biomass usable for energy production. Algae have several advantages over other biomass as a source of energy and especially in the production of biodiesel. These advantages include [2, 3]:

- Algae grows more rapidly and has higher photosynthetic efficiency than other biomass;
- It has a much higher oil content than other biomass (20 to 80 times more than soybeans);
- It is not a food crop;
- It can be grown in water with very high salt concentration that is not usable for other agriculture;
- It can be grown in otherwise non-arable land such as deserts;
- It has the potential for recycling of CO_2 from fossil fueled power plants; and
- Both biofuels and valuable co-products can be produced from algae.

Algae can be grown in either open ponds or in enclosed bioreactors. Although open pond algae farms are much more cost competitive, they have the disadvantages of being vulnerable to contamination by faster growing native algae, water loss through evaporation and exposure to extreme weather variations. Enclosed bioreactors overcome these drawbacks by growing the algae entirely enclosed in transparent containers of various forms. Not surprisingly, the enclosed bioreactors' main disadvantage is cost; bioreactors are much more expensive to build than open ponds. One potential application for the use of algae is the coupling of an algae bioreactor with a coal power plant to allow the power plant to provide the carbon dioxide needed for algae growth.

In this way a combined benefit of producing bioenergy while reducing carbon dioxide emission is achieved. Such an experiment was conducted at the Arizona Public Service Red Hawk power plant in 2006 and 2007 [4].

The production of algae for energy is still in the development stage. According to the DOE algae research program there are major technical hurdles to be overcome before commercial scale energy production from algae is a reality and energy from algae is more of a long term goal [2, 3].

4.2 Economics of organic waste biomass

Most of the current waste biomass energy is generated and consumed in the paper and pulp industry where the paper and pulp making byproducts are combusted in combined heat and power plants to supplement the electricity and steam supply of the paper and pulp mills. Several factors have combined to make the use of these residues and byproducts as an energy source economically attractive at pulp and paper mills. They include:

- The burning of the pulp making residue (black liquor) serves not only to generate energy, but also to recover process chemicals,
- The co-location of electricity and steam demand in the mills greatly increases the efficiency of the energy conversion process, and
- The ability to sell excess generation through either the favorable provisions of Public Utility Regulatory Policies Act of 1978 or more recently through the open transmission access associated with wholesale electricity markets provides a market for times when the plant's generation exceeds internal demand.

In the case of municipal solid waste (MSW), the need to reduce the amount of material going into landfills is the main motivation for building MSW based energy conversion facilities. Without this motivation MSW Power plants would be hard to justify financially since they are some of the most expensive plants to build and operate [5]. In the November 2010 Energy Information Administration (EIA) plant cost estimates, the MSW power plant was listed as having the highest capital cost at over $8,000/kW among the technologies considered and the highest fixed O&M cost at over $370/kW [6].

Similarly, other organic waste streams such as animal waste, wastewater treatment and landfills generate methane-rich biogas, and greenhouse gas emissions reduction is an added benefit to its conversion to energy. Further, the energy conversion efficiency, and therefore economics, can be improved by co-location of both heat and electricity demand. The anaerobic digesters used to produce the biogas in all cases except landfill gas provide a demand for the heat to maintain optimum temperatures for the microorganisms.

Agricultural crop residues are not currently being collected for use as bioenergy feedstock because it is not yet profitable for farmers. In 2005 the U.S. Department of Agriculture (USDA) and the U.S. Department of Energy (DOE) issued a joint report from a study investigating the viability of using energy from biomass to replace 30 percent of U.S. petroleum consumption by the year 2030, titled *Biomass Feedstock for a Bioenergy and Bioproducts Industry: the Technical Feasibility of a Billion-Ton Annual Supply* [7], and in 2011 an update to that report was released. In the 2011 update to this *billion-ton* study the amount of crop residue that would be produced at various farmgate prices was estimated using the agricultural sector model (POLYSYS). Residue production is estimated in conjunction with energy crop production and other cropland uses to account for the competition between uses for the available cropland. Figure 4-1 shows the total crop residue that would be supplied from 2012 to 2030 at six different farmgate prices ranging from $40 to $60 per dry ton. Figure 4-2 shows the supplies with corn stover separated from other residues.

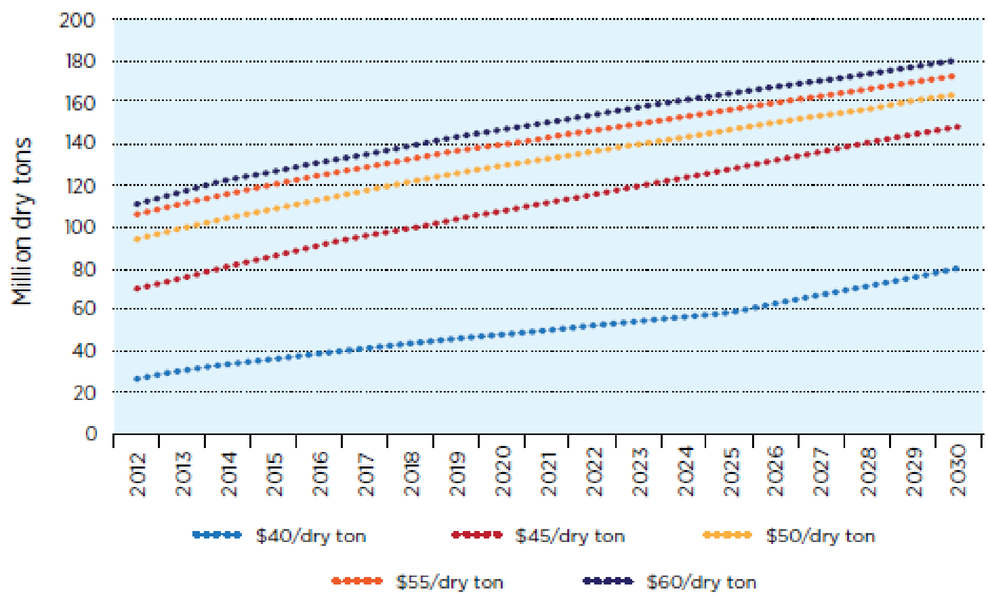


Figure 4-1 Supply of crop residues at various prices under DOE base-case assumptions (Source: DOE [8])

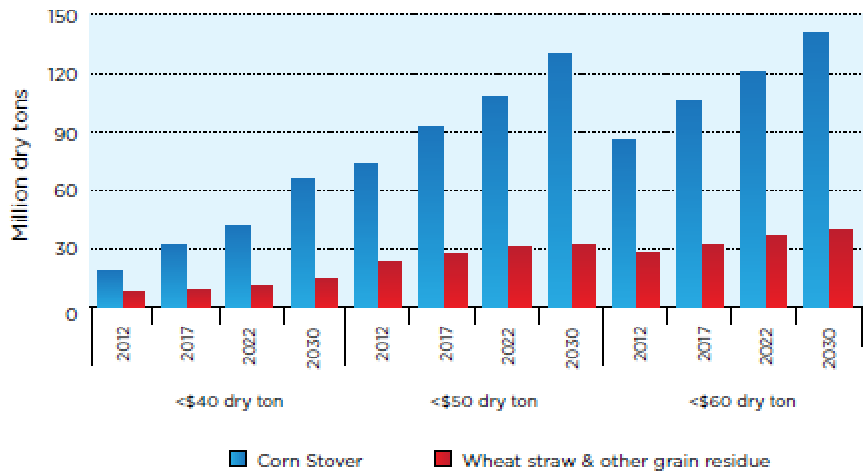


Figure 4-2: Corn stover and grain residue production at selected prices in 2012, 2017, 2022 and 2030 under DOE base-case assumptions (Source: DOE [8])

Although the concept of using algae for energy production has been proven at the laboratory level, no commercial scale sustainable production facility has been established. According to the 2010 DOE National Algal Biofuels Technology Roadmap document there was not yet a credible estimate of the cost of algal biofuel. In January 2013 DOE announced a $24 million research effort to overcome the key hurdles to the commercial production of algae-based biofuels. The funding was awarded to three consortia focusing on three phases of the algal-biofuels supply chain. The *Sustainable Algal Biofuels Consortium*, led by Arizona State University will focus on acceptability of algal biofuels as a substitute for petroleum-based fuels; the *Consortium for Algal Biofuels Commercialization*, led by the University of California will focus on developing algae as a robust feedstock for biofuels production; while the *Cellana LLC Consortium*, led by the Cellana Corporation of Hawaii will focus on large-scale production of fuels and feeds from seawater-based micro-algae [3].

4.3 State of organic waste biomass nationally

Historically organic waste biomass, and in particular residues from the wood products industry, has been one of the main sources of renewable energy in the U.S. As can be seen in Figure 4-3, wood and wood-derived fuels have been second only to hydroelectricity as a source of renewable energy in the U.S. Until the increase in wind and biofuels in the last decade, wood and wood-derived fuels comprised nearly half of the renewable energy consumed in the U.S. In 2012 wood and wood-derived fuels supplied 22 percent of the renewable energy while other organic wastes contributed 5 percent. This was second only to hydroelectricity's share of 30 percent.

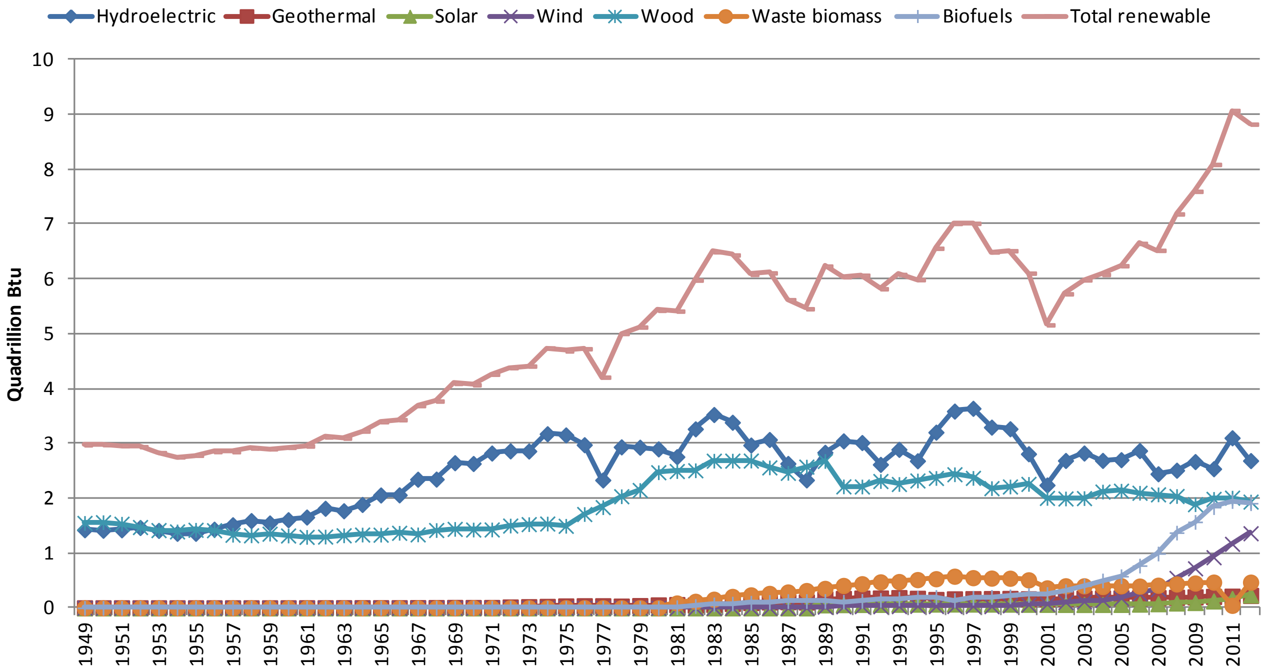


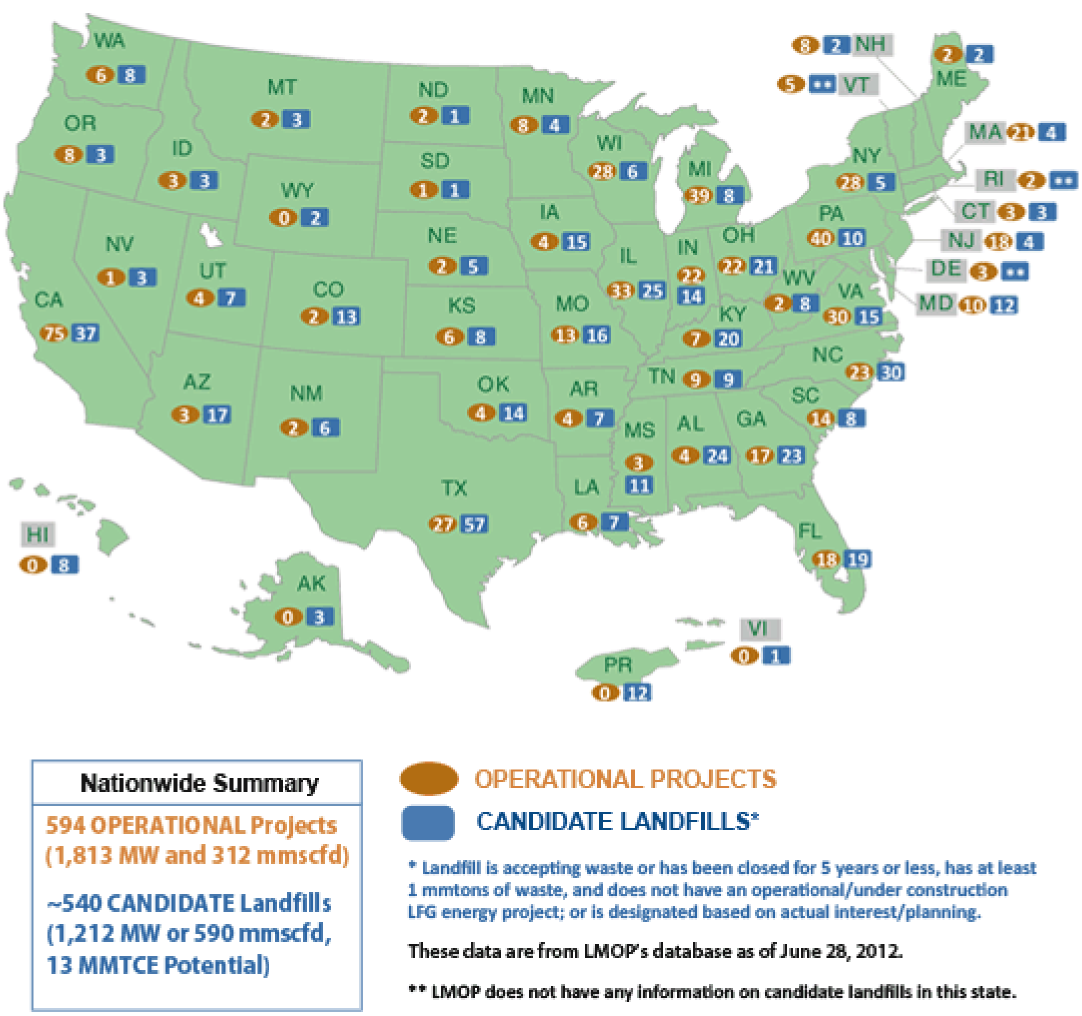
Figure 4-3: U.S. renewable energy consumption 1949-2012 (Source: EIA [9, 10])

Although not as large a source as wood and wood-derived fuels, municipal solid waste (MSW) has also been a significant contributor to the nation's renewable energy mix. According to the U.S. Environmental Protection Agency (EPA), there are 86 municipal solid waste burning power plants operating in 24 states with a combined electricity generating capacity of 2,720 MW [11]. Table 4-1 shows the location MSW energy conversion plants in the U.S.

State	Number of facilities	State	Number of facilities
Alabama	1	Minnesota	9
Alaska	1	New Hampshire	2
California	3	New Jersey	5
Connecticut	6	New York	10
Florida	11	North Carolina	1
Hawaii	1	Oklahoma	1
Indiana	1	Oregon	1
Iowa	1	Pennsylvania	6
Maine	4	Utah	1
Maryland	3	Virginia	5
Massachusetts	7	Washington	1
Michigan	3	Wisconsin	2

Table 4-1: Operating municipal solid waste energy plants (Data source: Energy Recovery Council [12])

The other organic waste stream in use as a source of energy is landfill gas. According to the EPA there were 594 landfills with operational energy conversion projects as of June 2012 with a combined capacity of 1,813 MW electricity generation and 312 million standard cubic feet per day (mmscfd) of gas for thermal energy production. In addition there were 540 'candidate' landfills that have the size and capacity necessary to support energy projects. These candidate landfills have the potential for 1,212 MW of electricity generation and 590 mmscfd of gas for thermal energy conversion. Figure 4-4 shows the location of operational and candidate landfill gas energy projects in the U.S [1].



Legend
mmscfd – million standard cubic feet per day; MMTCE – million metric tons of carbon equivalent

Figure 4-4: Landfill gas projects (Source: EPA [1])

Livestock manure is in use currently as an energy source with 202 anaerobic digester biogas recovery systems in operation on livestock farms in the U.S. as of the May 2013. The majority of these digesters (167) were on dairy farms, but there were also 23 on swine farms, 4 on poultry farms, 3 on beef farms and 5 on mixed cattle/swine farms. EPA estimates that there are 8,241 dairy and swine farms that could support biogas recovery systems with a combined potential electric generating capacity of 1,667 MW supplying approximately 13 million MWh of electricity per year [13]. Table 4-2 shows the top states with the potential for electricity generation from livestock farms. Biogas is more readily recovered from swine and dairy farms because the manure is handled in the wet slurry state that is hospitable to the waste-digesting microorganisms.

	Number of Candidate Farms	Methane Emissions Reductions (Thousand Tons)	Methane Production Potential (billion ft3/ year)	Energy Generation Potential (Thousand MMBtu/ year)	Electricity Generation Potential (Thousand MWh/year)
Swine Farms					
Iowa	1,997	301	21.5	6,243	1,829
North Carolina	939	203	13.2	3,826	1,121
Minnesota	707	63	7.3	2,119	621
Illinois	350	39	4.3	1,240	363
Missouri	154	34	3.5	1,028	301
Indiana	296	31	3.5	1,011	296
Oklahoma	56	51	3.4	997	292
Nebraska	177	27	3.2	927	272
Kansas	80	22	2.3	681	199
Texas	10	25	1.6	477	140
Remaining 40 States	830	109	10.6	3,096	907
Sub Total	5,596	905	74.4	21,645	6,341
Dairy Farms					
California	889	341	27.9	8,104	2,375
Idaho	203	99	8.9	2,601	762
New Mexico	110	64	5.3	1,553	455
Texas	155	66	5.0	1,463	429
Wisconsin	251	41	4.5	1,316	386
Washington	125	35	3.4	1,003	294
Arizona	54	44	3.1	898	263
Michigan	107	26	2.9	838	246
New York	111	18	2.1	603	177
Colorado	54	22	2.0	595	174
Remaining 40 States	588	152	14.6	4,244	1,243
Sub Total	2,647	908	79.7	23,218	6,804
U.S. Total	**8,243**	**1,813**	**154.1**	**44,863**	**13,145**

Table 4-2: Top ten states for potential electricity generation from swine and dairy farms (Data source: AgStar [14])

Municipal wastewater is yet another waste stream that is being used as a source of energy and that has potential for substantial expansion. According to the EPA there were 104 waste treatment facilities in 2011 that were capturing biogas and using it for electricity generation in combined heat and power (CHP) plants with a total 190 MW generating capacity. An additional 1,351 facilities had installed anaerobic digesters but not CHP plants. EPA estimated that if these facilities installed electricity generating equipment they could support a further 411 MW of electricity generation and 38,000 mmBtu per day of thermal energy [15]. In addition to the 104 units listed in Table 4-3 SUFG is aware of electricity generating plants in two locations in Indiana with a total capacity of 195 kW. More information about these plants is given in Section 4.4.

State	Number of Sites	Capacity (MW)	State	Number of Sites	Capacity (MW)
AR	1	1.73	MT	3	1.09
AZ	1	0.29	NE	3	5.40
CA	33	62.67	NH	1	0.37
CO	2	7.07	NJ	4	8.72
CT	2	0.95	NY	6	3.01
FL	3	13.50	OH	3	16.29
IA	2	3.40	OR	10	6.42
ID	2	0.45	PA	3	1.99
IL	2	4.58	TX	1	4.20
IN	1	0.13	UT	2	2.65
MA	1	18.00	WA	5	14.18
MD	2	3.33	WI	5	2.02
MI	1	0.06	WY	1	0.03
MN	4	7.19	Total	104	189.8

Table 4-3: Wastewater treatment combined heat and power systems in the U.S.
(Data source: EPA [15])

Although crop residues are not in use today as a source of energy, it is the most readily available biomass feedstock. According to the USDA/DOE billion-ton study referred to in Section 4.2 corn stover is the most abundant untapped source of biomass currently available from croplands. Corn stover is the material left in the field after the corn grain is harvested and consists of the stalks, leaves, husks and cobs. The USDA/DOE report estimates that 75 million dry tons per year of corn stover can be sustainably removed from U.S. croplands under current farming conditions. All other crops can together contribute 38 million tons a year under current farming practices [7]. In the 2011 update of the billion ton study, the total amount of agricultural residues produced at a farmgate price of $60 per dry ton is estimated at 140 million tons of corn stover, 36 million tons of wheat straw and 4 tons of other types of grain crop residues [8].

Table 4-4 shows total agricultural residue biomass projected by the POLYSYS model to be available in the U.S. at prices of $40, $50 and $60 per dry ton in the 2011 update of the billion-ton report [8]. As can be seen in the table corn stover is the dominant residue available. At a price of $60 per dry ton of biomass for energy, 140 million dry tons out of the total 265 million dry tons of agricultural residue collected for sale to the energy industry in the DOE baseline case would be corn stover. Animal manure would be the second largest source of biomass feedstock for energy with 59 million tons collected in 2030 at a price of $60 per dry ton.

	<$40 per dry ton				<$50 per dry ton				<$60 per dry ton			
Feedstock	2012	2017	2022	2030	2012	2017	2022	2030	2012	2017	2022	2030
	Million dry tons											
Baseline												
Corn	19	32	42	65	73	93	108	129	85	106	120	140
Wheat	6.7	7.8	9.1	12	18	22	26	31	23	26	31	36
Barley, Oats, Sorghum	1.0	1.3	1.6	2.9	2.4	2.5	2.4	3.6	2.8	2.7	2.6	3.7
Total primary residue	**27**	**41**	**52**	**80**	**94**	**117**	**136**	**164**	**111**	**135**	**154**	**180**
Secondary residues & wastes												
Rice field residue	6.5	6.9	7.4	8	6.5	6.9	7.4	8	6.5	6.9	7.4	8
Rice hulls	1.5	1.6	1.7	1.7	1.5	1.6	1.7	1.7	1.5	1.6	1.7	1.7
Cotton field residue	4.2	5.3	5.9	6.7	4.2	5.3	5.9	6.7	4.2	5.3	5.9	6.7
Cotton gin trash	1.4	1.6	1.7	1.8	1.4	1.6	1.7	1.8	1.4	1.6	1.7	1.8
Sugarcane residue	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Orchard and vineyard prunings	5.7	5.6	5.5	5.5	5.7	5.6	5.5	5.5	5.7	5.6	5.5	5.5
Wheat dust	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Animal manures	12	13	16	20	29	34	41	56	30	35	43	59
Animal fats	0	0	0	0	0	0	0	0	0	0	0	0
Total secondary residues & wastes	**33**	**36**	**40**	**46**	**50**	**56**	**65**	**82**	**51**	**58**	**67**	**84**
Total baseline	**59**	**77**	**92**	**126**	**143**	**174**	**201**	**245**	**162**	**192**	**221**	**265**
High-yield scenario												
Corn stover	71	132	157	221	143	200	228	264	153	209	234	271
Wheat Straw	9.8	12	13	16	60	35	38	42	35	39	42	46
Barley, Oats, Sorghum	1.5	1.5	1.4	1.7	3.6	3.4	2.8	3.1	4.0	3.6	2.9	3.0
Total primary residue	**83**	**146**	**171**	**238**	**176**	**239**	**269**	**309**	**193**	**252**	**279**	**320**
Total high-yield	**115**	**182**	**210**	**284**	**226**	**295**	**334**	**391**	**244**	**310**	**346**	**404**

Notes: *High-yield estimates for corn, wheat, barley, oats, and sorghum assume a 1% annual growth in energy crop yields. Increasing the assumed energy crop yield growth rate (e.g. 2 to 4% annually) will slightly change the estimated high-yield resource estimates above.*

Table 4-4: Agricultural residues and waste resources produced at various prices in 2012, 2017, 2022 and 2030 (Source: DOE [8])

4.4 Organic waste biomass in Indiana

Organic waste biomass, in particular wood residue and byproducts, has historically been the main source of renewable energy in Indiana. Figure 4-5 shows the contribution of the various renewable resources to the total annual energy consumed in Indiana since 1960. It was not until the rapid growth in corn ethanol production starting in 2007 that woody biomass energy's contribution was overtaken by ethanol as the primary source of renewable energy consumed in Indiana. The types of industries using wood residue and byproducts include the paper and pulp industry that has traditionally used the paper-making byproducts for cogeneration of electricity and process heat.

Municipal solid waste is the other major source of energy from woody biomass, for example the Covanta Energy Corporation's Indianapolis facility uses municipal solid waste to generate steam used for district heating in downtown Indianapolis. The plant has capacity to process 2,175 tons of solid waste per day to produce at least 4,500 tons of steam per ton of solid waste [16].

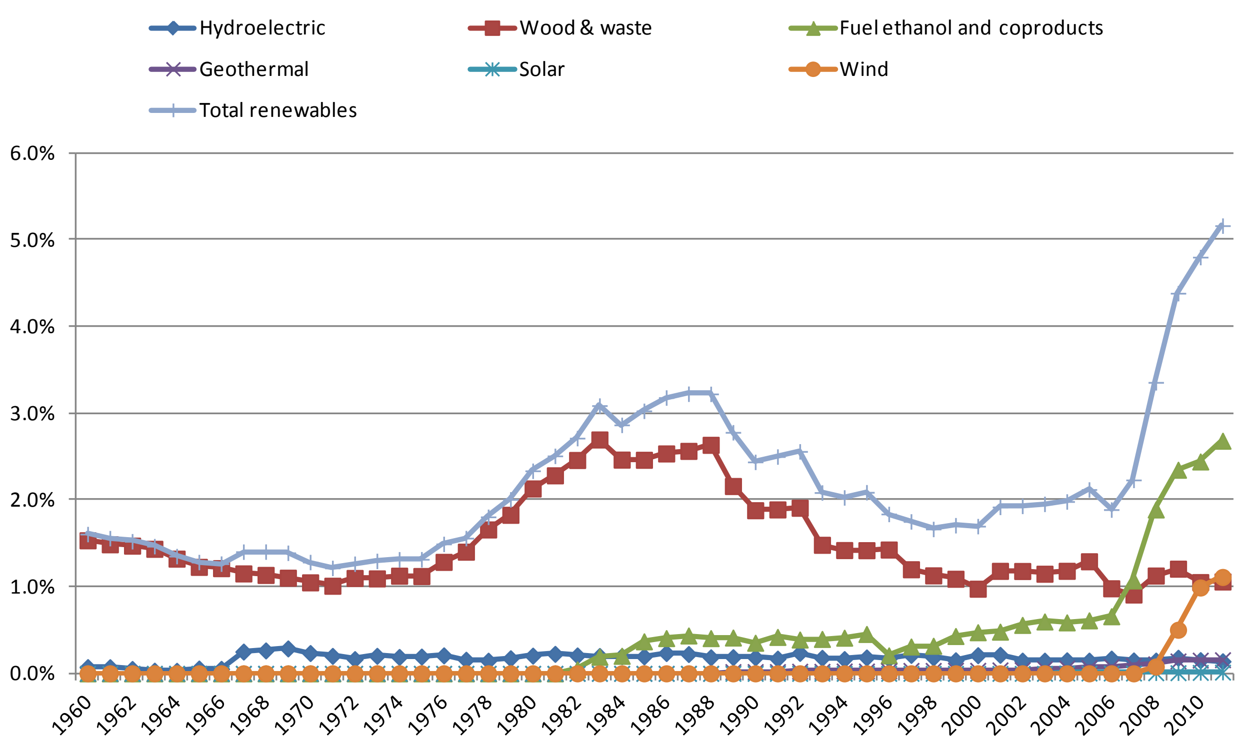


Figure 4-5: Renewables share of Indiana total energy consumption (1960-2011) (Source EIA [17])

The other organic waste biomass that is a significant source of energy in Indiana is landfill gas. The most active user of landfill gas is Wabash Valley Power Association which has a total of 49.6 MW of electricity generating capacity from seventeen power plants on 8 landfills.
Other major users of landfill energy include Hoosier Energy with 3.5 MW electricity generating capacity in a Clark County landfill and Granger Energy that has several energy conversion projects in the Southside landfill in Indianapolis. The Granger Energy project in the Southside Indianapolis landfill includes 4 MW of electricity generating capacity and supplies landfill gas to various area businesses for heating and steam generation. The total electricity generating capacity installed in Indiana landfills is 60.5 MW. Other operators of landfill electricity generating projects include Energy Systems LLC and the town of Munster with installed generating capacities of 3.2 MW and 0.1 MW respectively [18]. In a study done by Giraldo as part of his 2013 Masters Thesis [19] it was estimated that 10 other landfills in Indiana had the technical characteristics necessary to support an additional 16.9 MW of electricity generating capacity as shown in Table 4-5.

Facility Name	**Amount of garbage disposed on landfill (tons)**	**Potential electricity generation capacity (MW)**
Clinton county	1,170,254	560
New Paris Pike	1,900,000	870
Decatur Hills	1,363,442	900
Hoosier 2	2,143,024	1,030
Bartholomew county 2	1,468,927	1,170
Clinton county	1,170,254	560
New Paris Pike	1,900,000	870
Decatur Hills	1,363,442	900
Hoosier 2	2,143,024	1,030
Bartholomew county 2	1,468,927	1,170
Clinton county	1,170,254	560

Table 4-5: Potential electricity generating capacity in Indiana landfills (Data source: Giraldo [19])

Another source of biomass fuel use for electricity generation in Indiana is the anaerobic digestion of animal manure. According to the EPA there are 8 anaerobic digesters installed in farms in Indiana. In addition SUFG is aware of a recently installed digester at the Culver Duck Farm in Middlebury. Table 4-6 shows the locations and electricity generating capacities of anaerobic digesters in Indiana farms arranged in order of the year of commissioning. The combined installed generating capacity of these digesters is 9,050 kW. In addition the Fair Oaks Dairy Farm has installed purification and compression equipment to produce biogas to run 42 milk delivery trucks [20]. The potential to expand biogas production from livestock farms is substantial. Indiana is ranked among the top ten with potential for producing 3.5 billion cubic feet of biogas per year from livestock manure digesters in 296 farms [14].

Farm/Project Name	County	Year Operational	Animal Type	Population Feeding Digester	Biogas End Uses	Installed Capacity (kW)
Herrema Dairy	Jasper	2002	Dairy	3750	Cogeneration	800
Fair Oaks Dairy - Digester 1	Jasper	2004	Dairy	3000	Electricity	700
Bos Dairy	Jasper	2005	Dairy	3600	Electricity	700
Windy Ridge Dairy	Jasper	2006	Dairy	7000	Flared Full Time	
Bos Dairy	Jasper	2007	Dairy	3600	Electricity	350
Hidden View	Jasper	2007	Dairy	3500	Cogeneration	950
Fair Oaks Dairy - Digester 2	Jasper	2008	Dairy	9000	Cogeneration; CNG	1,050
Bio Town Ag, Inc.	White	2011	Swine, Cattle	800; 4500	Cogeneration	3,300
Culver Duck Farm (processing plant)*	Elkhart	2013	Ducks	105,000 gallons duck blood & offal per week	Electricity	1,200

*Data from Culver Duck from site visit

Table 4-6: Operational Anaerobic Digesters in Indiana (Data source EPA [13])

It is estimated that 144 concentrated animal feeding operations (CAFO) had the size and manure handling processes necessary to support an additional 2.6 MW of electricity generating capacity as shown in Table 4-7.

Operation type (size in head)	Number of candidate farms	Potential electrical generation capacity per farm (kW)
Dairy (500-999)	17	175
Dairy (1000-2499)	12	365
Dairy (2500 or more)	3	1,204
Hog farrow-to-wean (1000-1999)	4	22
Hog farrow-to-wean (2000-4999)	2	53
Hog farrow-to-wean (5000 or more)	2	184
Hog farrow-to-finish (1000-1999)	14	20
Hog farrow-to-finish (2000-4999)	14	43
Hog farrow-to-finish (5000 or more)	16	194
Hog finish only (1000-1999)	18	28
Hog finish only (2000-4999)	22	68
Hog finish only (5000 or more)	14	181
Hog nursery (1000-1999)	2	12
Hog nursery (2000-4999)	3	18
Hog nursery (5000 or more)	1	38
Total	144	2,605

Table 4-7: Potential electricity generating capacity in Indiana concentrated animal feeding operations (Data source: Giraldo [19])

Another biomass waste stream that is currently in use as a source of energy in Indiana is municipal wastewater. SUFG is aware of a total of 195 kW of electricity generating capacity in wastewater treatment plants (WWTP) in the cities of Jasper (65 kW) and West Lafayette (130 kW). The West Lafayette facility is also equipped to take in food related waste from Purdue University and other local businesses [21]. It is estimated that waste water treatment plants in 17 Indiana cities had the volume and processing infrastructure necessary to support an additional 10 MW of electricity generating capacity as shown in Table 4-8.

Facility name	Average flow (MGD)	Potential electricity generation capacity (kW)
Noblesville WWTP	5.0	130
Speedway WWTP	5.5	143
Shelbyville WWTP	6.8	177
Elkhart WWTP	8.3	216
J.B. Gifford WWTP	8.5	221
William Edwin Ross WWTF	9.0	234
Anderson WWTP	12.0	312
Mishawaka WWTP	12.0	312
Evansville Eastside WWTP	18.0	468
Muncie WWTP	19.0	494
Lafayette WWTP	20.7	537
Terre Haute WWTP	24.0	624
Hammond WWTP	27.0	702
City of South Bend WWTP	36.0	936
Gary Sanitary District	50.0	1,300
Fort Wayne WPCP	62.0	1,612
Carmel South WWTP	95.0	2,470
Total		**10,888**

Table 4-8: Potential electricity generating capacity in Indiana wastewater treatment plants (Data source: Giraldo [19])

Figure 4-6 shows the amount of agricultural and forest biomass residue potentially available for energy production in Indiana at various bioenergy feedstock prices. As can be seen in the figure, the most abundant residue available is corn stover increasing from approximately 3 million dry tons per year at $40 per dry ton to slightly over 8 million dry tons per year at $60 per dry ton.

Figure 4-6: Estimated biomass production potential in Indiana (Data source: DOE [8])

Assuming an energy content of 7,500 Btu/lb for agricultural residues (corn stover and wheat straw), 9,000 Btu/lb for wood, and 8,500 for manure the total energy available from the residues collected when the price is $60 per dry ton would be 170 trillion Btu. This is approximately 6 percent of Indiana's annual energy consumption of 2,800 trillion Btu. If this energy was converted to electricity in a power plant operating at 21 percent efficiency it would result in 11,000 GWh of electric energy, approximately 8 percent of Indiana's 125,000 GWh annual electricity generation.

Two Indiana companies (Algaewheel and Stellarwind Bio Energy) are involved in algae development. In 2010 Algaewheel installed an algae based wastewater treatment system at the city of Reynolds as part of the Biotown USA initiative intended to make Reynolds energy self-sufficient by supplying all its needs from local renewable resources. In 2009 Stellarwind Bio Energy LLC established a corporate headquarters and a small scale production facility to manufacture algal oil that can be refined to produce liquid transportation fuels [22].

4.5 Incentives for organic waste biomass

The following incentives have been available to assist in the use of organic waste biomass.

Federal Incentives

- Renewable Electricity Production Tax Credit (PTC) provides a 2.3 cents/kWh tax credit for closed-loop biomass and 1.1 cents/kWh for open-loop biomass, landfill gas municipal solid waste energy technologies. Dedicated energy crops fall under the closed loop biomass category.

As part of the February 2009 American Recovery and Reinvestment Act the PTC was modified to provide the option for qualified producers to take the federal business energy investment tax credit. The PTC is available for projects with a begin-construction deadline of December 31, 2013 [23].

- Business Energy Investment Tax Credit (ITC) credits up to 30 percent of expenditures on qualifying renewable energy systems [23].
- Modified Accelerated Cost-Recovery System (MACRS) + Bonus Depreciation allows businesses to recover investments in qualified renewable energy technologies through depreciation deductions. A provision for a 50 percent first year bonus depreciation was added by the Stimulus Act of 2008. This provision expires at the end of 2013 [23].
- Qualified Energy Conservation Bonds (QECBs) are qualified tax credit bonds that state, local and tribal governments may use to finance renewable energy projects and other energy conservation measures. Unlike the Clean Renewable Energy Bonds (CREBS) QECBs are not subject to U.S. Department of Treasury approval. The volume of the bonds is allocated to states in proportion to the state's percentage of the U.S. population [23].
- Rural Energy for America Program (REAP) covers up to 25 percent of costs for eligible projects at certain types of institutions. Eligible renewable energy projects include wind, solar, biomass and geothermal; and hydrogen derived from biomass or water using wind, solar or geothermal energy sources. REAP grants are available for agricultural producers and rural businesses. The program is administered by the USDA [23].
- High Energy Cost Grant Program administered by the USDA is aimed at improving the electricity supply infrastructure in rural areas having home energy costs exceeding 275 percent of the national average. Eligible infrastructure includes renewable resources generation. The USDA has allocated $21 million for the 2011 funding cycle. The individual grants range from $75,000 to $5 million [23].
- Green Power Purchasing Goal requires a minimum amount of the electric energy consumed by the federal government during any fiscal year to be from renewable sources. From 2013 forward this goal is 7.5 percent. The amount of renewable-energy credit is doubled for electricity produced and used on-site at a federal facility, produced on federal lands and used at a federal facility, or produced on Native American land [23].

Indiana Incentives

- Net Metering Rule allows utility customers with renewable resource facilities with a maximum capacity of 1 MW to receive a credit for net excess generation in the next billing cycle
- Emissions Credits are received by electricity generators that do not emit NO_x and that displace utility generation.

- They are eligible to receive NO_x emissions credits under the Indiana Clean Energy Credit Program. These credits can be sold on the national market. [24].
- Clean Energy Portfolio Goal sets a voluntary goal of obtaining 4 percent between 2013 and 2018, 7 percent between 2019 and 2024, and 10 percent by 2025, of electricity from clean energy sources based on 2010 retail sales. Participation in the goal makes utilities eligible for incentives that can be used to pay for the compliance projects [23].
- Northern Indiana Public Service Company (NIPSCO) offers feed-in tariff incentive rates for electricity generated from renewable resources for up to 15 years. The payment for biomass facilities is $0.106/kWh. The tariff is an experimental one running until December 31, 2013. The total system-wide renewable capacity allowed under the tariff is 30 MW with 500 kW of the cap reserved for solar projects of capacity less than 10 kW and 500 kW for wind projects of capacity less than 10 kW [23, 25].

4.6 References

1. U.S. Environmental Protection Agency (EPA). Landfill Methane Outreach Program. http://www.epa.gov/lmop/projects-candidates/index.html#map-area
2. National Renewable Energy Laboratory (NREL). A look back at the U.S. Department of Energy's aquatic species program: Biodiesel from algae. 1998. http://www.nrel.gov/biomass/pdfs/24190.pdf
3. U.S. Department of Energy (DOE). National algal biofuels technology roadmap. May 2010. http://www1.eere.energy.gov/biomass/pdfs/algal_biofuels_roadmap.pdf
4. Greentechmedia. http://www.greentechmedia.com/articles/read/aps-gets-70.5m-to-feed-captured-carbon-to-algae
5. EPA. http://www.epa.gov/wastes/nonhaz/municipal/wte/index.htm
6. Energy Information Administration (EIA). Updated capital cost estimates for electricity generation plants. November 2010. http://www.eia.gov/oiaf/beck_plantcosts/pdf/updatedplantcosts.pdf
7. DOE and U.S. Department of Agriculture (USDA). Biomass as feedstock for a bioenergy and bioproducts industry: the technical feasibility of a billion-ton annual supply. April 2005. http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf
8. DOE. 2011 U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry. R.D. Perlack and B.J. Stokes (Leads), ORNL/TM-2011/224. Oak Ridge National Laboratory, Oak Ridge, TN. 227p . http://www1.eere.energy.gov/biomass/pdfs/billion_ton_update.pdf
9. EIA. 2012 Annual Energy Review. Table 10.1. http://www.eia.gov/totalenergy/data/annual/index.cfm#renewable
10. EIA. May 2013 Monthly Energy Review Table 10.1 http://www.eia.gov/totalenergy/data/monthly/#renewable

11. EPA. Energy Recovery from Waste. http://www.epa.gov/wastes/nonhaz/municipal/wte/index.htm.
12. Energy Recovery Council. http://www.wte.org/userfiles/file/ERC_2010_Directory.pdf
13. EPA, AgSTar. Operating Anaerobic Digester Projects. http://www.epa.gov/agstar/projects/index.html.
14. AgSTar. Market opportunities for biogas recovery systems at U.S. livestock facilities. http://www.epa.gov/agstar/documents/biogas_recovery_systems_screenres.pdf.
15. EPA. Combined Heat and Power Partnership, Opportunities for and benefits of combined heat and power at wastewater treatment facilities. http://www.epa.gov/chp/markets/wastewater.html
16. Covanta Energy Corporation. http://www.covantaenergy.com/en/facilities/facility-by-location/indianapolis.aspx
17. EIA. State Energy Data System (SEDS). Table CT2. Primary Energy Consumption Estimates, Selected Years, 1960-2011, Indiana. http://www.eia.gov/state/seds/data.cfm?incfile=/state/seds/sep_use/total/use_tot_INcb.html&sid=IN
18. EPA. Landfill Methane Outreach Program (LMOP). http://www.epa.gov/lmop/projects-candidates/index.html
19. Juan S. Giraldo. An economic analysis of electricity generation potential from biogas resources in the state of Indiana. Master of Science Thesis, Purdue University May 2013.
20. U.S. Dairy Sustainability Committee. 2022. http://www.usdairy.com/Public%20Communication%20Tools/DairyPowerCaseStudy_RenewableEnergy.pdf
21. West Lafayette wastewater treatment plant. http://www.westlafayette.in.gov/department/division.php?fDD=11-185
22. Stellarwind Bio Energy LLC. http://stellarwindbioenergy.com/?q=About%20Us
23. Database of State Incentives for Renewables and Efficiency (DSIRE). http://www.dsireusa.org/
24. Indiana Department of Environmental Management. Indiana clean energy credit program. http://www.in.gov/idem/4134.htm
25 Northern Indiana Public Service Company. http://www.nipsco.com/en/our-services/connecting-to-the-grid.aspx

5. Solar Energy

5.1 Introduction

Solar energy is captured and converted into various forms of energy in two main ways: directly into electricity using photovoltaic cells and indirectly using solar thermal conversion technologies. The two conversion methods and associated technologies are presented in this report, starting with solar thermal conversion technologies in this section followed by photovoltaic cells in Section 6.

Solar thermal energy is captured using solar collectors, of which there are two main types: concentrating and non-concentrating collectors. Concentrating collectors use mirrors of various configurations to focus the solar energy onto a receiver containing a working fluid that is used to transfer the heat to a conversion engine. Concentrating collectors are typically used for electricity generating projects while non-concentrating collectors are typically used for applications such as water and space heating.

The most commonly used non-concentrating collectors are flat-plate designs. Flat-plate collectors consist of a flat-plate absorber, a transparent cover that allows solar energy to pass through while reducing heat loss, a heat-transport fluid flowing through tubes, and a heat insulating backing. Figure 5-1 shows the basic components of a flat-plate collector. Other non-concentrating collectors include evacuated-tube collectors and integral collector-storage systems [1].

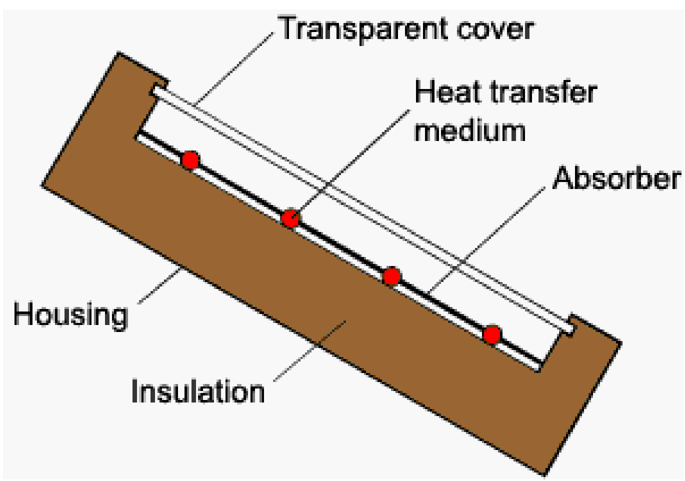


Figure 5-1: Cross-section layout of a flat-plate collector (Source: SolarServer [2])

The four main types of thermal concentrating solar power (CSP) systems are parabolic trough, linear Fresnel, solar power tower, and solar dish/engine system.

The trough CSP system has trough shaped collectors with a parabolic cross section and a receiver (or absorber) tube located at the focal line of the trough as shown in Figure 5-2. A working fluid is used to transport the heat from the receivers to heat exchangers. Trough CSP systems in use for utility scale electricity generation are typically coupled with a fossil-fuel fired boiler to supplement the supply of heat when the solar energy collected is not adequate. Trough systems can also be coupled with facilities to store the hot working fluid, thereby providing the ability for the plant to be dispatched to match system demand. The parabolic trough system is the most developed and widely used CSP technology in the U.S. and worldwide, with 506 MW out of the total 517 MW of installed CSP capacity in the U.S. being parabolic trough based.

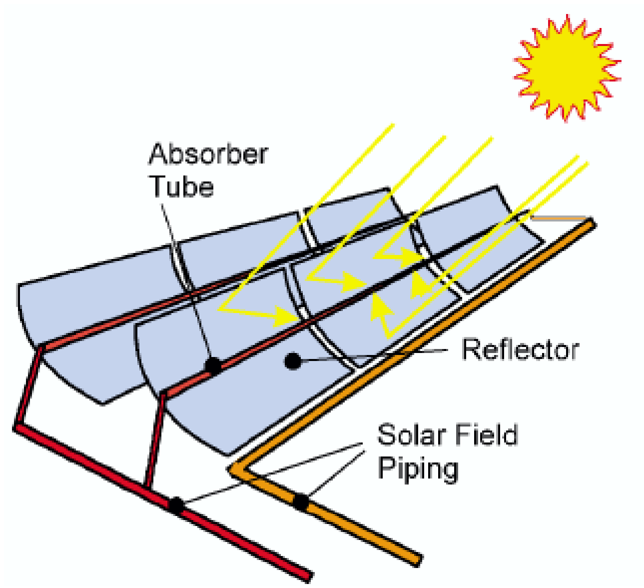


Figure 5-2: A parabolic trough CSP system (Source: NREL [3])

The linear Fresnel CSP system functions a lot like the parabolic trough system except for the collectors where the parabolic trough is replaced with a series of flat or slightly curved mirrors that focus the radiation onto a receiver tube as shown in Figure 5-3. There is only one linear Fresnel CSP plant operating in the U.S. It is the 5 MW Kimberlina plant in Bakersfield, California commissioned in 2009.

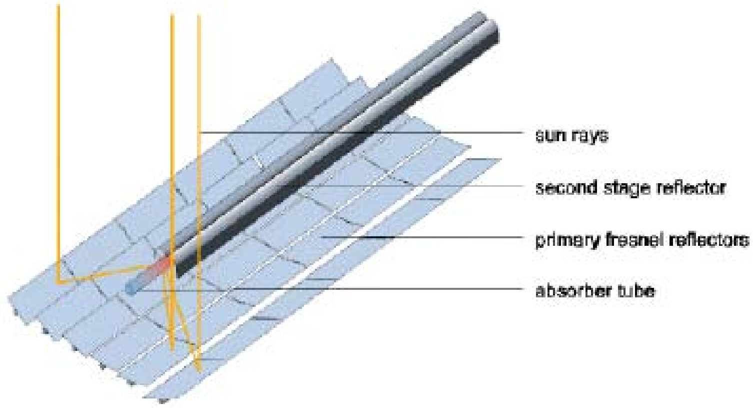


Figure 5-3: A linear Fresnel CSP system (Source: IEA [4])

The power tower CSP system utilizes thousands of flat sun-tracking mirrors that concentrate the solar energy on a tower-mounted heat exchanger as shown in Figure 5-4. This system avoids the heat lost during transportation of the working fluid to the central heat exchanger in a trough-based CSP system. Power tower CSP systems are typically equipped with molten salt energy storage tanks at the base of the towers that enable them to store energy for several hours [5]. This system provides higher efficiency than the trough system because all sunlight is concentrated on a single point [3]. The only power tower CSP power plant operating in the U.S. currently is the 5 MW Sierra SunTower in Lancaster, California.

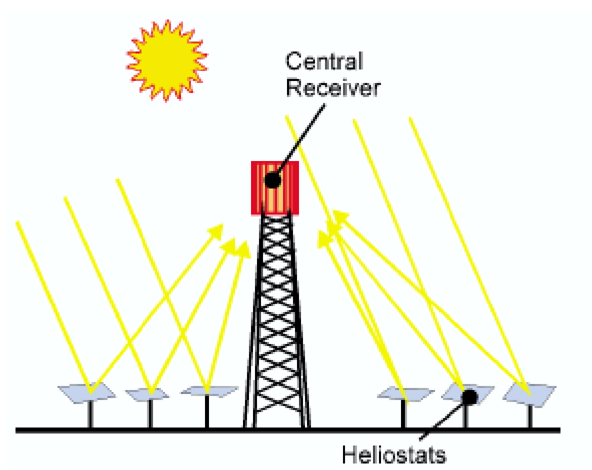


Figure 5-4: A power tower CSP system (Source: NREL [3])

The dish/engine system utilizes a parabolic shaped dish that focuses the sun's rays to a receiver at the focal point of the dish as shown in Figure 5-5. An engine/generator located at the focal point of the dish converts the absorbed heat into electricity. Individual dish/engine units currently range from 3-25 kW [6]. Many of these dish systems may be combined to make a utility-scale power plant. The dish/engine design results in the highest efficiency of the solar thermal designs [3]. The dish/engine system does not use any cooling water which puts it at an advantage over the other two systems. However, it is the least developed of the three CSP technologies with several challenges to be overcome in the design of the reflectors and the solar collectors. A 1.5 MW dish/engine based power plant, the Maricopa Solar Project, commissioned in Phoenix, Arizona in 2010 is the only dish/engine based power plant in the U.S.

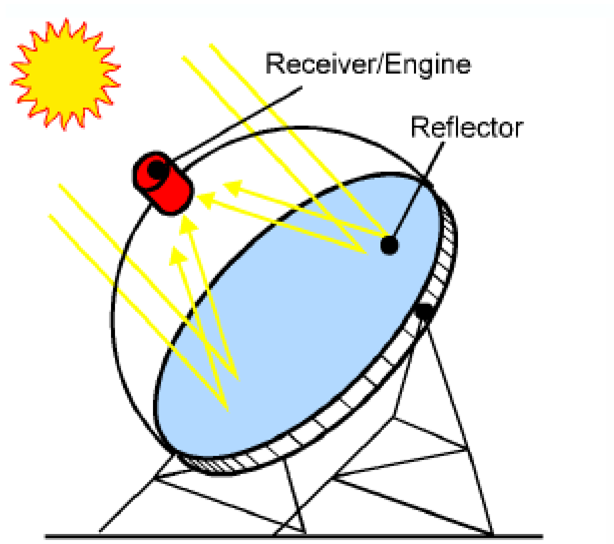


Figure 5-5: A dish/engine CSP system (Source: NREL [3])

5.2 Economics of solar technologies

Table 5-1 shows the overnight capital cost[4] estimates for CSP power plants provided by the National Renewable Energy Laboratory (NREL) [7] arranged in increasing capital cost ($/kW). The plant with the lowest capital cost, the Colorado integrated Solar Project (Cameo), is not a stand-alone generating station, but rather a solar preheat of boiler feed water in a coal fired power plant. The plant with the highest cost, the Gemasolar plant in Spain, is a power tower with 15 hours worth of molten salt storage.

[4] Overnight capital cost "*is an estimate of the cost at which a plant could be constructed assuming that the entire process from planning through completion could be accomplished in a single day*" [8]. The overnight cost concept is used to avoid the impact of the differences in financing methods chosen by project developers on the estimated costs.

Project Name	Developer, Owner	Location	Capacity (MW)	Technology	Status	Online Date	Total cost (million $)	Capital cost ($/kW)
Colorado Integrated Solar Project (Cameo)	Abengoa, Xcel	Palisades, Colorado	2	Parabolic Trough	Operational	2010	4.5	2,250
Nevada Solar One	Acciona	Boulder City, Nevada	64	Parabolic Trough	Operational	2007	266	4,156
Ibersol Ciudad Real	Iberdrola Renewables	Puertollano, Spain	50	Parabolic Trough	Operational	2009	256*	5,120
Ivanpah Solar Electric Generating System	BrightSource Energy	Primm, CA	377	Power Tower	Under construction	2013	2,200	5,836
Shams 1	Abengoa, Masdar,Total	Madinat Zayed, United Arab Emirates	100	Parabolic Trough	Operational	2013	600	6,000
Mojave Solar Project	Abengoa	Harper Dry Lake, CA	250	Parabolic Trough	Under construction	2014	1,600	6,400
Solana Generating Station	Abengoa	Phoenix, Arizona	250	Parabolic Trough	Under development	2013	2,000	8,000
Gemasolar Thermosolar Plant	Torresol, Masdar, Sener	Andalucía, Spain	20	Power Tower	Operational	2011	294*	14,794

*cost converted from Euros (€) at 1.28 $ per €

Table 5-1 Estimated overnight capital cost of CSP plants (Sources NREL [7])

Figure 5-6 shows the overnight capital cost estimates of utility scale electricity generating technologies given in the November 2013 EIA update of generating plant costs [8]. The solar thermal technology's capital cost of approximately $5,067 /kW is in the mid-range among the renewable technologies between the low end of wind generation at $2,213/kW and the high end $8,312/kW for municipal solid waste based generation technology.

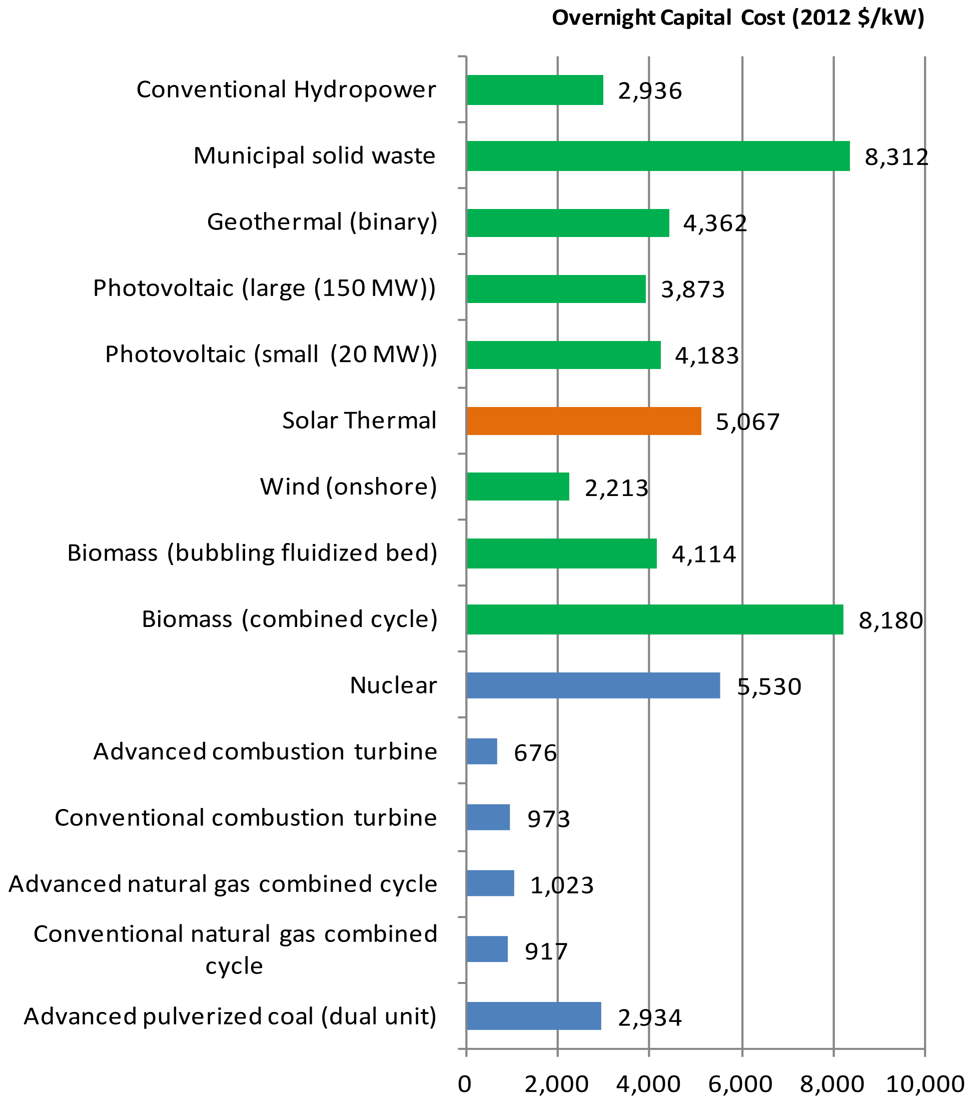


Figure 5-6: Capital cost of generating technologies (Data source: EIA [8])

Figure 5-7 shows the estimate of the fixed and variable operating and maintenance (O&M) costs. As can be seen in Figure 5-7 solar thermal technology has moderate O&M cost, with a zero variable O&M cost and a fixed annual O&M cost of $67 /kW. This fixed annual O&M cost is higher than that of photovoltaic technologies which is estimated at $25 /kW for large scale photovoltaic plants and $28 /kW for small utility scale photovoltaic systems.

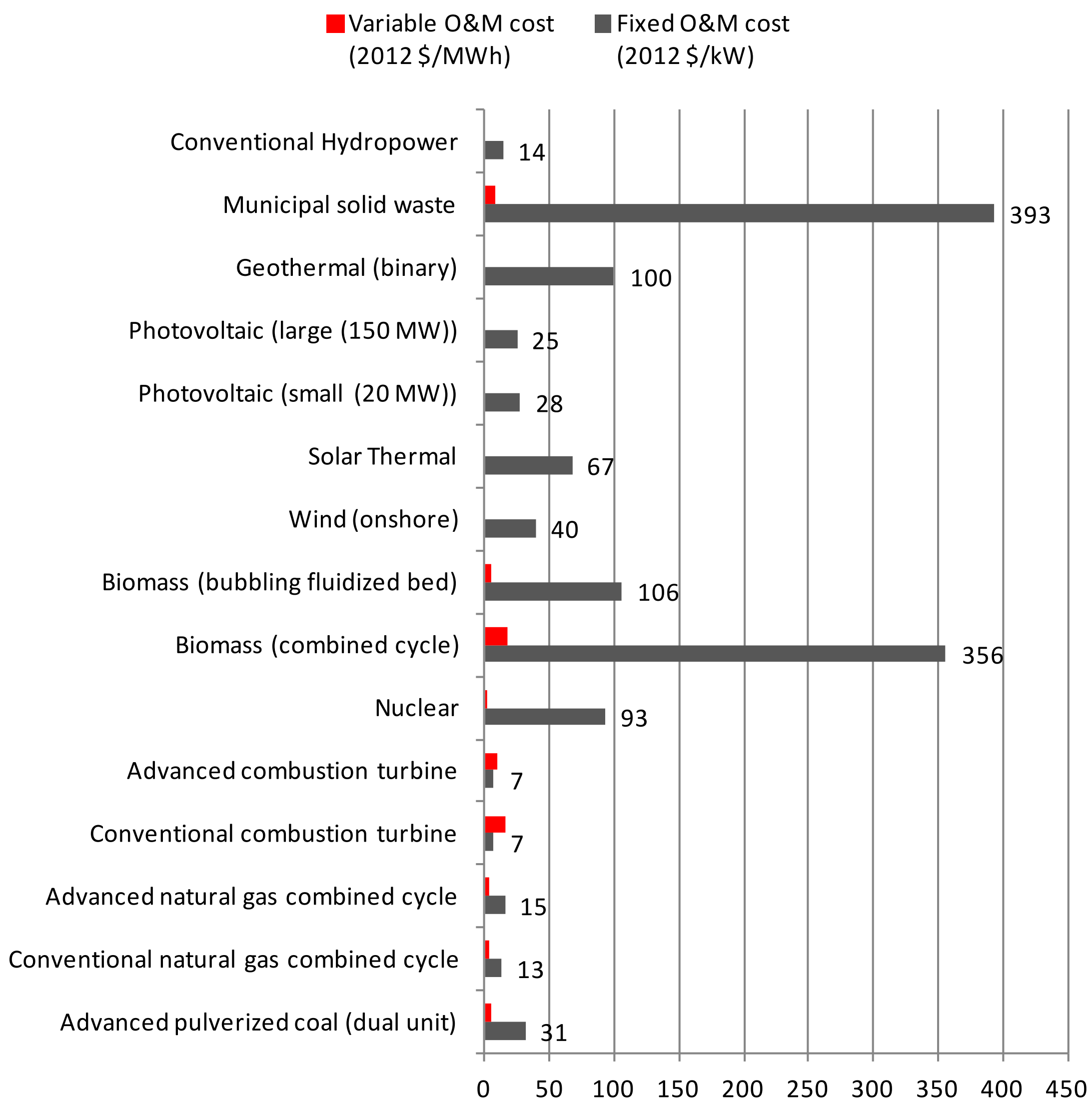


Figure 5-7: Operating and maintenance cost of generating technologies (Data source: EIA [8])

5.3 State of solar energy nationally

As can be seen in Figures 5-8, there are substantial solar resources available in the U.S., especially in the southwestern region.

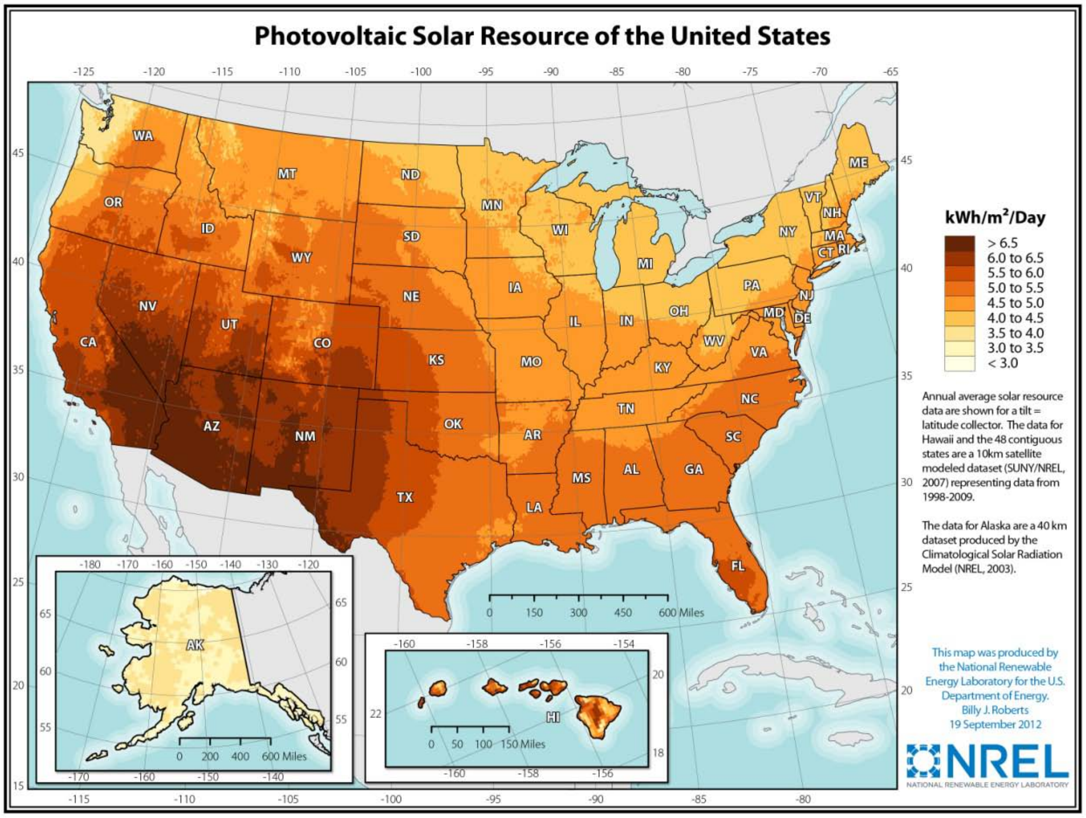


Figure 5-8: Concentrating solar power resource in the U.S. (Source: NREL [9])

Like the PV systems presented in Section 6, there has been a surge in the installation of CSP capacity in the U.S. in the last 7 years. After a period of approximately 25 years when no new CSP capacity was built in the U.S. the first major project, the 64 MW Nevada Solar One CSP project in Boulder City, Nevada was commissioned in 2007. The next major project commissioned was the 75 MW Martin Next Generation Solar Project near Indianatown in Martin County, Florida. Table 5-2 contains a list of CSP projects in operation in the U.S. as of the writing of this report.

Project Name	Developer/ Owner	City/County	State	Capacity (MW)	Technology	Online Date
Solar Energy Generating System (SEGS) I	Luz/Nextra	Dagett	CA	13.8	Parabolic Trough	1985
SEGS II	Luz/Nextra	Dagett	CA	30	Parabolic Trough	1986
SEGS III	Luz/Nextra	Kramer Junction	CA	30	Parabolic Trough	1987
SEGS IV	Luz/Nextra	Kramer Junction	CA	30	Parabolic Trough	1987
SEGS V	Luz/Nextra	Kramer Junction	CA	30	Parabolic Trough	1988
SEGS VI	Luz/Nextra	Kramer Junction	CA	30	Parabolic Trough	1989
SEGS VII	Luz/Nextra	Kramer Junction	CA	30	Parabolic Trough	1989
SEGS VIII	Luz/Nextra	Harper Lake	CA	80	Parabolic Trough	1990
SEGS IX	Luz/Nextra	Harper Lake	CA	80	Parabolic Trough	1991
Saguaro Solar Power Plant	Solargenix	Red Rock	AZ	1	Parabolic Trough	2005
Nevada Solar One	Acciona	Boulder City	NV	72	Parabolic Trough	2007
Kimberlina	Ausra	Bakersfield	CA	5	Linear Fresnel	2009
Sierra SunTower	eSolar	Lancaster /Antelope Valley	CA	5	Tower	2009
Holaniku at Keyhole Point	Sopogy	Kona	HI	2	Parabolic Trough	2009
Martin Next Generation Solar Energy Center	Florida Power & Light	Martin County	FL	75	Parabolic Trough	2010
Maricopa Solar Power Plant	Tessera Solar	Phoenix	AZ	1.5	Dish-engine	2010
Colorado Integrated Solar Project (Cameo)*	Abengoa/Xcel	Palisades	CO	2	Parabolic Trough	2010

*Colorado Integrated Solar Project uses solar energy to preheat water boiler feed water in a coal fired plant

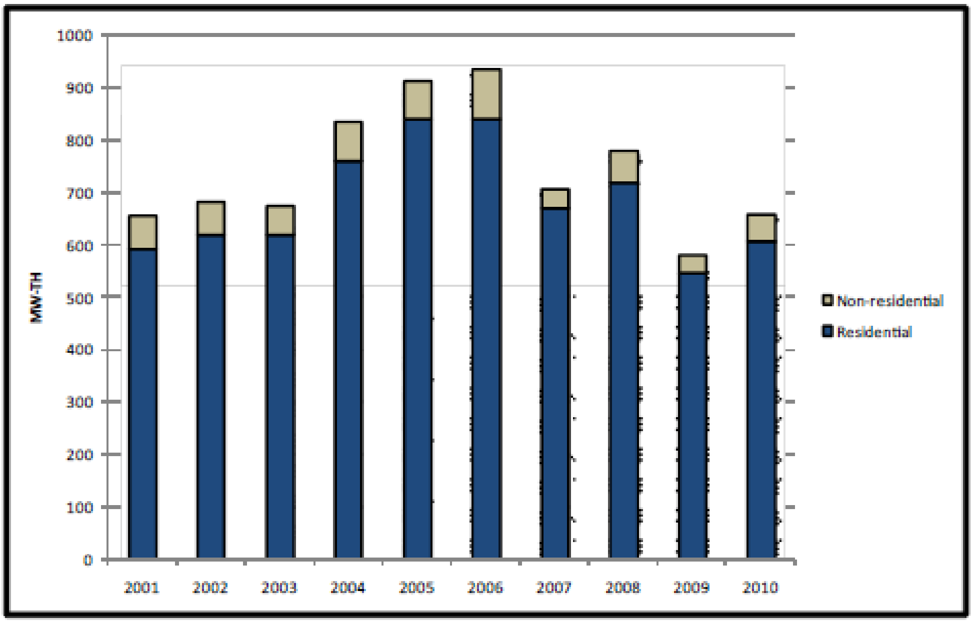
Table 5-2: CSP plants in the U.S. (Data sources NREL [7]

According to the National Renewable Laboratory there are 6 CSP projects under construction in the U.S. as shown in Table 5-3. Four projects with a combined capacity of 738.5 MW are scheduled for completion in 2013 and two projects with a combined capacity of 500 MW in 2014. Those scheduled for completion in 2013 include the 250 MW Solana plant in Arizona and the 377 MW Ivanpah power tower plant in California.

Project Name	Developer/ Owner	City/County	State	Capacity (MW)	Technology	Online Year
Tooele Army Depot	Infinia	Tooele	UT	1.5	Dish/ Engine	2013
Ivanpah Solar Electric Generating System	BrightSource Energy	Primm	CA	377	Power tower	2013
Crescent Dunes Solar Energy Project	SolarReserve	Tonopah	NV	110	Power tower	2013
Solana Generating Station	Abengoa Solar	Pheonix /Maricopa	AZ	250	Parabolic Trough	2013
Genesis Solar Energy Project	Genesis Solar, NextEra	Blythe	CA	250	Parabolic Trough	2014
Mojave Solar Project	Mojave Solar, Abengoa Solar	Harper Dry Lake	CA	250	Parabolic Trough	2014

Table 5-3 CSP plants under construction in the U.S. (Data sources: NREL [7], Ivanpah Solar Electric[10]

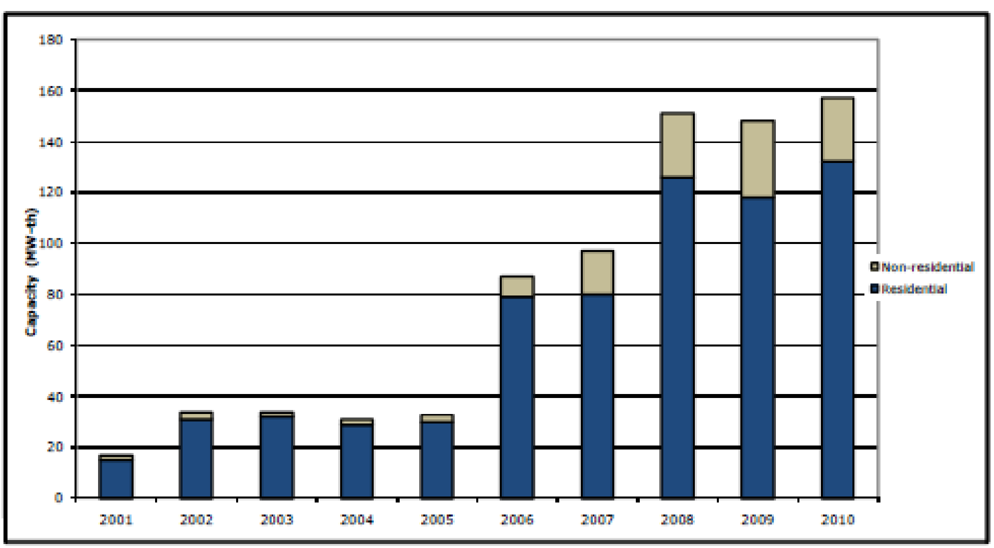
One of the most common applications for solar thermal energy in the U.S. is for heating swimming pools. Solar pool heating installations are concentrated in California and Florida. Figure 5-9 shows the capacity installed annually, in thermal megawatts (MW_{th}), of solar thermal systems used for heating swimming pools.



*Capacity in thermal megawatts (MW_{th})

Figure 5-9: Annual installed U.S. capacity for solar pool heating (2001-2010) (Source: IREC [11])

The other major uses of solar thermal energy are water heating and space heating/cooling. Figure 5-10 shows the annual installed capacity of solar thermal systems used for water heating and space heating/cooling from 2002 to 2010.



*Capacity in thermal megawatts (MW_{th})

Figure 5-10: Annual installed U.S. capacity for solar heating and cooling (2002-2010) (Source: IREC [11])

5.4 Solar energy in Indiana

As can be seen in the U.S. solar radiation map (Figures 5-8) Indiana is in a region of the country that has the lowest annual average solar radiation. It is therefore unlikely that it would be the location of choice for multi-megawatt electricity generating plants such as the 354 MW SEGS facility in California or the 64 MW Nevada Solar One plant referred to in Section 5.3. However there is some potential for water heating applications of solar thermal technologies. According to the EIA 2011 solar thermal collector manufacturing report, Indiana was the 20th top destination for solar thermal collectors in 2009 [12].

Figure 5-11 shows the solar radiation available to a flat collector facing south in Indiana. Flat plate collectors are typically used for water heating applications. As can be seen in the figure, the southern half of the state has more radiation available.

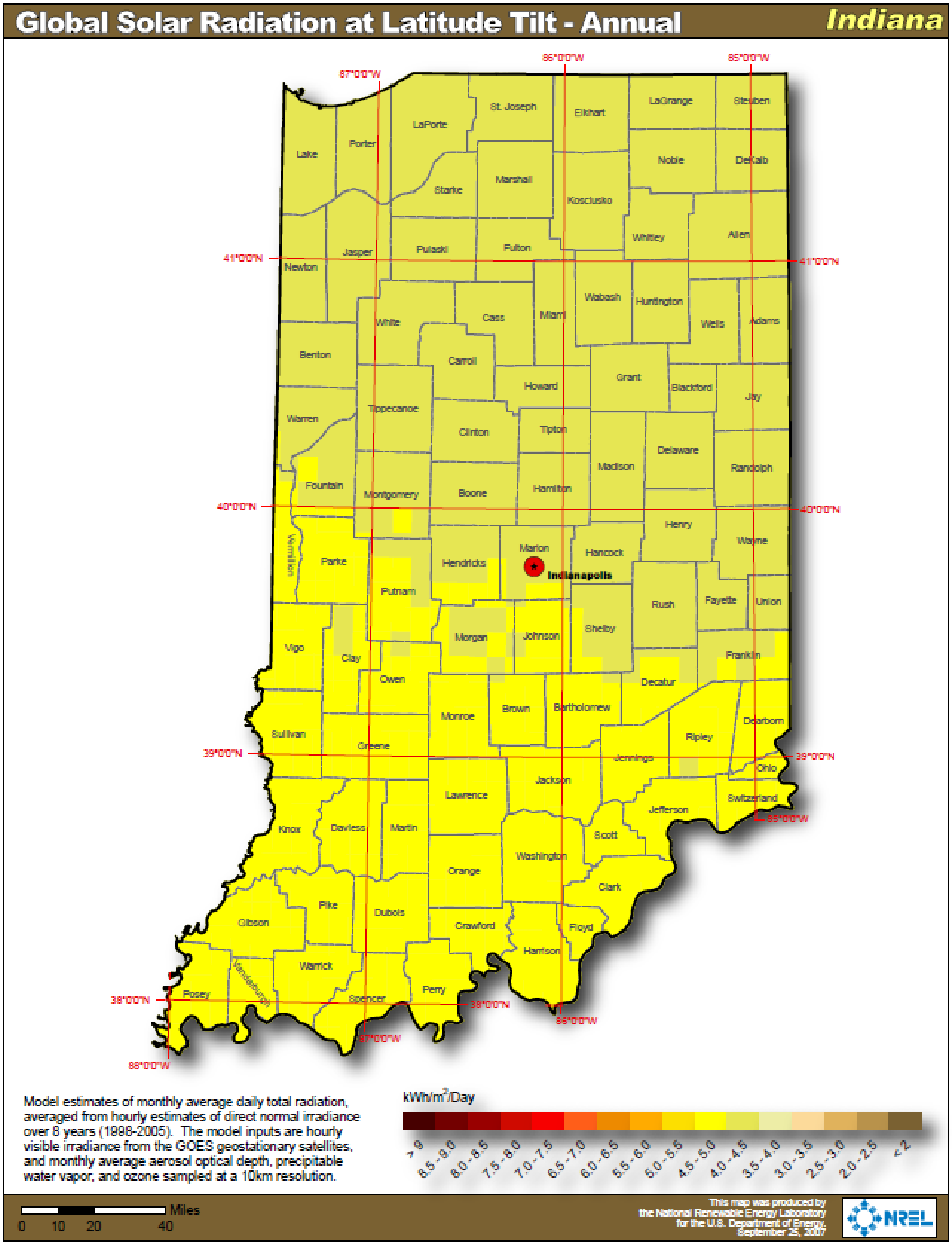


Figure 5-11: Direct normal solar radiation (flat-plate collector) (Source: NREL [13])

5.5 Incentives for solar energy

The following available incentives are available for solar thermal energy projects:

Federal Incentives

- Business Energy Investment Tax Credit (ITC) credits up to 30 percent of expenditures on solar systems [14].
- U.S. DOE Loan Guarantee Program (Section 1703, Title IV of Energy Policy Act (EPAct) of 2005 provides loan guarantees for large scale innovative renewable energy projects. The program is authorized for $10 billion and focuses on projects costing over $25 million. A supplementary loan guarantee program authorized by the American Recovery and Reinvestment Act of 2009 under Section 1705 of EPAct expired in 2011 [14].
- Modified Accelerated Cost-Recovery System (MACRS) + Bonus Depreciation allows businesses to recover investments in qualified renewable energy technologies through depreciation deductions. A provision for a 50 percent first year bonus depreciation was added by the Stimulus Act of 2008. This provision expires at the end of 2013 [14].
- Qualified Energy Conservation Bonds (QECBs) are qualified tax credit bonds that are allocated to each state based upon the state's percentage of the U.S. population. The states are then required to allocate a certain percentage to "large local governments." In February 2009, these funds were expanded to $3.2 billion [14].
- Residential Energy Conservation Subsidy Exclusion established by Section 136 of the IRS Code, makes direct and indirect energy conservation subsidies provided by public utilities nontaxable [14].
- Rural Energy for America Program (REAP) covers up to 25 percent of costs for eligible projects at certain types of institutions. Eligible renewable energy projects include wind, solar, biomass and geothermal; and hydrogen derived from biomass or water using wind, solar or geothermal energy sources. REAP incentives are generally available to state government entities, local governments, tribal governments, land-grant colleges and universities, rural electric cooperatives and public power entities, and other entities, as determined by USDA [14].
- High Energy Cost Grant Program administered by USDA is aimed at improving the electricity supply infrastructure in rural areas having home energy costs exceeding 275 percent of the national average. Eligible infrastructure includes renewable resources generation [16].
- Energy Efficiency Mortgage can be used by homeowners to finance a variety of energy efficiency measures, including renewable energy technologies, in new or existing homes. The federal government supports these loans by insuring them through FHA or VA programs. This allows borrowers who might otherwise be denied loans to pursue energy efficient improvements, and it secures lenders against loan default,

providing them confidence in lending to customers who would usually have been denied credit [14].

- Residential Renewable Energy Tax Credit allows taxpayers to claim 30 percent of their qualifying expenditures on installation of renewable energy technologies including solar electric systems, solar water heaters, wind turbines and geothermal heat pumps [14].
- Green Power Purchasing Goal requires a minimum amount of the electric energy consumed by the federal government during any fiscal year to be from renewable sources. From 2010 to 2012 this goal was 5 percent, but from 2013 forward this goal is 7.5 percent. The amount of renewable-energy credit is doubled for electricity produced and used on-site at a federal facility, produced on federal lands and used at a federal facility, or produced on Indian land [11].

Indiana Incentives

- Solar Access Laws prevent planning and zoning authorities from prohibiting or unreasonably restricting the use of solar energy. Indiana's solar-easement provisions do not create an automatic right to sunlight, though they allow parties to voluntarily enter into solar-easement contracts which are enforceable by law [14].
- Net Metering Rule qualifies renewable resource facilities with a maximum capacity of 1 MW for net metering. The net excess generation is credited to the customer in the next billing cycle [14].
- Renewable Energy Property Tax Exemption provides property tax exemptions for solar thermal, PV, wind, hydroelectric and geothermal systems [14].
- Emissions Credits are available by electricity generators that do not emit NO_x and that displace utility generation under the Indiana Clean Energy Credit Program. These credits can be sold on the national market [17].
- Clean Energy Portfolio Goal sets a voluntary goal of obtaining 4 percent between 2013 and 2018, 7 percent between 2019 and 2024, and 10 percent by 2025, of electricity from clean energy sources based on 2010 retail sales. Participation in the goal makes utilities eligible for incentives that can be used to pay for the compliance projects [14].
- Northern Indiana Public Service Company offers feed-in tariff incentive rates for electricity generated from renewable resources for up to 15 years. The payments for solar facilities are $0.30/kW for solar facilities with a capacity below 10 kW and $0.26/kW for facilities up to 2 MW. The tariff is experimental and slated to run until December 31, 2013. The allowable generator generating unit size under the tariff is between 5 and 5,000 kW and the total system-wide capacity allowed is 30 MW. Five hundred kW of the total system-wide cap are reserved for solar projects of capacity less than 10 kW, and 500 kW for wind projects of capacity less than 10 kW [14, 18].

5.6 References

1. U.S. Department of Energy, Energy Efficiency and Renewable Energy (EERE). http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=12850
2. Solar Server, Online Portal to Solar Energy. http://www.solarserver.com/knowledge/basic-knowledge/solar-collectors.html
3. National Renewable Energy Laboratory (NREL). Fuel from the sky: solar energy's potential for Western energy supply. http:// www.nrel.gov/docs/fy02osti/32160.pdf
4. International Energy Agency. SolarPACES solar thermal power systems network. http://www.solarpaces.org/CSP_Technology/csp_technology.htm
5. EERE. Solar Energy technologies program: Multi-year program plan 2007 – 2011. January 2006. http://www1.eere.energy.gov/solar/pdfs/set_myp_2007-2011_proof_1.pdf
6. EERE. Dish engine for concentrating solar power. http://www.eere.energy.gov/basics/renewable_energy/dish_engine.html
7. NREL. Concentrating solar projects. http://www.nrel.gov/csp/solarpaces/
8. U.S. Energy Information Administration (EIA). Updated capital cost estimates for utility scale electricity generation plants. April 2013. http://www.eia.gov/forecasts/capitalcost/pdf/updated_capcost.pdf
9. NREL. http://www.nrel.gov/gis/solar.html
10. Ivanpah Solar Electric Generating System. http://ivanpahsolar.com/about
11. IREC. U.S. solar market trends 2010. http://irecusa.org/wp-content/uploads/2011/07/IREC-Solar-Market-Trends-Report-revised070811.pdf
12. EIA. Solar Thermal Collector Manufacturing Activities 2009. Table 2-6 Shipments of Solar Thermal Collectors by Destination. ftp://ftp.eia.doe.gov/renewables/017409.pdf
13. NREL. MapSearch. http://www.nrel.gov/gis/mapsearch/
14. Database of State Incentives for Renewables and Efficiency (DSIRE). http://www.dsireusa.org/
15. Center for Rural Affairs. Value added producer grants program fact sheet, 2007. http://www.cfra.org/resources/vapg/fact_sheet
16. U.S. Department of Agriculture, Rural Development, Electric Programs. http://www.rurdev.usda.gov/UEP_Our_Grant_Programs.html
17. Indiana Department of Environmental Management. Indiana clean energy credit program. http://www.in.gov/idem/4134.htm
18. Northern Indiana Public Service Company. http://www.nipsco.com/en/our-services/connecting-to-the-grid.aspx

6. Photovoltaic Cells

6.1 Introduction

Unlike solar thermal systems discussed in Section 5 of this report, photovoltaic (PV) cells convert solar energy directly into electricity without having to first convert it to heat. In addition, since PV cells use both direct and indirect sunlight, their use is more geographically widespread than solar thermal systems that require access to direct solar radiation. Figure 6-1 shows the layout and functioning of a PV cell. When the photons in sunlight strike the surface of a photovoltaic cell, some of them are absorbed. The absorbed photons cause free electrons to migrate in the cell, thus causing "holes." The resulting imbalance of charge between the cell's front and back surfaces creates a voltage potential like the negative and positive terminals of a battery. When these two surfaces are connected through an external load, electricity flows [1].

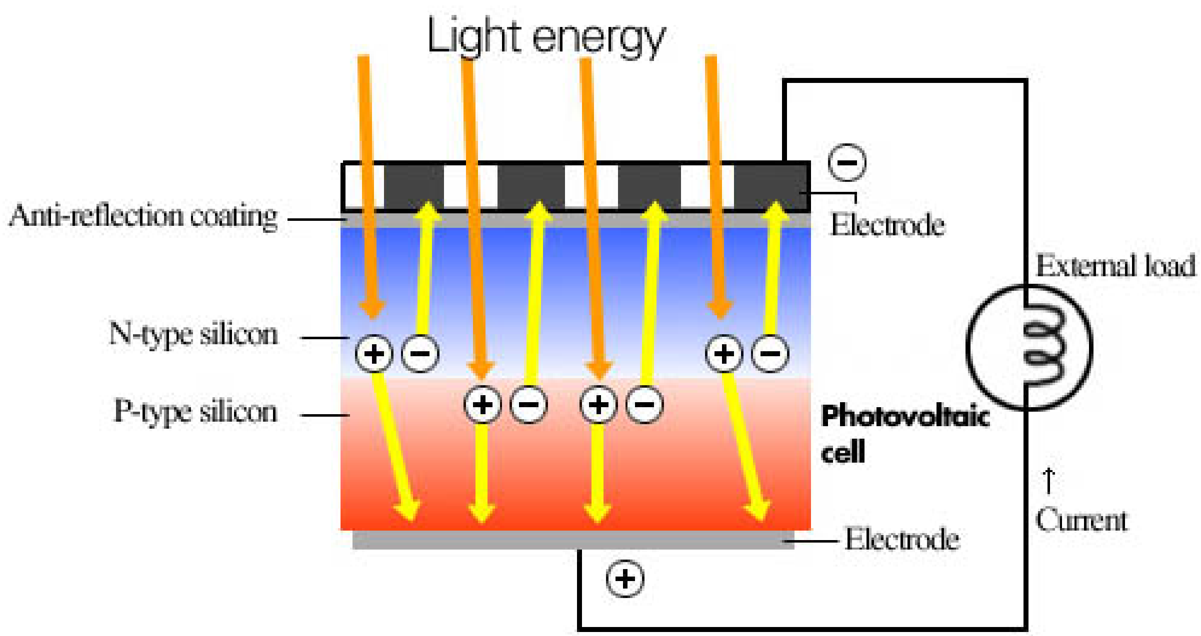


Figure 6-1: Photovoltaic cell operation (Source: EIA [2])

The photovoltaic cell is the basic building block of a PV system. Individual cells range in size from 0.5 to 4 inches across with a power output of 1 to 2 watts (W). To increase the power output of the PV unit, the cells are interconnected into a packaged, weather-tight module, typically with a 50-100 W power output as shown in Figure 6-2. Several PV modules are then connected to form an array. A complete PV system will include other components such as inverters and mounting systems [1Q, 3].

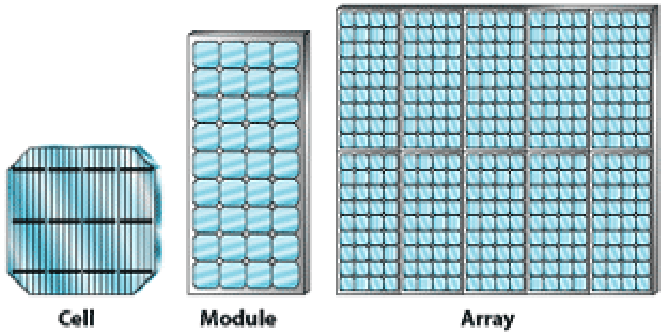


Figure 6-2: Illustration of a cell, module and array of a PV system (Source: EERE [3])

There are currently three main types of PV cell technologies in commercial use: crystalline silicon, thin-film and concentrating PV cells. Other PV cells being developed use new materials instead of silicon, including solar dyes, solar inks and organic polymers. The crystalline silicon cell is the most common PV cell technology and was the first PV technology to be developed. It was developed in the 1950s and was initially used to power satellites and smaller items like watches and electronic calculators. As the prices of PV systems declined, their use spread to other areas such as highway signs and other facilities remote from the electricity grid. In more recent years PV power systems have gained more widespread application as grid-connected generating resources with nearly 8,000 MW of grid-connected PV systems installed in the U.S. since 2000 [4, 5].

Unlike crystalline silicon cells, thin-film cells are made by depositing thin layers of non-crystalline (amorphous) silicon or other photovoltaic material on low-cost substrate material. As a result, thin-film PV cells have a lower cost per unit of area than crystalline silicon cells. However, since they have a lower energy conversion efficiency, this cost advantage is reduced by the required larger surface area relative to a crystalline silicon PV system with the same power rating. One of the main advantages of thin-film PV cells is that they can be made into flexible panels that are easily fitted onto building structures such as roofing shingles, facades and glazing on sky lights. Although a much newer technology, thin-film based PV systems have gained widespread use in the U.S. with 782 MW of grid-connected thin-film PV capacity having been installed in the U.S. in the last ten years [4, 5].

The third category of photovoltaic cell technology in commercial use is the concentrating photovoltaic cell (CPV) technology. CPV systems use optical lenses to focus the sun's rays onto small, high efficiency PV cells thus reducing the amount of photovoltaic material needed. Unlike the other photovoltaic technologies, CPV systems require direct sunlight and therefore their viability is restricted to sunny locations. At the writing of this report there were four grid-connected CPV systems with a total capacity of 37 MW in operation in the U.S. [5, 6].

The largest of these is the Alamosa Solar Generating Station installed in Alamosa, Colorado 2012. Figure 6-3 shows the layout of a CPV cell.

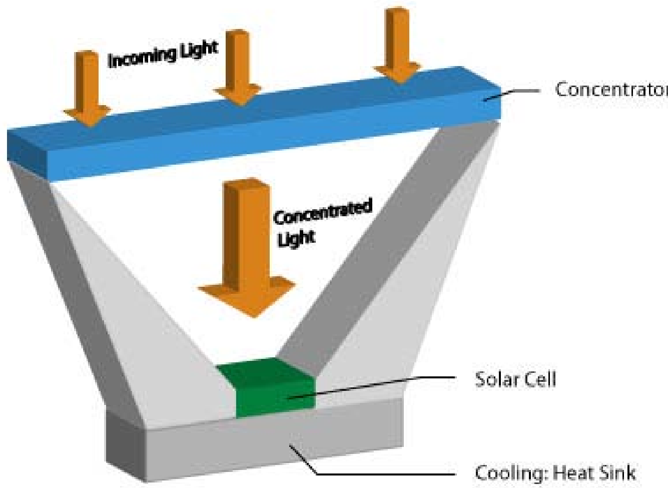
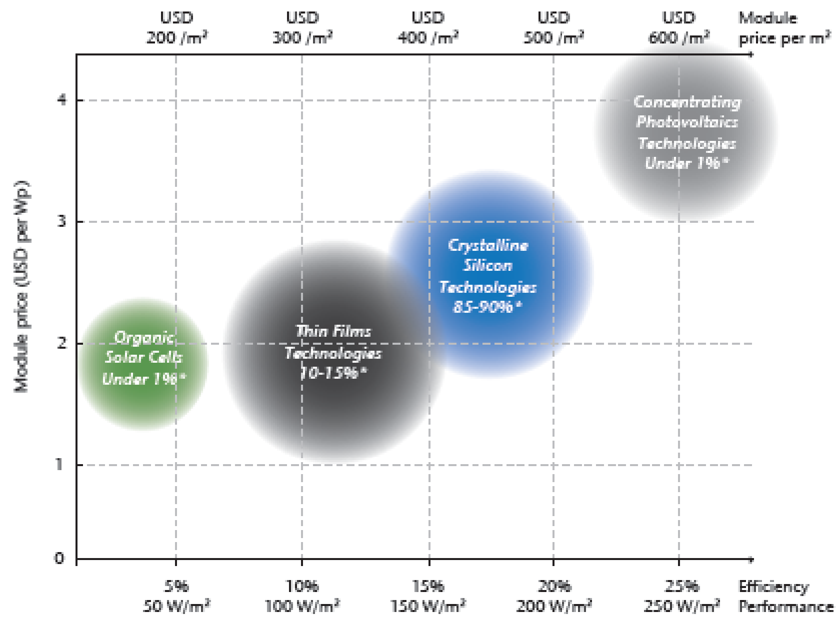


Figure 6-3: Illustration of concentrating photovoltaic cell (Source: Green Rhino Energy [6])

Figure 6-4 shows an overview of the costs, efficiencies, and energy output per unit of surface area of various PV cell technologies given by the International Energy Agency in their 2010 roadmap. As can be seen in the figure, the crystalline silicon technology occupies a mid-range in the cost/efficiency continuum, thin-film technology's lower cost comes with a lower efficiency and the CPV technology's higher efficiency is coupled with proportionally higher cost. (Figure 6-4 also shows the costs and efficiency of organic cells; however, this technology is still in the development phase.)



*percentage share of 2008 global market

Figure 6-4: Performance and price of different PV technologies (Source IEA [1])

6.2 Economics of PV systems

Figure 6-5 shows EIA's estimates of the overnight capital cost[5] of a utility scale photovoltaic electricity generating plant alongside other utility scale electricity generating technologies. The photovoltaic capital cost is mid-range among the renewable technologies, with the larger of the two plants modeled by EIA having an overnight capital cost of $3,873/kW and the smaller plant (50 MW) having an overnight capital cost of $4,183/kW. On-shore wind has the lowest capital cost among the renewables at $2,200/kW and municipal solid waste has the highest at $8,312/kW.

[5] Overnight capital cost "*is an estimate of the cost at which a plant could be constructed assuming that the entire process from planning through completion could be accomplished in a single day*" [7]. The overnight cost concept is used to avoid the impact of the differences in financing methods chosen by project developers on the estimated costs.

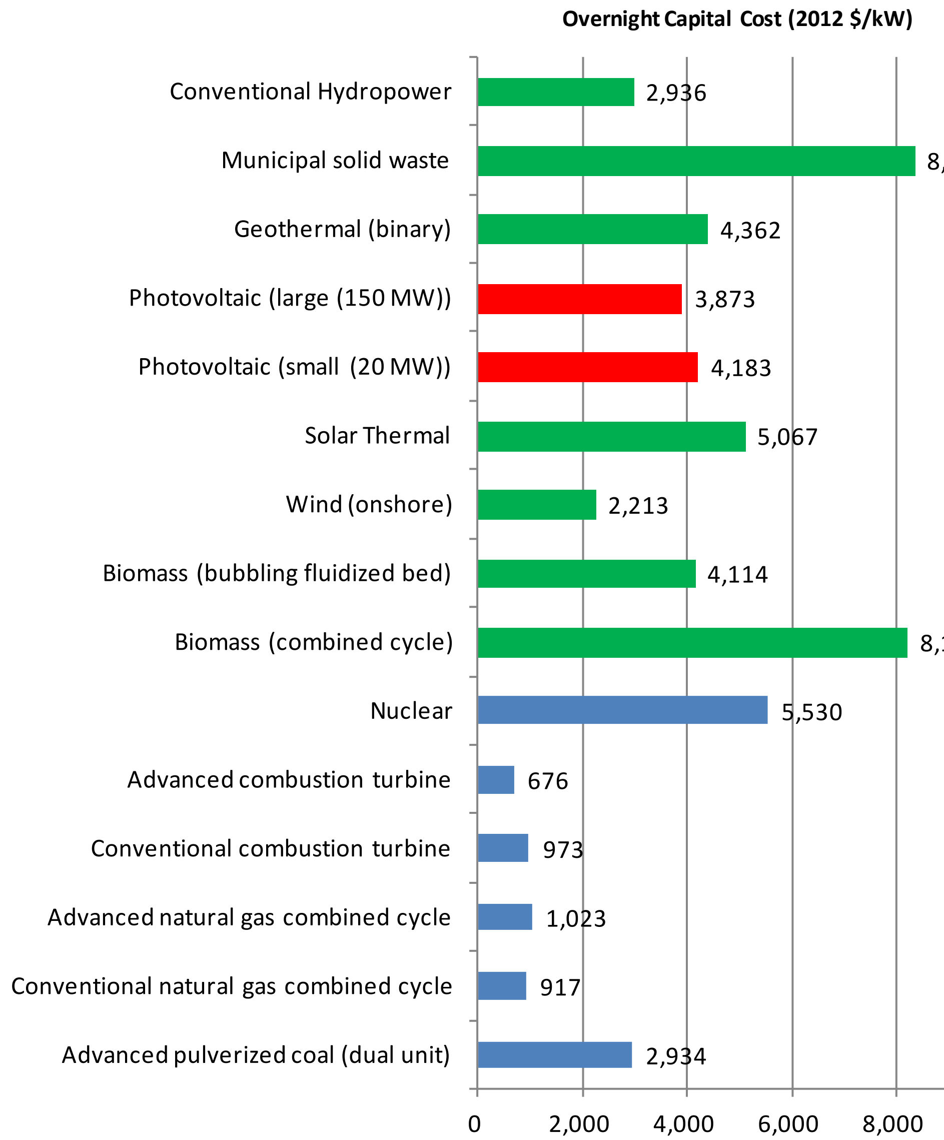


Figure 6-5: Capital cost of generating technologies (Data source: EIA [7])

Since 2008 the Lawrence Berkeley National Laboratory has issued an annual report on the historical trends in the installed price of PV systems in the U.S. Figure 6-6 and Figure 6-7 show those trends for the two categories in the Berkeley Lab report. The system installed price shown in the figures is upfront cost born by the PV systems not including any financial incentives. The residential and commercial PV category includes all systems installed at residential customer sites, all rooftop mounted systems in non-residential customer sites and all ground-mounted systems less than 2 MW installed on non-residential customer sites. The utility-scale systems in Figure 6-7 includes all ground-mounted systems of 2 MW and above.

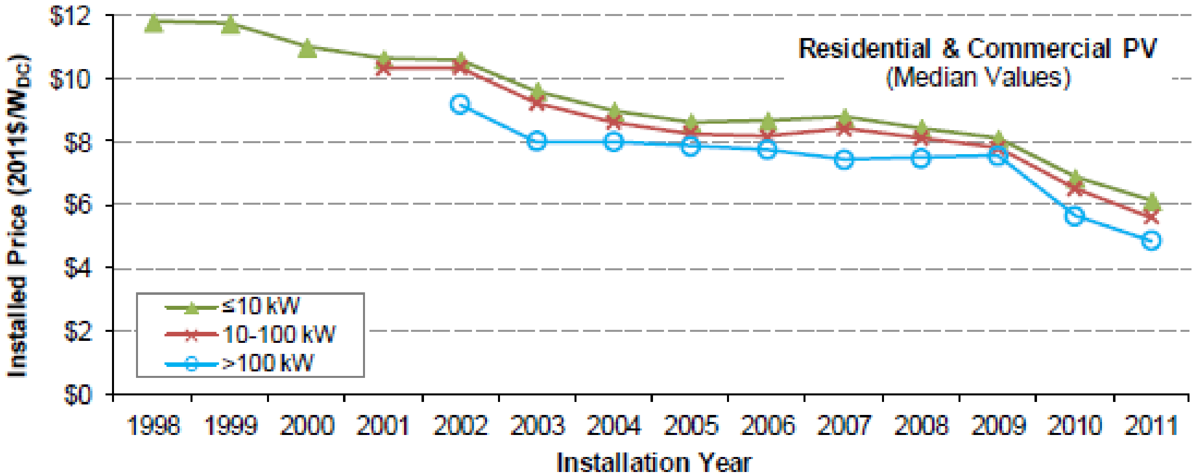


Figure 6-6: Installed price trends over time for residential and commercial PV systems (Source: Berkeley [8])

As can be seen in Figure 6-6 the installed price for residential and commercial systems has been in steady decline in the entire period represented in the sample, declining by an average of 5-7 percent depending on the system size. According to the Berkeley Lab report the two year halt in the declining trend 2005 to 2009 is attributed to a supply shortage as the PV suppliers struggled to keep pace with the rapid growth in PV installations worldwide. The year to year decline in installed prices for residential and commercial PV systems in 2011 was 14 percent for systems larger than 10 kW and 11 percent for systems 10 kW and below.

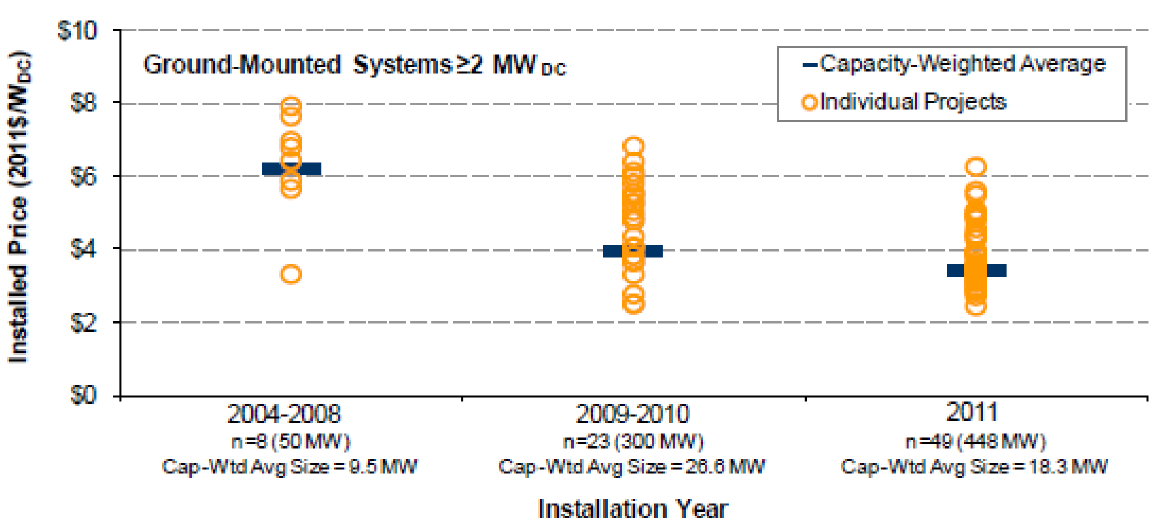


Figure 6-7: Installed price trends over time for utility-scale PV systems (Source: Berkeley [8])

Although there was an overall decline in installed prices for the utility-scale systems shown in Figure 6-7, the trend is not as clear as in the residential and commercial sector.

According to the Berkeley Lab report the challenge in establishing a clear trend in this set of PV systems is attributable to the sample size being rather small and also very diverse. The number of utility-scale systems in the Berkeley data set is only 80 as compared to 152,311 in the residential and commercial category.

6.3 State of PV systems nationally

PV installed capacity in the U.S. has been increasing rapidly in the last decade growing from a mere 4 MW in 2000 to nearly 8,000 MW at the end March 2013. Figure 6-8 shows the annual and the cumulative installed capacity of grid-connected PV in the U.S.

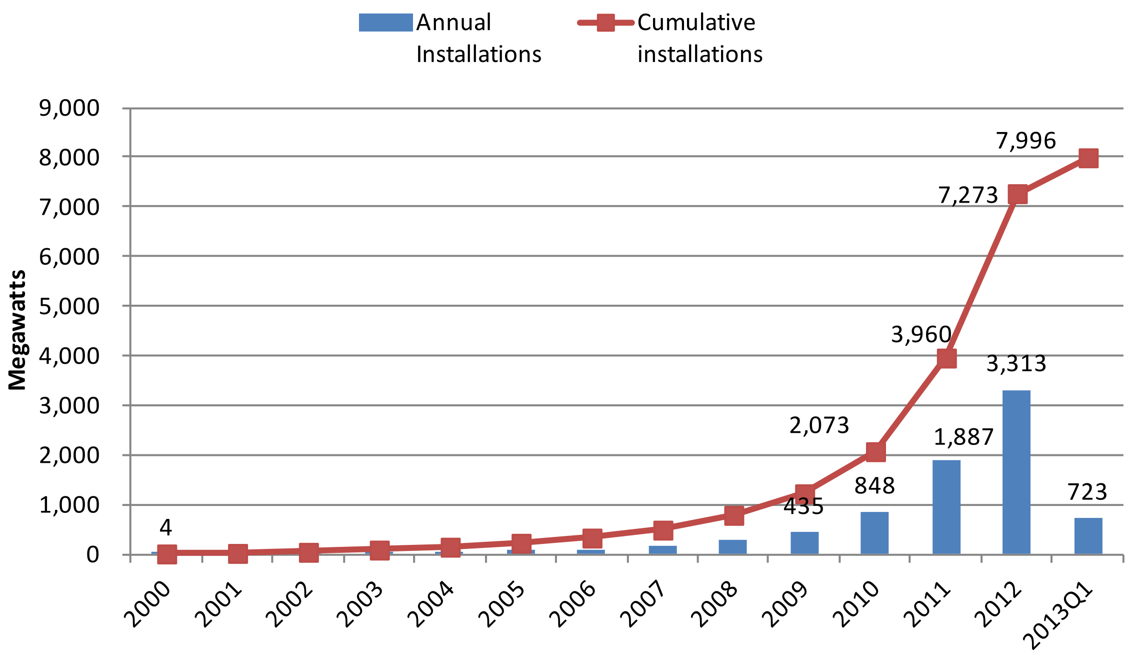


Figure 6-8: Grid-connected U.S. PV installed 2000 to 2011 (Data source SEIA [9, 10])

The main factors behind this rapid expansion have been state and federal financial incentives and state renewable portfolio standards (RPS) with specific provisions for solar technologies. At the state level, sixteen states and the District of Columbia (DC) have a RPS with specific quota for solar or for customer-side distributed generation. PV systems are the most common renewable energy technologies in use for residential customer-side distributed generation. Figure 6-9 shows the various forms of solar provisions in state RPSs. Sixteen states and the District of Columbia offer rebates for PV projects and 46 states offer some form of financial incentive for PV projects. Figure 6-10 shows the various types of financial incentives offered by states for solar projects [11]

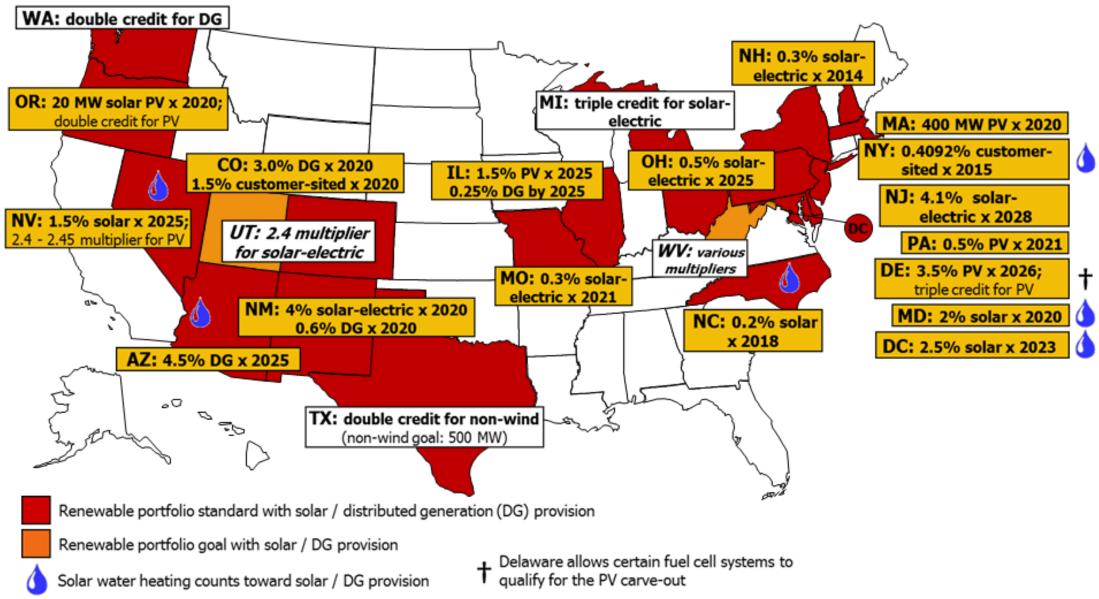


Figure 6-9: Renewable portfolio standards with solar carve-outs (Source DSIRE [11])

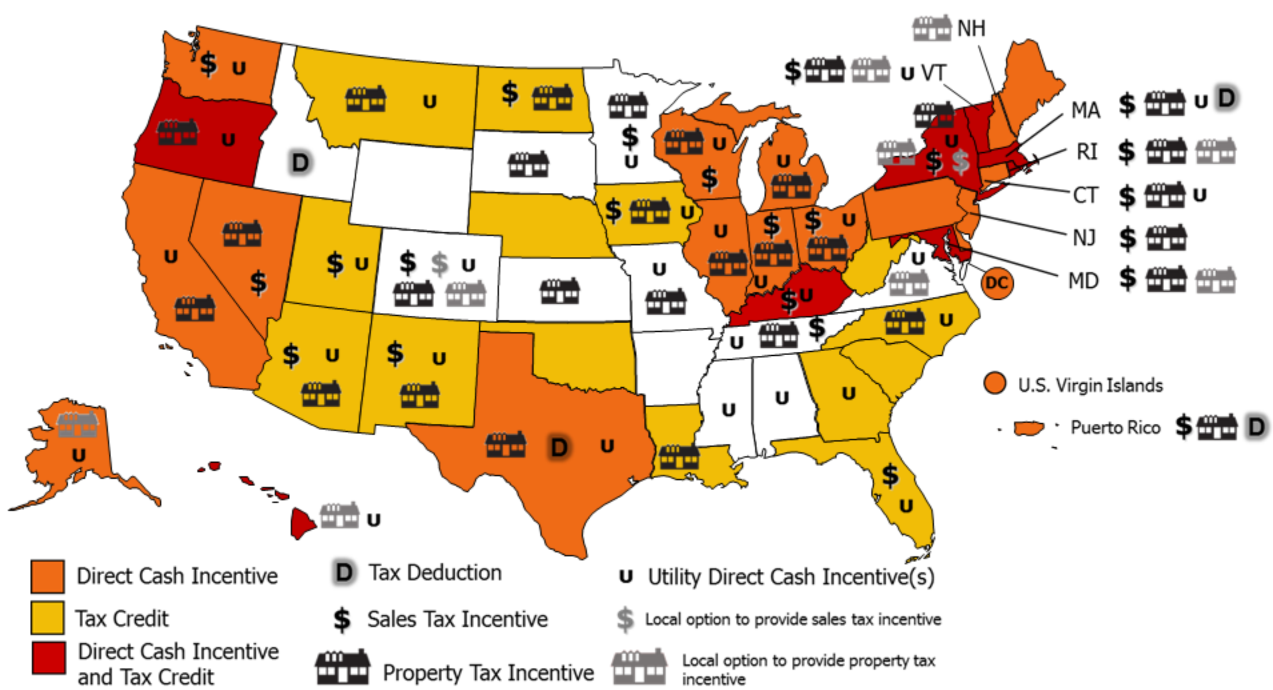


Figure 6-10: Financial incentives for solar-photovoltaic systems (Source DSIRE [11])

Federal financial incentives introduced in 2008 and 2009 have added to the accelerated growth, especially in multi-megawatt utility scale projects. These federal incentives are:

- The extension and modification of the 30 percent investment tax credit (ITC) to remove the $2,000 cap on personal ITC and to allow electric utilities access to the ITC;
- The provision by the American Recovery and Reinvestment Act (ARRA) for a 30 percent cash grant in lieu of the ITC and the production tax credit; and
- The provision in ARRA for funds for a U.S. Department of Energy (DOE) loan guarantee program targeted towards renewable energy resources (and transmission projects).

These federal incentives are credited with the rapid rise in multi-megawatt utility scale projects that have been constructed since then. Table 6-1 lists PV projects in the U.S. having a capacity greater than 20 MW and above, all of which have been constructed since 2009. The two federal programs enacted under ARRA, the loan guarantee and the 30 percent cash grant program, expired in September of 2011 and December 2011, respectively. The ITC in its current state is authorized until 2016 after which the amount of credit will be reduced from 30 percent to 10 percent for solar systems.

Project Name	Developer	Capacity (MW)	Online Date	Electricity Purchaser	State
California Valley Solar Ranch	SunPower	130	2012	Pacific Gas & Electric	CA
AV Solar Ranch One	First Solar	115	2013	Pacific Gas & Electric	CA
Agua Caliente	First Solar	100	2012	Pacific Gas & Electric	AZ
Copper Mountain 2	First Solar	92	2012	Pacific Gas & Electric	NV
Agua Caliente	First Solar	70	2012	Pacific Gas & Electric	AZ
Alpine Solar Project	First Solar	66	2013	Pacific Gas & Electric	CA
Mesquite Solar	Sempra Generation	66	2013	Pacific Gas & Electric	AZ
Catalina Solar Project	EDF Renewables	60	2013	San Diego Gas & Electric	CA
Copper Mountain Solar Project	First Solar/Sempra Generation	55	2010	Pacific Gas & Electric	NV
Silver State North Solar Project	First Solar	50	2012	NV Energy	NV
Agua Caliente	First Solar	50	2012	Pacific Gas & Electric	AZ
Alpaugh	GCL-Poly Solar Project Solutions	50	2012	Pacific Gas & Electric	CA
Mesquite Solar	Sempra Generation	46	2012	Pacific Gas & Electric	AZ
Long Island Solar Farm	BP Solar	38	2011	Long Island Power Authority	NY
Mesquite Solar Phase 1	Sempra Generation	38	2011	Pacific Gas & Electric	AZ
Austin Energy PV Project	SunEdison	34	2011	Austin Energy	TX
Alamosa Solar Generating Project	Cogentrix	30	2012	Public Service Company of Colorado	CO
Cimarron I Solar Project	First Solar	30	2010	Tri-State G&T Cooperative	NM
Agua Caliente	First Solar	30	2012	Pacific Gas & Electric	AZ
McKenzie Road Solar Farm	Recurrent Energy	30	2013	Sacramento Municipal Utility District	CA
San Luis Valley Solar Ranch	SunPower/Iberdrola	30	2011	Xcel Energy	CO
Borrego Solar Project	NRG Energy/SunPower	26	2013	SDG&E	CA
DeSoto Next Generation Solar Energy Center	SunPower	25	2009	Florida Power & Light	FL
McHenry Solar Farm	SunPower	25	2012	Modesto Irrigation District	CA
Sun City Project	Eurus	23	2011	Pacific Gas & Electric	CA
Imperial Valley Solar Company 1	SunPeak Power	23	2012	Imperial Irrigation District	CA
Copper Crossing	SunPower/Iberdrola	23	2011	Salt River Project	AZ
Sand Drag Solar Project	Eurus	22	2011	Pacific Gas & Electric	CA
FSE Blythe	First Solar	21	2009	Southern California Edison	CA

Table 6-1: PV systems with capacity greater than 20 MW installed in the U.S. (Data source: SEIA [5])

6.4 PV systems in Indiana

Similar to the nation, Indiana has seen a rapid growth in the amount of PV capacity installed. According to the *Open PV Project* database maintained by the National Renewable Energy Laboratory (NREL) [12], there were 313 PV installations in Indiana totaling 4.4 MW at the time this report was written. Over 65 percent of that capacity was installed in 2011. The installed capacity is set to increase substantially with the 10 MW installation currently under construction at the Indianapolis International Airport. In addition Indianapolis Power & Light has power purchase agreements that will increase the PV capacity in its supply portfolio from the current 2.1 MW to 100 MW [13]. Figure 6-11 shows the annual and cumulative PV capacity installations as reported to the NREL *Open PV Project* database.

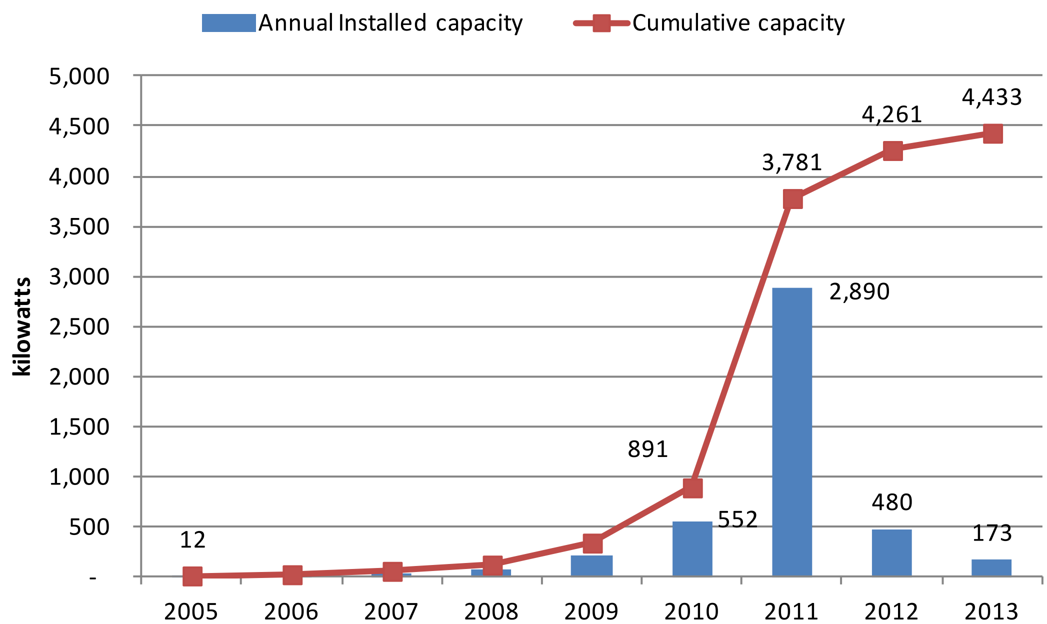


Figure 6-11: Indiana installed PV capacity in NREL *Open PV Project* database (Data source NREL [12]

The largest PV installation currently is the 2,010 kW project at the Fort Harrison Federal Compound in Indianapolis. The second largest PV installation in Indiana is a 186 kW project at the Metal Pro Roofing Corporation of Franklin City in Johnson County, followed by a 100 kW installation at the Johnson Melloh renewable energy demonstration laboratory in Indianapolis. Table 6-2 lists the 32 PV installations with a capacity of 13 kW and above.

Owner /Developer	Rated Capacity (kW)	Location	Date Installed	Cost ($/Watt)
US General Services Administration	2,010	Fort Benjamin Harrison, Indianapolis	2011	n/a
Metal Pro Roofing	186	Franklin, Johnson County	2011	n/a
Johnson Melloh Solutions Demonstration Lab	100	Indianapolis	2011	n/a
Transpo Bus Station	93	South Bend	2010	n/a
Lakestation Indiana City Hall	73	Lakestation, Lake County	2011	n/a
Monroe County Board of Commissioners	64	Bloomington	2012	n/a
Laurelwood Apartments	60	Indianapolis	2011	n/a
Johnson Melloh Solutions	50	Carmel, Hamilton County	2012	n/a
Stinson-Remick Hall, Notre Dame	50	University of Notre Dame	2010	10.00
Greenworks Energy	48	Educational Institution, Marion County	January 2013	n/a
IUPUI Business School	43	Indianapolis	April 2013	5.70
Home Energy	29	Valparaiso	2012	2.26
Unitarian Church Bloomington	24	Bloomington	April 2013	3.26
Roosevelt Center	20	Elkhart	2012	n/a
Home Energy LLC	20	Elkhart	2012	6.08
Home Energy LLC	20	Goshen	2011	6.40
Goshen Family Physicians	20	Goshen	2011	n/a
Residential	19	Mentone, Kosciusko County	2010	n/a
Residential	17	Newburgh, Warrick County	2012	4.05
Agricultural	17	Whitley County	2012	n/a
Residential	17	Markleville, Hancock County	2011	n/a
Residential	16	Warrick County	2012	n/a
Cool Creek Park	16	Carmel, Hamilton County	2010	8.35
Nusun Solar	15	Columbus	2011	4.50
Residential	15	Dale, Spencer County	2012	3.42
Morton Solar Wind, LLC	14	Evansville	2012	3.66
IBEW Local Union 725	14	Terre Haute	2010	6.04
Commercial Establishment	14	Connersville, Fayette County	2007	14.25
Residential	13	Terre Haute	2009	7.76
McCormick Motors	13	Nappanee, Elkhart County	2011	n/a
Commercial Establishment	13	Elkhart	2010	5.00
Hope Builders	13	Elkhart	2010	n/a

Table 6-2: PV systems in Indiana of 13kW and above capacity (Data source: NREL [12])

As explained previously, the factors being credited with the rapid growth in the PV market in last few years include federal, state and utility incentives. The federal incentives include the renewal and expansion of the investment tax credit to remove the $2,000 cap on personal tax credit and to allow electric utilities access to the investment tax credit. In addition the 2009 American Recovery and Reinvestment Act provided for an alternative 30 percent cash grant in lieu of the investment tax credit and provided additional funds for renewable energy projects in the DOE loan guarantee program. The favorable factors in Indiana include the experimental feed-in tariffs by Indianapolis Power and Light (IPL) and Northern Indiana Public Service Company (NIPSCO) and the expansion of the Indiana net metering rule to include all customer classes and systems up to 1 MW. The IPL experimental feed-in tariff has since been discontinued. While it was in place it had offered $0.24/kWh for systems between 20 and 100 kW and $0.20/kWh for systems greater than 100kW up to 10 MW. The NIPSCO feed-in tariff, which is set to expire at the end of 2013, offers $0.30/kWh for electricity and the associated renewable credits for units less than 10 kW and $0.26 for solar facilities up to 2 MW. The total system-wide capacity available under the NIPSCO feed-in tariff was 30 MW with a requirement that no one technology would take up more than half of the cap. In addition 700 kW of the capacity was set aside for small PV projects (100 kW or less name-plate capacity) and 300 kW for small wind turbines. As of July 2013 the system-wide cap was fully subscribed except for 298.9 kW of the small wind set-aside. PV capacity of 12,348 kW had been committed for installation in NIPSCO territory under the tariff while an additional 2,762 kW was approved and in the queue [14].

6.5 Incentives for PV systems

Federal Incentives

- Business Energy Investment Tax Credit (ITC) credits up to 30 percent of expenditures on solar systems [11].
- U.S. DOE Loan Guarantee Program (Section 1703, Title IV of Energy Policy Act (EPAct) of 2005 provides loan guarantees for large scale innovative renewable energy projects. The program is authorized for $10 billion and focuses on projects costing over $25 million. A supplementary loan guarantee program authorized by the American the American Recovery and Reinvestment Act of 2009 under Section 1705 of EPAct expired in 2011 [11].
- Modified Accelerated Cost-Recovery System (MACRS) + Bonus Depreciation allows businesses to recover investments in qualified renewable energy technologies through depreciation deductions. A provision for a 50 percent first year bonus depreciation was added by the Stimulus Act of 2008. This provision expires at the end of 2013 [11].
- Qualified Energy Conservation Bonds (QECBs) are qualified tax credit bonds that are allocated to each state based upon the state's percentage of the U.S. population. The states are then required to allocate a certain percentage to "large local governments." Qualified energy conservation projects include renewable energy production projects [11].

- Residential Energy Conservation Subsidy Exclusion established by Section 136 of the IRS Code, makes direct and indirect energy conservation subsidies provided by public utilities nontaxable. Eligible technologies include PV, solar water heating and solar space heating [11].
- Rural Energy for America Program (REAP) promotes energy efficiency and renewable energy for agricultural producers and rural small businesses through the use of grants and loan guarantees for energy efficiency improvements and renewable energy systems. The program covers up to 25 percent of costs [11].
- High Energy Cost Grant Program administered by USDA is aimed at improving the electricity supply infrastructure in rural areas having home energy costs exceeding 275 percent of the national average. Eligible infrastructure includes renewable resources generation. USDA has allocated $21 million for the 2011 funding cycle [15].
- Energy Efficiency Mortgage program provides mortgages that can be used by homeowners to finance a variety of energy efficiency measures, including renewable energy technologies, in a new or existing home. The federal government supports these loans by insuring them through FHA or VA programs. This allows borrowers who might otherwise be denied loans to pursue energy efficient improvements, and it secures lenders against loan default, providing them confidence in lending to customers whom they would deny without the federal insurance [11].
- Residential Renewable Energy Tax Credit allows taxpayers to claim 30 percent of their qualifying expenditures on installation of renewable energy technologies including solar electric systems, solar water heaters, wind turbines and geothermal heat pumps [11].
- Green Power Purchasing Goal requires a minimum amount of the electric energy consumed by the federal government during any fiscal year to be from renewable sources. From 2010 to 2012 this goal was 5 percent, but from 2013 forward this goal is 7.5 percent. The amount of renewable-energy credit is doubled for electricity produced and used on-site at a federal facility, produced on federal lands and used at a federal facility, or produced on Native American land [11].

Indiana Incentives

- Solar Access Laws prevent planning and zoning authorities from prohibiting or unreasonably restricting the use of solar energy. Indiana's solar-easement provisions do not create an automatic right to sunlight, though they allow parties to voluntarily enter into solar-easement contracts which are enforceable by law [11].
- Net Metering Rule qualifies renewable resources with a maximum capacity of 1 MW for net metering in Indiana. The net excess generation is credited to the customer in the next billing cycle [11].

- Renewable Energy Systems Property Tax Exemption provides property tax exemptions for the entire renewable energy device and affiliated equipment. In March 2012 solar PV was added to the list of technologies eligible for property tax exemption. The exemption applies to both real property and mobile homes equipped with renewable energy systems and may only be claimed by property owners [11].
- Emissions Credits are available to electricity generators that do not emit NO_x and that displace utility generation under the Indiana Clean Energy Credit Program. These credits can be sold on the national market [16].
- Community Conservation Challenge Grant provides $25,000-$250,000 in grants for community energy conservation projects located in Indiana using commercially-available technologies. Projects include improving energy efficiency, renewable energy, reduction in energy demand or fuel consumption, and energy recycling. Projects must be public and have at least one community partner [11, 17].
- Sales and Use Tax Exemption for Electrical Generating Equipment exempts transactions involving manufacturing machinery, tools, and equipment used for the production of tangible personal property from state gross retail tax. This includes renewable generation equipment [11].
- Clean Energy Portfolio Goal sets a voluntary goal of obtaining 4 percent between 2013 and 2018, 7 percent between 2019 and 2024, and 10 percent by 2025, of electricity from clean energy sources based on 2010 retail sales. Participation in the goal makes utilities eligible for incentives that can be used to pay for the compliance projects [11].
- Indianapolis Power & Light Co. – Small Scale Renewable Energy Incentives Program offers compensation for new photovoltaic installations for residential and small-business customers. The compensation for solar is $2 per watt up to $4,000. Eligible solar systems are between 1kW and 19.9 kW [11, 18].
- Northern Indiana Public Service Company offers feed-in tariff incentive rates for electricity generated from renewable resources for up to 15 years. The payments for solar facilities are $0.30/kW for solar facilities with a capacity below 10 kW and $0.26/kW for facilities up to 2 MW. The tariff is experimental and slated to run until December 31, 2013. The maximum allowed generating unit size is 5 MW and the total system-wide capacity allowed under the tariff is 30 MW. Five hundred kW of the system-wide cap are reserved for solar projects of capacity less than 10 kW, and 500 kW for wind projects of capacity less than 10 kW [11, 19].

6.6 References

1. International Energy Agency (IEA) Technology roadmap, solar photovoltaic energy, October 2010. http://www.iea.org/publications/freepublications/publication/pv_roadmap.pdf.
2. Asia-Pacific Economic Cooperation. Virtual Center for Environmental Technology Exchange. http://www.apec-vc.or.jp/e/modules/tinyd00/index.php?id=74

3. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Department of Energy (EERE). PV systems. http://www.eere.energy.gov/basics/renewable_energy/pv_systems.html.
4. National Renewable Energy Laboratory (NREL). Solar photovoltaic technology basics. http://www.nrel.gov/learning/re_photovoltaics.html.
5. Solar Energy Industries Association (SEIA), Utility-scale solar projects in the United States: operating, under construction, or under development. http://www.seia.org/research-resources/major-solar-projects-list
6. Green Rhino Energy. Concentrating Photovoltaics (CPV). http://www.greenrhinoenergy.com/solar/technologies/pv_concentration.php
7. EIA. Updated capital cost estimates for utility scale electricity generation plants. April 2013. http://www.eia.gov/forecasts/capitalcost/pdf/updated_capcost.pdf
8. Lawrence Berkeley National Laboratory. Tracking the sun V: An historical summary of the installed cost of photovoltaics in the U.S. from 1998-2011. http://emp.lbl.gov/sites/all/files/lbnl-5919e.pdf
9. SEIA. U.S. solar market insight report, 2011 year-in-review, executive summary. http://www.seia.org/cs/research/SolarInsight
10. SEIA, U.S. solar market insight, first quarter 2013. http://www.seia.org/galleries/pdf/SEIA_Q2_2010_EXEC_SUMMARY.pdf
11. Database of State Incentives for Renewables and Efficiency (DSIRE). http://www.dsireusa.org/
12. NREL. The open PV Project. http://openpv.nrel.gov/
13. Indianapolis Power and Light Company. Small Scale Renewable Energy Incentive Program. http://www.iplpower.com/Business/Programs_and_Services/Renewable_Energy_Incentive_Program.aspx?terms=Small%20Scale%20Renewable%20Energy%20Incentive.
14. George Stevens. Indiana Utility Regulatory Commission.
15. U.S. Department of Agriculture, Rural Development, Electric Programs. http://www.usda.gov/rus/electric/hecgp/overview.htm.
16. Department of Environmental Management. Indiana clean energy credit program. http://www.in.gov/idem/4134.htm.
17. National Indiana Office of Energy Development. Community Conservation Challenge. http://energy.gov/savings/community-conservation-challenge.
18. Indianapolis Power & Light (IPL). March 4, 2013 news release. http://www.iplpower.com/Our_Company/Media/News/News_Items/2013/More_than_30_solar_projects_in_development_pipeline_for_IPL/.
19. Northern Indiana Public Service Company. http://www.nipsco.com/en/our-services/connecting-to-the-grid.aspx.

7. Hydropower

7.1 Introduction

Hydroelectric energy is produced by converting the kinetic energy of falling water into electrical energy. The moving water rotates a turbine, which in turn spins a generator to produce electricity. There are several different types of hydropower facilities, including [1]:

- Impoundment hydropower: This facility uses a dam to store water. Water is then released through the turbines to meet electricity demand or to maintain a desired reservoir level. Figure 7-1 shows a schematic of this type of facility.
- Pumped storage: When electricity demand and price are low, excess electricity is used to pump water from a lower reservoir to an upper reservoir. The water is released through the turbines to generate electricity when electricity demand and price is higher.
- Diversion projects: This facility channels some of the water through a canal or penstock. It may require a dam but is less obtrusive than that required for impoundment facilities.
- Run-of-river projects: This facility utilizes the flow of water of the river and requires little to no impoundment. Run-of-river plants can be designed for large flow rates with low head[6] or small flow rates with high head.
- Microhydro projects: These facilities are small in size (about 100 kW or less) and can utilize both low and high heads. These are typically be used in remote locations to satisfy a single, nearby home or business.

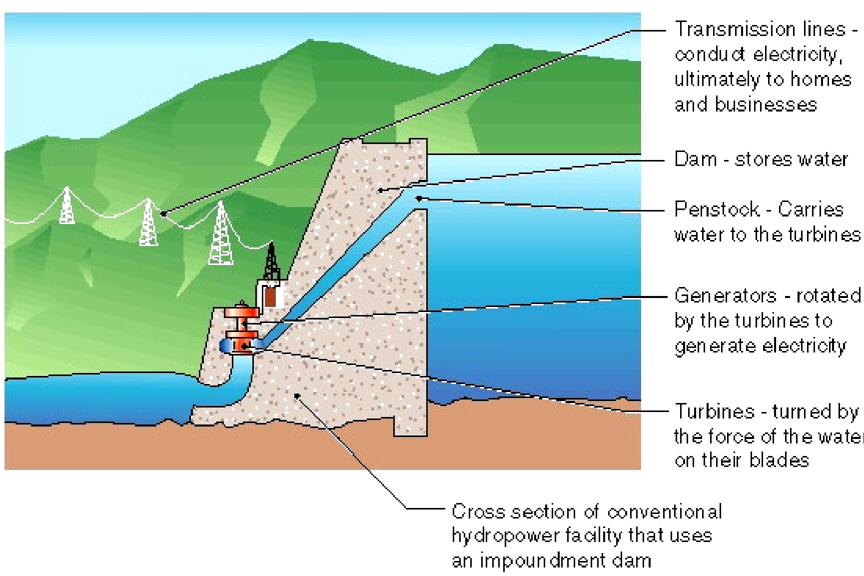


Figure 7-1: Schematic of impoundment hydropower facility (Source: INL [1])

[6] Head is the elevation difference between the water level above the turbine and the turbine itself. Higher head results in greater potential energy.

In addition, there are a variety of turbine technologies that are utilized for hydropower production. The type of turbine is chosen based on its particular application and the height of standing water. There are two main groups of turbines used in hydro power projects – the impulse and the reaction turbine types. The impulse turbine type uses the velocity of the water while the reaction turbine uses both the velocity of the water and the pressure drop as the water passes through the turbine. The impulse turbine is more suited to a high head, low flow application while the reaction turbine is more suited to a lower head, faster flow situation [2].

Hydropower is a renewable resource that has many benefits, including [3]:

- Hydropower is a domestic energy resource and does not require the transportation of fuels;
- Current hydropower turbines are capable of converting 90 percent of available energy to electricity, which is more efficient than any other form of generation;
- Hydroelectric facilities have quick startup and shutdown times, making them an operationally flexible asset, which is desirable in competitive and fluctuating electricity markets; and
- Hydroelectric facilities with impoundment can be used as a means of energy storage when combined with a pumped storage system.

Hydropower facilities also provide recreational opportunities for the community such as fishing, swimming, and boating in its reservoirs. Other benefits may include water supply and flood control. It has been estimated that of the 82,000 U.S. dams, only 3 percent have electricity production as their primary function [4].

One of the main limitations of hydroelectricity is that the amount of electricity that a facility can produce is very sensitive to the amount of precipitation in the watershed feeding the facility. Prolonged periods of below-normal rainfall can significantly cut hydropower production potential. Other unfavorable environmental impacts of hydroelectric facilities include:

- Blockage of upstream fish passage;
- Fish injury and mortality from passage through the turbine; and
- Changes in the quality and quantity of water released below dams and diversions, including low dissolved oxygen levels [5].

Other factors may also act as deterrents to potential hydropower projects, including the increasingly costly and uncertain process of licensing or relicensing. About 300 hydroelectric facilities will have to be relicensed through 2017. Though the Energy Policy Act of 2005 helped reform the licensing procedure, many still consider the process to be burdensome and complicated. Obtaining a license for a new facility, or renewing the license of an older facility, can take 8-10 years or longer [6].

7.2 Economics of hydropower

Hydropower projects are very capital intensive and the cost is very site specific. Table 7-1 shows the capital costs estimates from various sources. The capital cost estimates range from as low as $1,700/kW in 1996 dollars done by Idaho National Laboratory (INL) to nearly $14,000/kW cost estimate in 2008 dollars for the Susitna project in Alaska. Once constructed, a hydroelectric project has a major cost advantage since the fuel (water) is virtually free and also because hydroelectric plants have very low O&M costs.

Project		Time*	Initial Capital Costs ($/kW)**
Idaho National Lab estimates		1996	1,700-2,300
EIA estimates	Hydroelectric	2010	3,076
	Pumped Storage	2010	5,595
Hawaii Pumped Storage Hydroelectric Project (Maui Electric Co.)	Umauma	2005	1,966
	East/WestWailuaiki		3,011
	Big Island		2,432-2,842
	Maui		3,477
Susitna Project (Alaska)		2008	7,713-13,833
American Municipal Power (AMP)	Belleville	1999	2,857
	Cannelton	2009	4,951
	Smithland	2010	6,226
	Meldahl	2010	4,504
	Willow Island	2011	7,889
	Robert C. Byrd	2015	6,250
	Pike Island	2016	7,414

* Time the project's cost estimate was made or the project's expected start date.

** The basis year for the capital cost estimates is 1996 for INL, 2012 for EIA, 2005 for Hawaii and 2008 for Alaska. The basis year for the AMP projects was not available. The document on which the AMP capital cost estimates were obtained was dated June 2011.

Table 7-1: Initial capital costs of hydropower projects (Data sources: [8-13])

According to the EIA updated plant costs [10], hydroelectric plants have one of the lowest O&M costs among electricity generating technologies. Figure 7-2 shows the variable and fixed O&M costs of various generating technologies. As can be seen in the Figure 7-2, hydroelectricity's variable O&M costs are estimated at zero and the fixed O&M cost of $14/kW is the second lowest after natural gas combustion turbines.

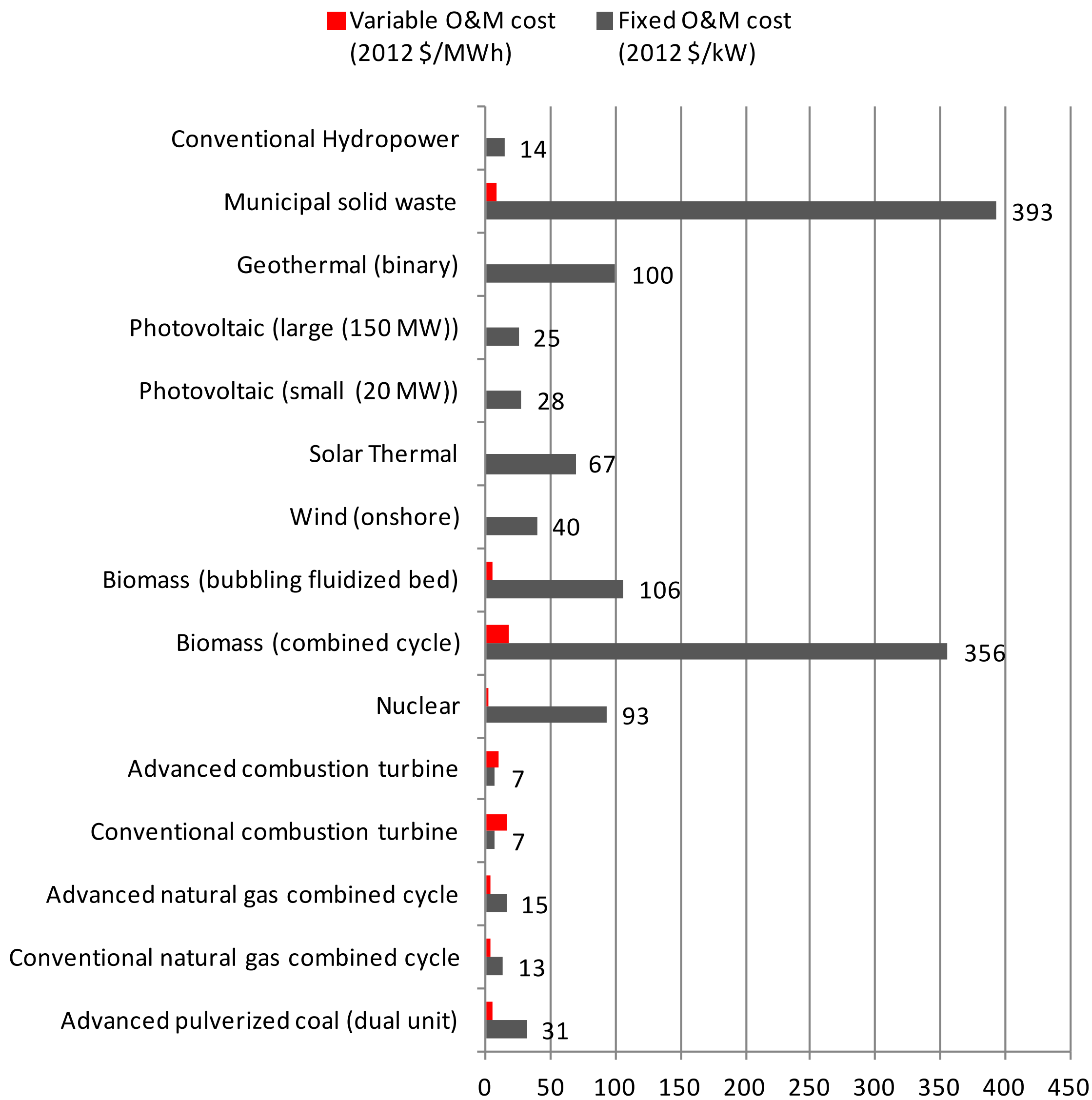


Figure 7-2: Variable and fixed O&M costs of generating technologies (Data source: EIA [10])

7.3 State of hydropower nationally

As can be seen in Figure 7-3 and Figure 7-4 hydroelectricity has historically been the largest source of renewable energy in the U.S. accounting for 30 percent of the total renewable energy consumed and 56 percent of the net renewable electricity generated in 2012. Renewable resources contributed 8 percent of the total energy consumed and 12 percent of the net electricity generated in the U.S. in 2012.

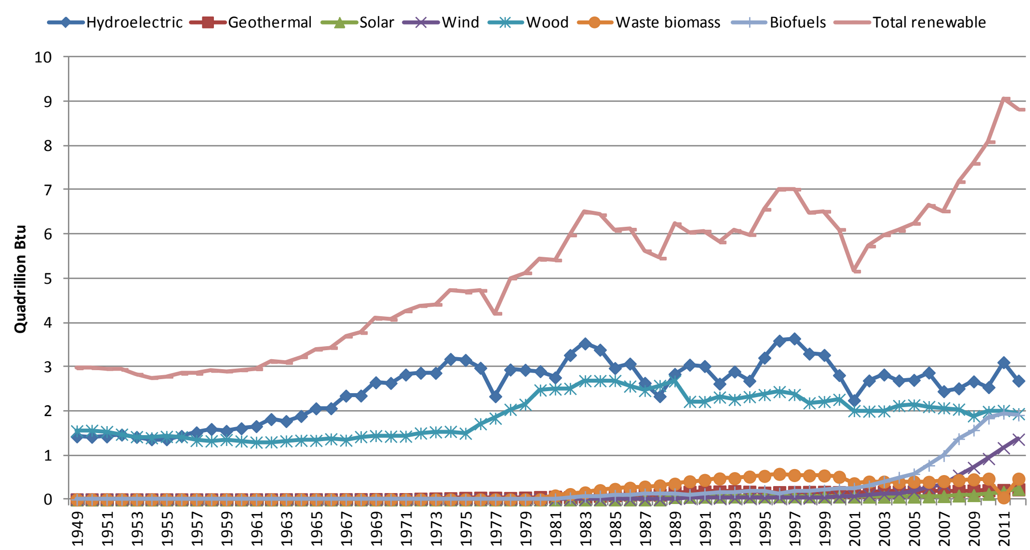


Figure 7-3: Renewable energy consumption in the U.S. (1949-2012) (Data source: EIA [14, 15])

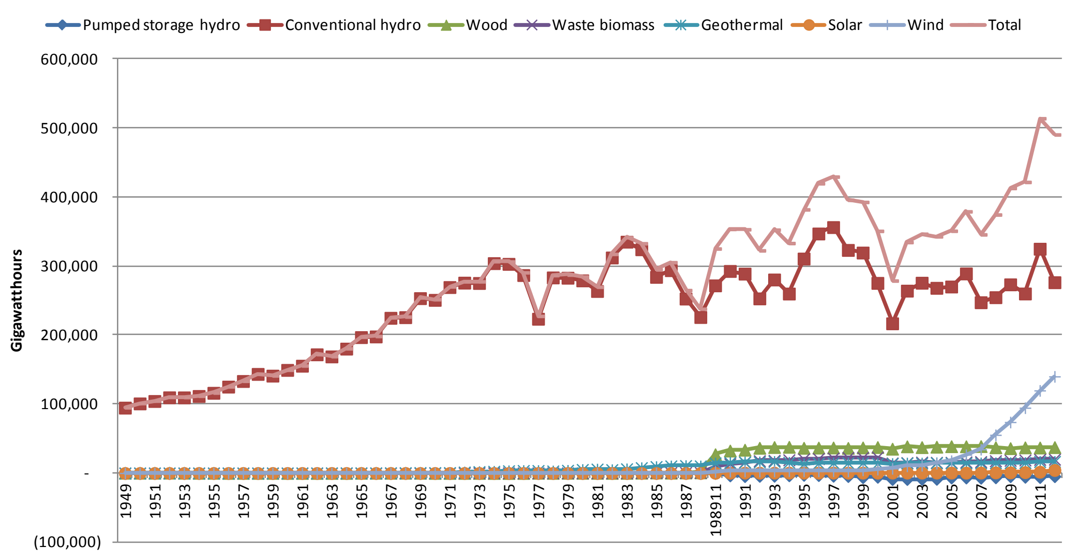


Figure 7-4: Net renewable electricity generation in the U.S. (1949-2012) (Data source: EIA [16, 17])

The current hydropower installed capacity is 78 GW conventional hydro and 22 GW pumped storage hydro [18]. Table 7-2 shows the top ten hydro states ranked by their hydroelectricity output in 2010. Over half of the hydroelectricity generation in 2010 was from the top three states of Washington, Oregon, and California.

1.Washington	68,288,383		6.Idaho	9,154,244
2.California	33,430,870		7.Alabama	8,704,254
3.Oregon	30,542,260		8.Arizona	8,704,000
4.New York	25,471,697		9.Tennessee	8,137,795
5.Montana	9,414,662		10.North Carolina	4,757,000

Table 7-2: Top ten U.S. hydropower generating states in 2010 (MWh) (Data source: EIA, National Hydropower Association [17, 19])

According to the U.S. Hydropower Resource Assessment Final Report issued by the Idaho National Laboratory updated in 2006 there was an undeveloped potential for 30 GW of hydropower available from 5,677 sites across the U.S. Of this capacity, 57 percent (17.0 GW) was at sites with some type of existing dam or impoundment but with no power generation. Another 14 percent (4.3 GW) was at projects that already had hydropower generation but were not developed to their full potential; only 28 percent (8.5 GW) of the potential would require the construction of new facilities. Therefore the potential for hydropower from existing dams was about 21.4 GW [20].

In April 2012 DOE released an assessment of the hydropower potential available at hydro sites that had dams already in place but no power generation equipment installed. According to the DOE there were a total of 80,000 such non-powered dam providing services such as navigation, water supply and recreation. The combined electricity generating potential at these sites was assessed at 12 GW [18]. Figure 7-5 shows the location of the non-powered dams with a hydropower potential greater than 1 MW. Table 7-3 shows the hydropower potential from non-powered dams for the states in the contiguous U.S.

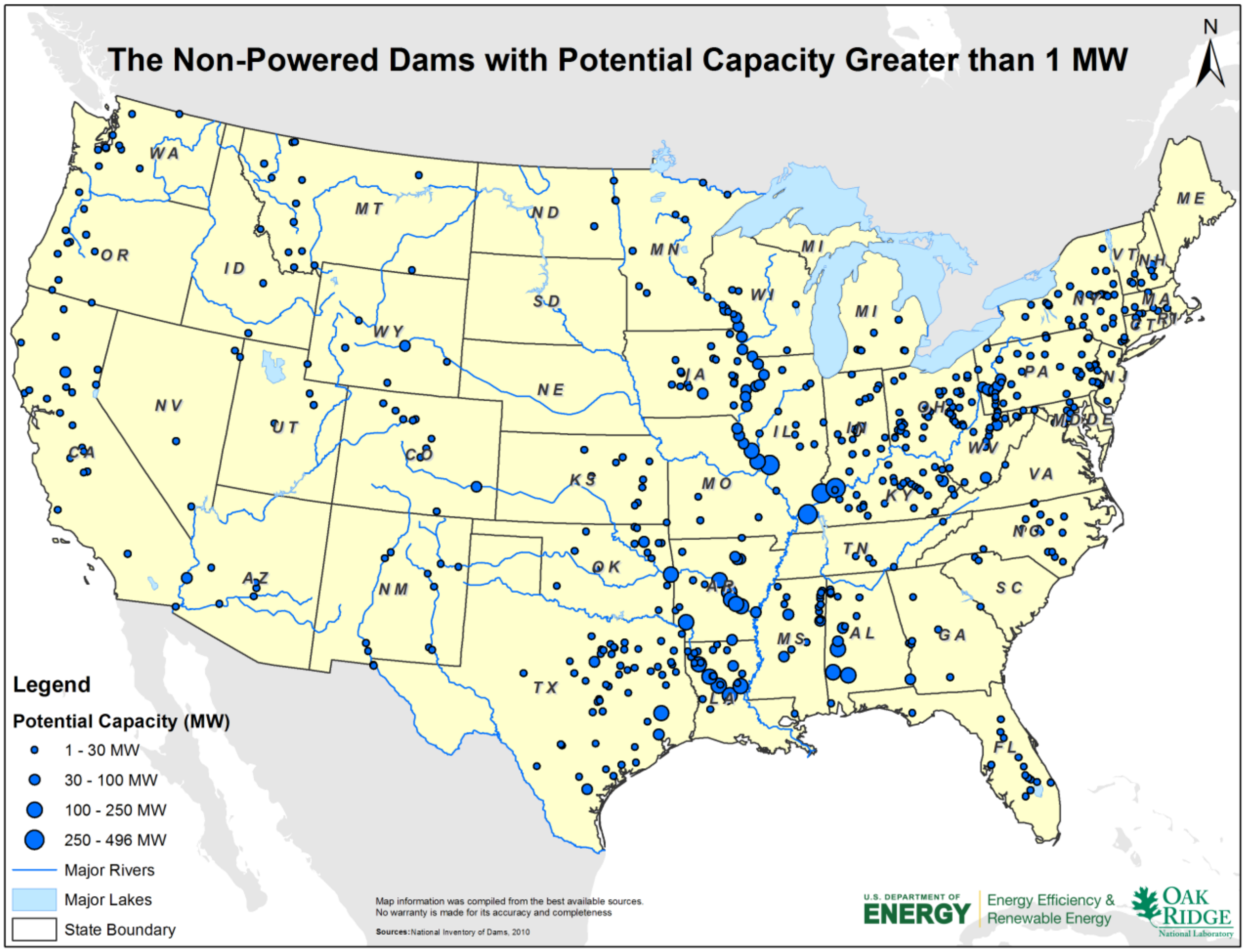


Figure 7-5: Non-powered dams with potential capacity over 1 MW (Source: DOE [18])

State	Potential Capacity (MW)		State	Potential Capacity (MW)
Illinois	1269		Kansas	92
Kentucky	1253		Montana	88
Arkansas	1136		Washington	85
Alabama	922		Arizona	80
Louisiana	857		Connecticut	68
Pennsylvania	679		Massachusetts	67
Texas	658		New Hampshire	63
Missouri	489		Virginia	50
Indiana	**454**		Maryland	48
Iowa	427		Michigan	48
Oklahoma	339		Wyoming	45
New York	295		Tennessee	40
Ohio	288		Utah	40
Mississippi	271		South Carolina	38
Wisconsin	245		New jersey	33
West Virginia	210		North Dakota	31
California	195		Maine	19
Minnesota	186		Vermont	17
Florida	173		Nevada	16
Colorado	172		Rhode Island	13
North Carolina	167		Idaho	12
Georgia	144		South Dakota	12
Oregon	116		Nebraska	7
New Mexico	103		Delaware	3

Table 7-3: Hydropower potential from non-powered dams by state (Data source: DOE [18])

7.4 Hydropower in Indiana

Until the commissioning of the first wind farm in Indiana in 2008, hydroelectricity was the main source of renewable electricity in Indiana as shown in Figure 7-6. With over 1,340 MW of installed wind capacity compared to 73 MW of hydroelectricity in Indiana, wind is now the dominant source of renewable electricity. This is a significant change from the situation in 2008 when only 20 kW of grid-connected wind capacity was in operation in Indiana.

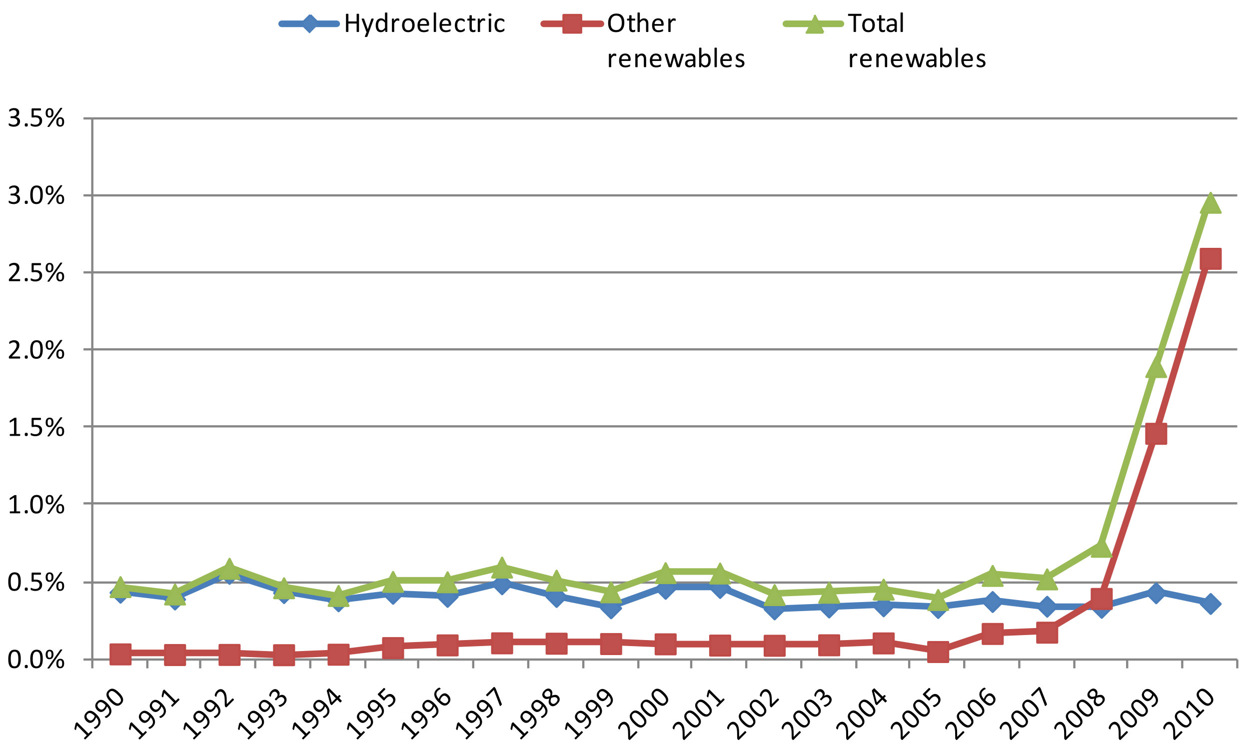


Figure 7-6: Renewables share of Indiana net electricity generation (1990-2010) (Data source: EIA [21])

However when one considers total Indiana energy consumption, wood and more recently ethanol dominate as sources of renewable energy consumed in Indiana as shown in Figure 7-7. Hydroelectricity comes in third contributing less 0.2 percent of the total energy consumed in Indiana.

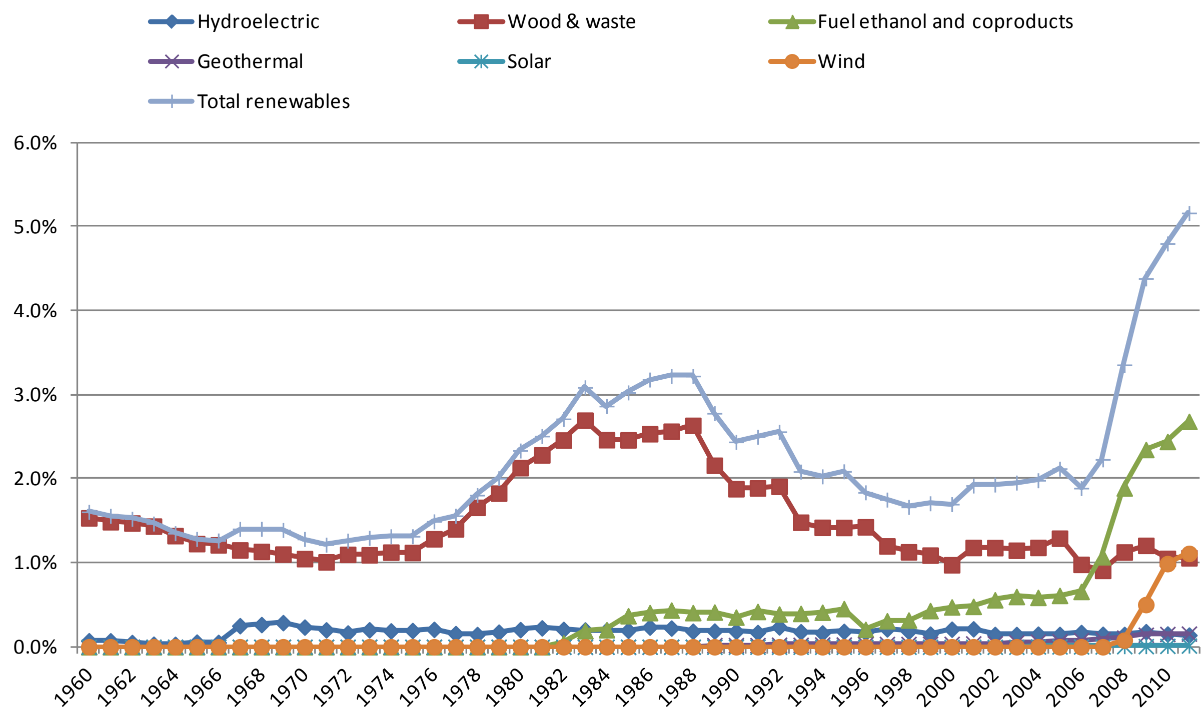


Figure 7-7: Renewables share of Indiana total energy consumption (1960- 2011) (Data source: EIA [22])

The 2012 DOE national assessment of hydropower potential from non-powered dams referred to in the preceding section of this report estimated that Indiana had a total potential of 454 MW hydropower from these, already existing, non-powered dams. This assessment is much higher than the 1995 DOE assessment that had estimated Indiana's gross potential at 84 MW [18]. Table 7-4 lists the dams in Indiana with a potential greater than 1 MW. The capacity of the two dams on the Ohio River is assigned in equal proportions between Indiana and Kentucky.

Dam Name	County	City	River	Hydropower Potential (MW)
John T. Myers locks and dams	Posey	Mt. Vernon	Ohio River	395
Newburgh locks and dams	Henderson	Newburgh	Ohio River	319
Mississinewa Lake dam	Miami	Peru	Mississinewa River	14
J. Edward Roush Lake dam	Huntington	Huntington	Wabash River	9
Salamonie Lake dam	Wabash	Lagro	Salamonie River	9
Brookville Lake dam	Franklin	Brookville	White Water River (East fork)	8
Monroe Lake dam	Monroe	Guthrie	Salt Creek	8
White River dam	Marion	Indianapolis	White River	3
Patoka Lake dam	Dubois	Jasper	Patoka River	3
Cagles Mill Lake dam	Putman	Bowling Green	Mill Creek	2
Cecil M. Harden lake dam	Parke	Mansfield	Raccoon Creek	2
Ball Band dam	St. Joseph	Mishawaka	St. Joseph River	2
Seymour Water Co. dam	Jackson	Seymour	White Water River (East fork)	2
Eagles Creek Reservoir dam	Marion	Clermont	Eagle Creek	2
West fork White River dam	Morgan	Martinsville	White River	2
Harding St. power plant dam	Marion	Indianapolis	White River	2
Versailles State Park dam	Ripley	Versailles	Laughery Creek	1.4
Emerichsville dam	Marion	Indianapolis	White River	1.3
Broad Ripple dam	Marion	Indianapolis	White River	1.3
Geist Reservoir dam	Marion	Indianapolis	Fall Creek	1.3
Cedarville dam	Allen	Cedarville	St. Joseph River	1.3
Hosey (Maumee River) dam	Allen	Fort Wayne	Maumee River	1.2

Table 7-4: Indiana non-powered dams with potential capacity over 1 MW (Data source: DOE [23])

American Municipal Power, a wholesale electricity supplier to municipal utilities in Ohio, Pennsylvania, Michigan, Virginia, Kentucky and West Virginia is in the process of developing six run-of-the-river hydroelectric projects on existing dams along the Ohio River. Four of these projects – Cannelton, Melhahl, Smithland and Willow Island are already under construction while two projects, Robert Byrd and Pike Island, are undergoing the licensing process at the Federal Energy Regulatory Commission (FERC). One of the projects under construction, the 84 MW Cannelton project, is in the Indiana/Kentucky section of the river. Table 7-5 shows the estimated capital cost and expected commissioning dates of the projects.

Project	Capacity (MW)	Estimated capital cost (million $)	Estimated capital cost ($/kW)	Construction start date	Expected commissioning date
Cannelton	84	415.9	4,951	2009	2014
Meldahl	105	472.9	4,504	2010	2014
Smithland	72	448.3	6,226	2010	2015
Willow Island	35	276.1	7,889	2011	2014
Robert C. Byrd	48	300	6,250	2015	2017
Pike Island	49.5	367	7,414	2016	2019

Table 7-5: AMP hydropower projects along Ohio River (Source: AMP [12, 13, 24])

In addition the potential for installing hydroelectric generating capacity is being considered as part of the proposed Mounds Lake Reservoir project on the White River in Madison and Delaware counties [25, 26].

7.5 Incentives for hydropower

Federal Incentives

- Renewable Electricity Production Tax Credit (PTC) provides a 1.1 cents/kWh tax credit for qualified small hydroelectric and marine energy technologies. As part of the February 2009 American Recovery and Reinvestment Act the PTC was modified to provide the option for qualified producers to take the 30 percent federal business energy investment credit (ITC) [27].
- U.S. DOE Loan Guarantee Program (Section 1703, Title IV of Energy Policy Act (EPAct) of 2005 provides loan guarantees for large scale innovative renewable energy projects. The program is authorized for $10 billion and focuses on projects costing over $25 million. A supplementary loan guarantee program authorized by the American the American Recovery and Reinvestment Act of 2009 under Section 1705 of EPAct expired in 2011 [8].
- Rural Energy for America Program (REAP) was converted by the Food, Conservation, and Energy Act of 2008 from the USDA Renewable Energy Systems and Energy Efficiency Improvements Program to the Rural Energy for America Program (REAP). Hydroelectric facilities are eligible for grants of up to 25 percent of the cost of the system, and loans for another 50 percent of the cost [27].

- High Energy Cost Grant Program administered by the USDA is aimed at improving the electricity supply infrastructure in rural areas having home energy costs exceeding 275 percent of the national average. Eligible infrastructure includes renewable resources generation. The USDA has allocated a total of $15.5 million for the 2010 funding cycle. The individual grants range from $75,000 to $5 million [28].

Indiana Incentives

- Net Metering Rule qualifies renewable resource facilities with a maximum capacity of 1 MW for net metering. The net excess generation is credited to the customer in the next billing cycle [27].
- Renewable Energy Property Tax Exemption provides property tax exemptions for solar, wind, hydroelectric and geothermal systems [27].
- Emissions Credits are earmarked for electricity generators that do not emit NO_x and that displace utility generation. Qualified generators are eligible to receive NO_x emissions credits under the Indiana Clean Energy Credit Program. These credits can be sold on the national market [29].
- Sales and Use Tax Exemption for Electrical Generating Equipment exempts transactions involving manufacturing machinery, tools, and equipment used for the production of tangible personal property from state gross retail tax. This includes renewable generation equipment [27].
- Clean Energy Portfolio Goal sets a voluntary goal of obtaining 4 percent between 2013 and 2018, 7 percent between 2019 and 2024, and 10 percent by 2025, of electricity from clean energy sources based on 2010 retail sales. Participation in the goal makes utilities eligible for incentives that can be used to pay for the compliance projects [27].
- Northern Indiana Public Service Company offers feed-in tariff incentive rates for electricity generated from renewable resources for up to 10 years. The payment for hydroelectric facilities is $0.12/kWh for new hydroelectric facilities with a capacity no more than 1 MW. The tariff is experimental and slated to run until December 31, 2013. The total system-wide renewable capacity allowed under the tariff is 30 MW with 500 kW of the cap reserved for solar projects of capacity less than 10 kW, and 500 kW reserved for wind projects of capacity less than 10 kW [27, 30].

7.6 References

1. Idaho National Laboratory (INL). Hydropower: Types of hydropower facilities. http://hydropower.inel.gov/hydrofacts/hydropower_facilities.shtml
2. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy (EERE). Types of hydropower turbines. http://www1.eere.energy.gov/water/hydro_turbine_types.html

3. Colorado River Storage Project (CRSP) Power Office. Benefits of hydropower. http://www.usbr.gov/uc/power/hydropwr/benefits.html
4. Hydro world. Adding hydropower to non-hydro dams offers huge development potential. http://www.hydroworld.com/index/display/article-display/0814332230/articles/hrhrw/hydroindustrynews/newdevelopment/2010/06/adding-hydropower.html
5. EERE. DOE hydropower program annual report for FY 2002. July 2003. http://hydropower.inl.gov/techtransfer/pdfs/hydro_final_fy_02.pdf
6. Church Ciocci, Linda. Power Engineering International. Hydropower licensing reform: What's all the fuss? July 2003. http://www.power-eng.com/articles/2003/07/hydropower-licensing-reform-whats-all-the-fuss.html
7. Energy Policy Act of 2005. http://doi.net/iepa/EnergyPolicyActof2005.pdf
8. INL. Hydropower: Plant costs and production expenses. http://hydropower.inel.gov/hydrofacts/plant_costs.shtml
9. Alaska Energy Authority. Susitna hydroelectric project: Project evaluation. http://www.akenergyauthority.org/SusitnaFiles/031609EvaluationWOappen.pdf
10. U.S. Energy Information Administration (EIA). Updated capital cost estimates for utility scale electricity generation plants. April 2013. http://www.eia.gov/oiaf/beck_plantcosts/pdf/updatedplantcosts.pdf
11. Maui Electric Company, Ltd. Hawaii pumped storage hydroelectric project: Advisory group meeting, November 1, 2005. http://www.mauielectric.com/vcmcontent/FileScan/PDF/MECO/IRP/M_hydro.pdf
12. American Municipal Power (AMP). Hydroelectric power http://amppartners.org/generation-assets/hydroelectric/
13. AMP. Organization and generation project overview, June 2011. http://amppartners.org/pdf/AMP_Projects_Overview_June_2011.pdf
14. EIA. 2012 Annual Energy Review Table 10.1. http://www.eia.gov/totalenergy/data/annual/index.cfm#renewable
15. EIA. May 2013 Monthly Energy Review Table 10.1 http://www.eia.gov/totalenergy/data/monthly/#renewable
16. EIA. 2012 Annual Energy Review. Table 8.2a. http://www.eia.gov/totalenergy/data/annual/index.cfm#electricity
17. EIA. May 2013 monthly energy review Table 7.2a. http://www.eia.gov/totalenergy/data/monthly/#electricity
18. DOE. An Assessment of Energy Potential at Non-Powered Dams in the United States. http://www1.eere.energy.gov/water/pdfs/npd_report.pdf
19. National Hydropower Association. U.S. hydro generating profile. http://hydro.org/why-hydro/available/hydro-in-the-states/
20. Conner, A.M., J.E. Francfort, and B.N. Rinehart. U.S. hydropower source assessment final report. December 1998. http://www1.eere.energy.gov/water/pdfs/doewater-10430.pdf

21. EIA. Indiana Electricity Profile Table 5, Release date: January 2012. http://www.eia.gov/electricity/state/indiana/
22. EIA. State Energy Data System (SEDS), Table CT2. Primary Energy Consumption Estimates, Selected Years, 1960-2011, Indiana. http://www.eia.gov/state/seds/data.cfm?incfile=/state/seds/sep_use/total/use_tot_INcb.html&sid=IN
23. DOE. National hydropower assessment program. December 1995. http://nhaap.ornl.gov/content/non-powered-dam-potential
24. American Municipal Power. http://amppartners.org/generation-assets/hydroelectric/, http://amppartners.org/images/Ohio_River_Hydro_map.jpg
25. Email communication with the Anderson/Delaware County Corporation for Economic Development.
26. Mounds Lake Reservoir project website. http://moundslake.com/
27. Database of State Incentives for Renewables and Efficiency (DSIRE). http://www.dsireusa.org/library/
28. U.S. Department of Agriculture, High Energy Cost Grant Program overview. http://www.rurdev.usda.gov/UEP_Our_Grant_Programs.html
29. Indiana Department of Environmental Management. Indiana clean energy credit program. http://www.in.gov/idem/4134.htm
30. Northern Indiana Public Service Company. http://www.nipsco.com/en/about-us/Rates-Tariffs/electric-service-tariff-122711.aspx