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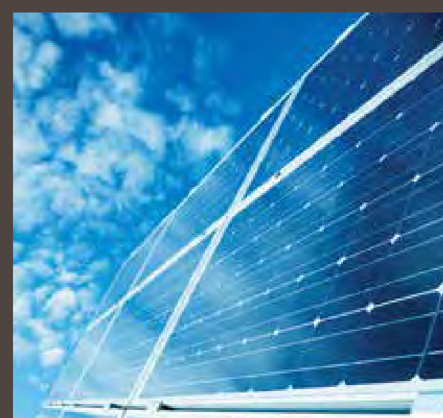
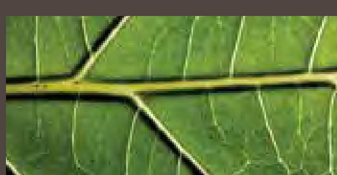
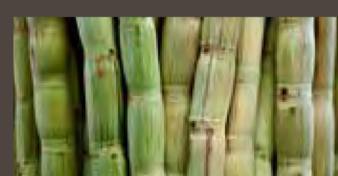
ENERGY CENTER

September 2015

2015 INDIANA RENEWABLE ENERGY RESOURCES STUDY







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

2015 INDIANA RENEWABLE ENERGY RESOURCES STUDY

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Acronyms and Abbreviations

AC	Alternating current
ARRA	American recovery and reinvestment act
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	Direct current
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
ft	Feet
ft^3	Cubic feet
GIS	Geographical information system
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
IRS	Internal Revenue Service
ITC	Business energy investment tax credit
IURC	Indiana Utility Regulatory Commission
I&M	Indiana Michigan Power
KDF	Bioenergy Knowledge Discovery Framework, U.S. Department of Energy
kV	Kilovolts
kW	Kilowatt
kWh	Kilowatthour
LLC	Limited liability company
LMOP	Landfill Methane Outreach Program, Energy Information Administration, U.S. Department of Energy
m	Meters
m/s	Meters per second
MACRS	Modified accelerated cost-recovery system
MGD	Million gallons per day
MGY	Million gallons per year
mmBtu	Million British thermal unit
mmscfd	Million standard cubic feet per day
MMTCO2e/yr	million metric ton of carbon dioxide-equivalent per
mph	Miles per hour
MSW	Municipal solid waste
MTBE	Methyl tertiary butyl ether – a gasoline oxygenating additive
MW	Megawatt
MWh	Megawatthour
NAABB	National Alliance for Advanced Biofuels and Bioproducts
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
PPA	Power purchase agreements
PTC	Production tax credit
PV	Photovoltaic
QECB	Qualified energy conservation bonds
REAP	Rural Energy for America Program, U.S. Department of Agriculture
RPS	Renewable portfolio standard
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
VEETC	Volumetric ethanol tax credit
W	Watts
W_{DC}	Direct Current Watts
W/m^2	Watts per square meter
WPCP	Water pollution control plant
WVPA	Wabash Valley Power Association
WWTP	wastewater treatment plant

Foreword

This report represents the thirteenth 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.

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 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 2015 Indiana Renewable Energy Resources Report presents an overview of the trends in renewable energy penetration 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 2014. Until the early 2000s hydroelectricity and woody biomass were the dominant sources of renewable energy consumed in the U.S. The last fifteen years have seen a rapid increase in biofuels (mainly corn-based ethanol), wind and solar as sources of renewable energy. In 2014 biofuels, wind and solar combined contributed nearly 44 percent of the 9.6 quadrillion Btu of renewable energy consumed in the U.S. 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, first authorized in the 2005 Energy Policy Act and then expanded in 2007, which created mandates for the production of biofuels. This rapid increase in corn-ethanol has since slowed 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 (PTC) in 1992, and continued with the proliferation of renewable portfolio standards in a number of states. The PTC expired in December 2014, but projects that were under construction before January 1, 2015 remain eligible. The rapid expansion in solar capacity installations is attributed to a combination of state Renewable Portfolio Standards (RPS) and financial incentives offered by the federal government as part of the 2008/2009 economic recovery packages. These federal incentives include the modification of the 30 percent Investment Tax Credit (ITC) to remove the $2,000 cap and to allow utilities access to the ITC, the provision for investors to take a 30 percent cash grant in lieu of the ITC and PTC, and the provision of extra funds for the U.S. Department of Energy loan guarantee program (DOE). The cash grant provision and the special DOE loan guarantee program have since been retired.

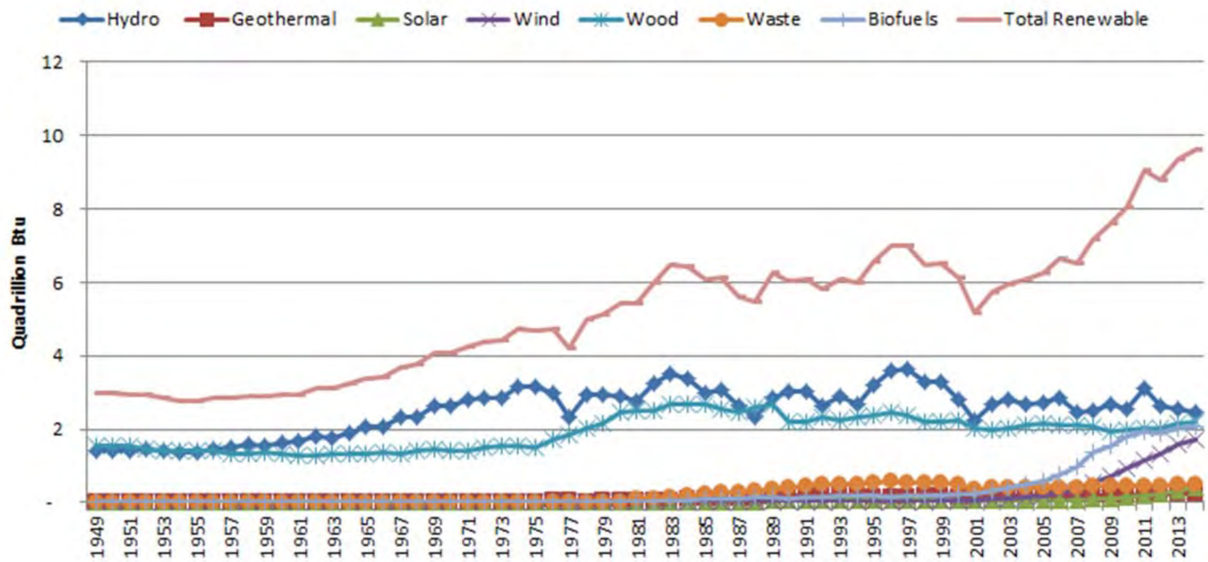


Figure 1-1: Renewable energy consumption in the U.S. (1949-2014) (Data source: EIA [1])

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 (8 percent). Figure 1-2 shows the sources of total energy consumed in the U.S. from 1949 to 2014.

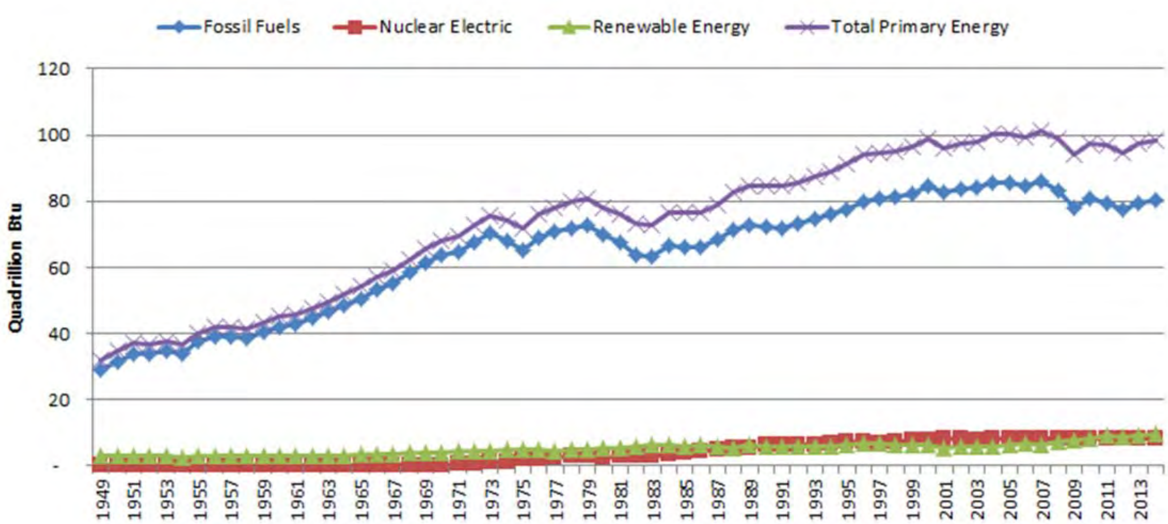


Figure 1-2: U.S. energy consumption by source (1949-2013) (Data source: EIA [2])

Figure 1-3 shows the contribution of the various energy sources to total energy consumed in the U.S. in 2014. Petroleum continued to be the dominant energy source supplying 35 percent, followed by natural gas at 28 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 26 percent. Wind power's contribution rose to 18 percent from 17 percent in 2013, solar rose one percentage point to 4 percent and geothermal remained at 2 percent.

When one considers renewable resources in electricity generation (Figure 1-4), hydroelectricity played a dominant role in 2014, contributing 47 percent of the total renewable electricity generated. Wind energy was second at 34 percent of the renewable electricity and woody biomass was a distant third at 8 percent. Waste biomass contributed 4 percent, geothermal 3 percent and solar 3 percent. As expected, pumped hydroelectricity's net energy contribution was negative.[1]

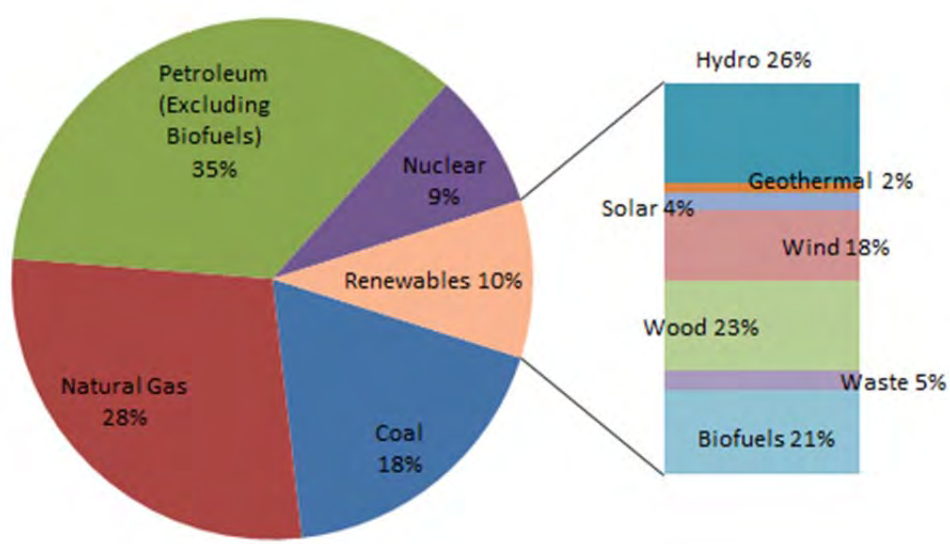


Figure 1-3: U.S. total energy consumption by energy source in 2014 (Data source: EIA [1, 3])

[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.

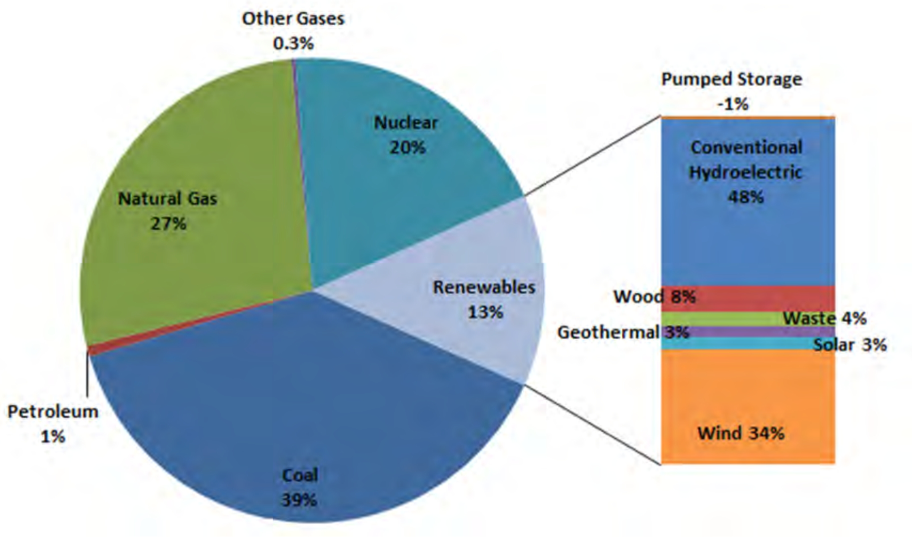


Figure 1-4: Net U.S. electricity generation by energy source in 2014 (Data source: EIA [4])

1.2 Trends in renewable energy consumption in Indiana

Figure 1-5 shows renewable energy consumption in Indiana from 1960 to 2012. 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, until the recent expansions in ethanol and wind increased renewable resources to over 5 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. This has since changed with biofuels becoming the dominant source of renewable energy, supplying over half of the renewable energy consumed in Indiana in 2012. Wind energy was second providing 21 percent of the renewable energy, and woody biomass was relegated to third place at 20 percent.

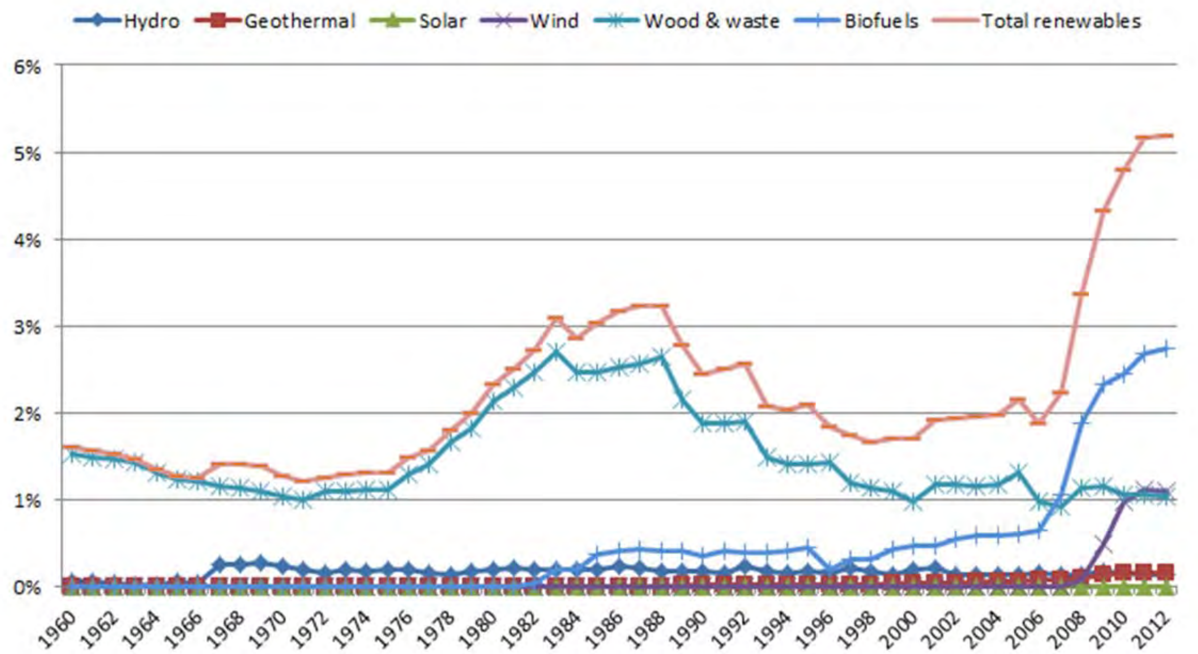


Figure 1-5: Renewables share of Indiana total energy consumption (1960-2012) (Data source: EIA [5])

Figure 1-6 shows the contribution of renewable energy to Indiana's electricity generation from 1990 to 2013. The arrival of utility-scale wind energy projects in 2008 caused a rapid increase in renewable energy's share of Indiana's electricity generation. The renewables share of annual electricity generation rose from 0.5 percent in 2007 to 3.9 percent in 2013 most of which (81 percent) was from wind. Hydroelectricity, which until 2007 was the primary source of renewable electricity, maintained its share of annual generation at 0.4 percent. Although solar generation has increased from virtually none in 2011 to 30 GWh in 2013, it was still barely one percent of Indiana's 4,300 GWh generated from renewable resources in 2013. Solar energy's contribution is likely to increase much more in 2015 when the generation from the 100 MW photovoltaic capacity installed in 2013 and 2014 is taken into account.

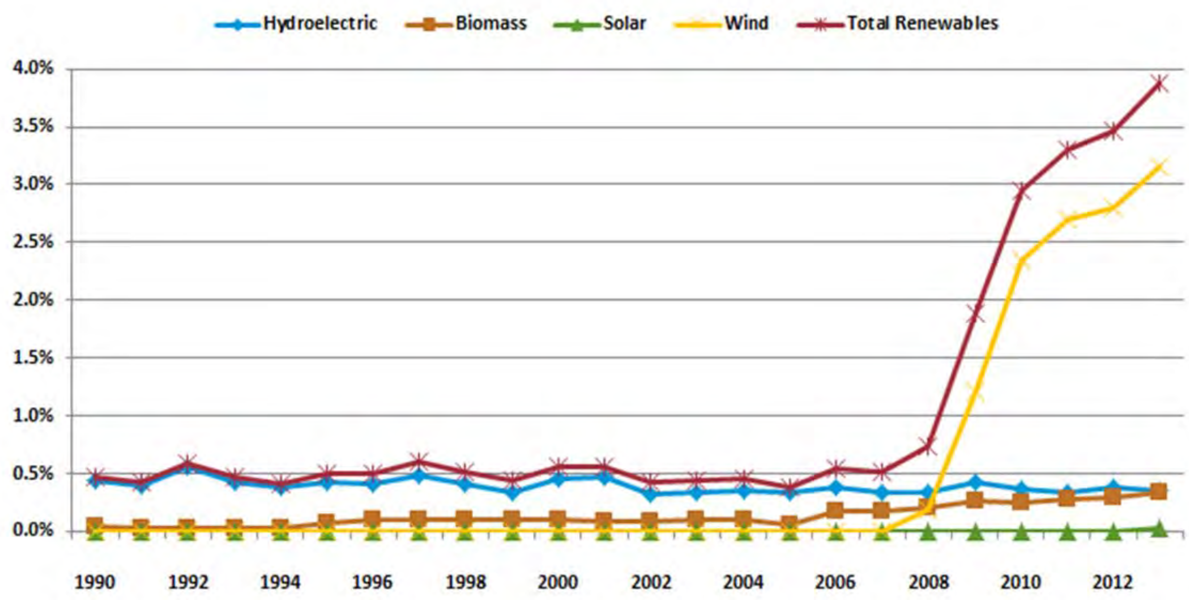


Figure 1-6: Renewables share of Indiana electricity generation (1990-2012) (Data source: EIA [6])

In keeping with the national trend, the rapid growth in wind energy capacity in Indiana has slowed down with only two wind farms with a combined capacity of 400 MW commissioned in the last four years. The latest of these is the 200 MW Headwaters wind farm in Randolph County completed in December 2014. The factors that have resulted in the slowing down of wind energy capacity expansion include the reduced availability of capital after the 2008 global financial crisis and the reduced competitiveness of wind in the face of abundant low cost natural gas as a result of the hydraulic fracturing and horizontal drilling technological breakthroughs in the oil and gas extraction industry. Figure 1-7 shows the annual and cumulative installed wind energy capacity in Indiana. Indiana utilities have a total 1,152 MW contracted with power purchase agreements, 747 MW from wind farms in Indiana and 405 MW from out of state wind farms.

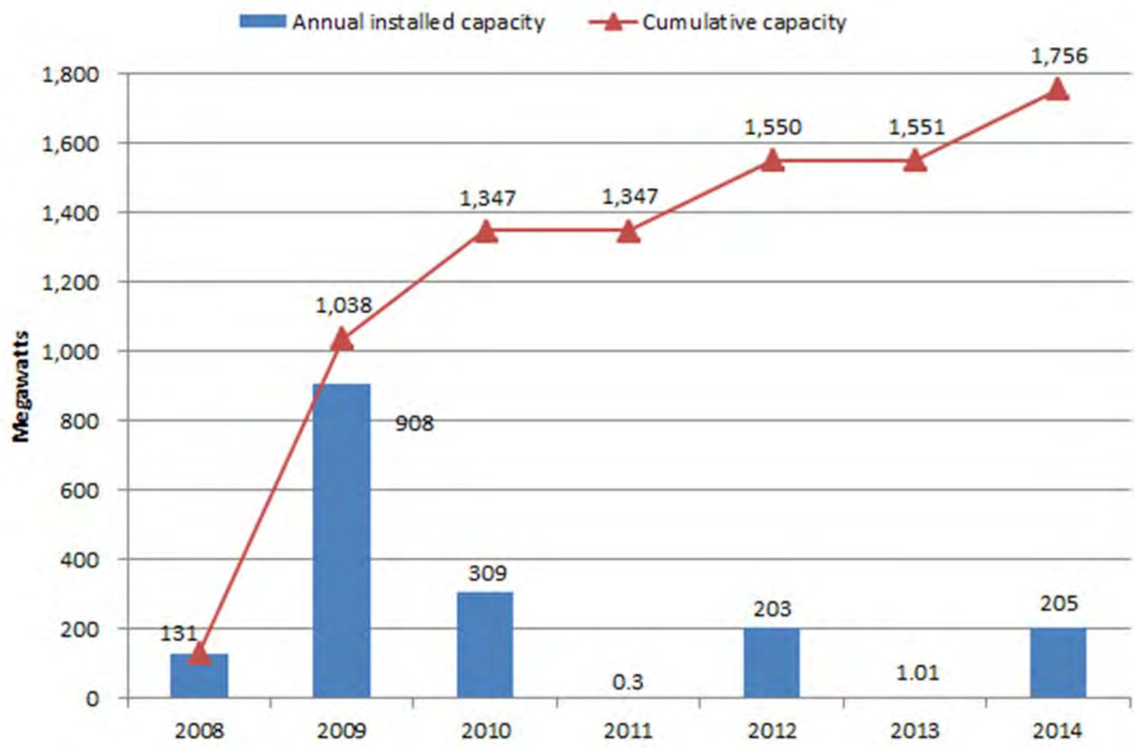


Figure 1-7: Wind energy installed capacity in Indiana (Data sources: IURC, DOE [7-10]).

As the construction of wind energy capacity has slowed, another renewable resource, solar photovoltaic, has been experiencing very rapid growth with the installed capacity increasing from virtually none in 2008 to nearly 120 MW at the time this report was written. Ninety four percent of that capacity (113 MW) was commissioned in 2013 and 2014. Figure 1-8 shows the annual and cumulative PV capacity installations in Indiana as reported to the National Renewable Energy Laboratory's (NREL) *Open PV Project* database as of July 2015. Five large projects installed in Marion County account for 76 percent of Indiana's installed capacity. They are the 26.2 MW Indy Solar I and II solar farm located in Franklin township, the 21.9 MW Indianapolis International Airport solar farm, the 11.3 MW Solar Indy III project in Decatur township, and 11.2 MW project at the Indianapolis Motor Speedway, and the 10.9 MW Maywood Solar farm at the Reilly Superfund site in Indianapolis. Table 1-1 lists PV installations in Indiana with a capacity of 100 kW and above.

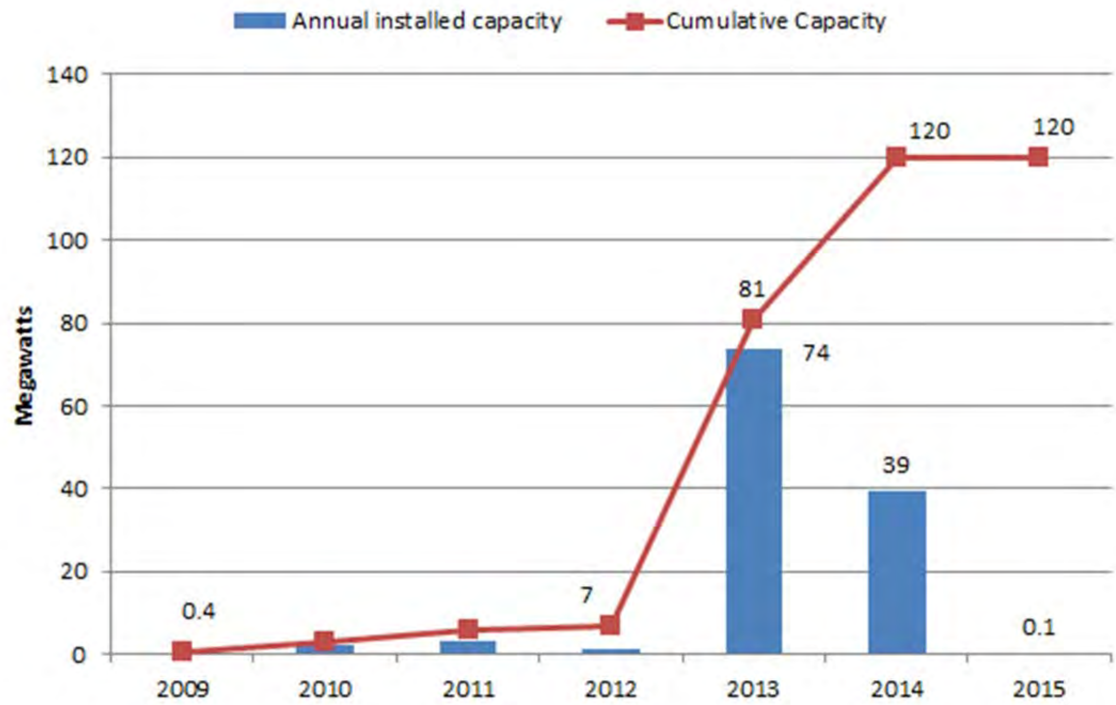


Figure 1-8: Indiana installed PV capacity in NREL *Open PV Project* database (Data source NREL [11]

Owner/Developer	Rated Capacity (kW)	Location	Date Installed
Dominion Resources	26,209	Franklin, Marion County	2013
Johnson Melloh Solutions, Telemon Corporation, General Energy Solutions	21,944	Indianapolis International Airport	2013
Dominion Resources	11,275	Decatur, Marion County	2013
SunWize Technology and Blue Renewable Energy	11,204	Indianapolis Motor Speedway	2014
Maywood Solar Farm	10,860	Reilly Tar and Chemical Superfund Site, Indianapolis	2014
REC Group, Melink Corp.	3,189	Indianapolis	2014
Melink Corp	3,102	Rexnord Industries, Indianapolis	2014
groSolar	2,693	Griffith, Lake County	2013
groSolar	2,693	East Chicago	2013
U.S. General Services Administration	2,012	Emmett Bean Federal Center, Indianapolis	2011
ERMCO	1,800	Indianapolis	2010
Indiana Municipal Power Agency	1,000	Richmond	2014
Indiana Municipal Power Agency	1,000	Frankton	2014
Indiana Municipal Power Agency	1,000	Rensselear	2014
Johnson-Melloh Solutions	1,000	Indianapolis	2013
Johnson-Melloh Solutions	750	Speedway	2013
Lake Village Solar LLC	650	Lake Village, Newton County	2013
Seating Technology, Inc.	627	Goshen	2013
Johnson-Melloh Solutions	524	Schaefer Technologies, Indianapolis	2013
Turtle Top Corp.	375	Elkhart County	2013
Indy Southside Sports Academy	200	Indianapolis	2014
Metal Pro Roofing	186	Franklin, Johnson County	2011
Harness Farms	144	Frankfort	2013
Indiana Veneers, Indianapolis	110	Indianapolis	2012
Johnson-Melloh Solutions	109	Indianapolis Department of Public Works	2013
A-Pallet, Indianapolis	108	Indianapolis	2013
Johnson Melloh Solutions Demonstration Lab	100	Indianapolis	2011

Table 1-1: PV systems in Indiana of 100kW and above capacity (Data source: NREL [11])

The factors credited for rapid growth in photovoltaic generation capacity in Indiana include federal, state and utility incentives. Federal incentives include the extension and modification of the 30 percent investment tax credit (ITC) to remove the $2,000 cap for solar and small wind, the provision by the 2009 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 the ARRA for funds for a U.S. Department of Energy loan guarantee program targeted towards renewable energy resources. The favorable conditions at the state level include the expansion of the net metering rule to include all customer classes, renewable generating systems up to 1 MW, and the increase of the cap at which a utility may limit system-wide net metering[2] capacity to one percent of its most recent summer peak [12]. Another major factor has been the feed-in tariffs[3] offered by two of Indiana's utilities. The Indianapolis Power and Light (IPL) feed-in tariff, which ended in 2013, offered 15 year contracts for the renewable generators as follows:

- $0.24/kWh for PV systems between 20 and 100 kW and $0.20/kWh for systems greater than 100kW up to 10 MW,
- $0.14/kWh for windmills 50 kW to 100 kW, $0.105 for those 100 kW to 1 MW, and $0.075/kWh for those greater than 1 MW, and
- $6.18/kW per month plus $0.085/kWh for biomass facilities [13].

The first phase of the Northern Indiana Public Service Company (NIPSCO) feed-in tariff, which ended in March 2015, offered 15 year contracts at the following rates:

- $0.30/kWh for PV units less than 10 kW and $0.26/kWh for facilities up to 2 MW,
- $0.17/kWh for wind units with a capacity less than or equal to 100 kW and $0.10/kW for units with capacities between 101kW and 2 MW, and
- $0.106/kWh for biomass facilities [14].

[2] The net metering rule allows customers with eligible renewable resource generating facilities to receive credit for the self-generated electricity at the retail rate. At the end of each billing cycle the customer pays for the net electricity received from the utility. In the Indiana rule excess generation by the customer is credited to the next billing cycle.

[3] A feed-in tariff by a utility offers a long-term contract to buy electricity from a customer-owned renewable resource generating facility at incentive rates that reflect the cost of generating electricity from the renewable technology.

The purchase rates for the second phase of the NIPSCO feed-in tariff are arranged into two categories referred to as *allocation 1* and *allocation 2* as shown in Table 1–2.

Technology	Nameplate Range	Purchase Rate per kWh		Total system capacity available (MW)
		Allocation 1	Allocation 2	
Micro Wind	3 kW and ≤ 10 kW	$0.25	$0.23	1
Intermediate Wind	> 10 kW and ≤ 200 kW	$0.15	$0.138	1
Micro Solar	5 kW and ≤ 10kW	$0.17	$0.1564	2
Intermediate Solar	> 10 kW and ≤ 200kW	$0.15	$0.138	8
Biomass	100 kW and ≤ 1 MW	$0.0918	≤ $0.0918	4

Table 1-2: Purchase rates under NIPSCO renewable feed-in tariff (Data source: NIPSCO [15, 16])

The capacities available in the NIPSCO tariff for the various technologies are allocated to the two purchase categories (*allocation 1* and *allocation 2*) as follows.

- For micro wind, intermediate wind and micro solar projects, the full system capacity limit for the technology as shown in Table 1-2 is made available to *allocation 1* by a lottery process to projects that will have submitted an acceptably complete application within the first approximately four month period starting March 2015. If any room for more projects is available after this lottery more projects will be accepted into the tariff under the *allocation 2* category with a lower purchase rate as shown in Table 1-2.

- For intermediate solar and biomass projects, half the system wide capacity limit for the technology is available for *allocation 1* category and the other half for *allocation 2*. To qualify for *allocation 1* the projects must meet all the application qualifications before March 4, 2017.

Detailed information on NIPSCO feed-in tariff application process and capacity allocation process are available on the NIPSCO feed-in tariff web page and March 4, 2015 information document [16, 17].

Table 1-3 shows the 8.8 MW of net metering generation in the respective territories of Indiana utilities while Table 1-4 shows the 126.7 MW contracted to two Indiana utilities under their feed-in tariffs.

	Wind (kW)	Solar (kW)	Total (kW)
Duke	2,210	2,283	4,495
Indiana Michigan	254	360	614
IPL	50	253	303
NIPSCO	1,926	773	2,699
Vectren	4	677	681
total	**4,444**	**4,431**	**8,792**

Table 1-3: Renewable generation contracted under net metering (Data source: IURC [7])

	Wind (kW)	Photovoltaic (kW)	Biomass (kW)	Total (kW)
IPL	0	96,978	0	96,978
NIPSCO	160	15,194	14,350	29,702
Total kW	**160**	**112,172**	**14,350**	**126,680**

Table 1-4: Renewable generation contracted under feed-in tariffs (Data source: IURC [7])

1.3 Cost of renewable resources

One of the main barriers to widespread use of renewable resources for electricity generation is the cost. Figure 1-9 shows the estimated capital costs of utility scale electricity generating technologies provided in the 2013 EIA update of generating plant costs. As can be seen in the figure, only wind and hydropower have a capital cost that is competitive with fossil fueled generation [18].

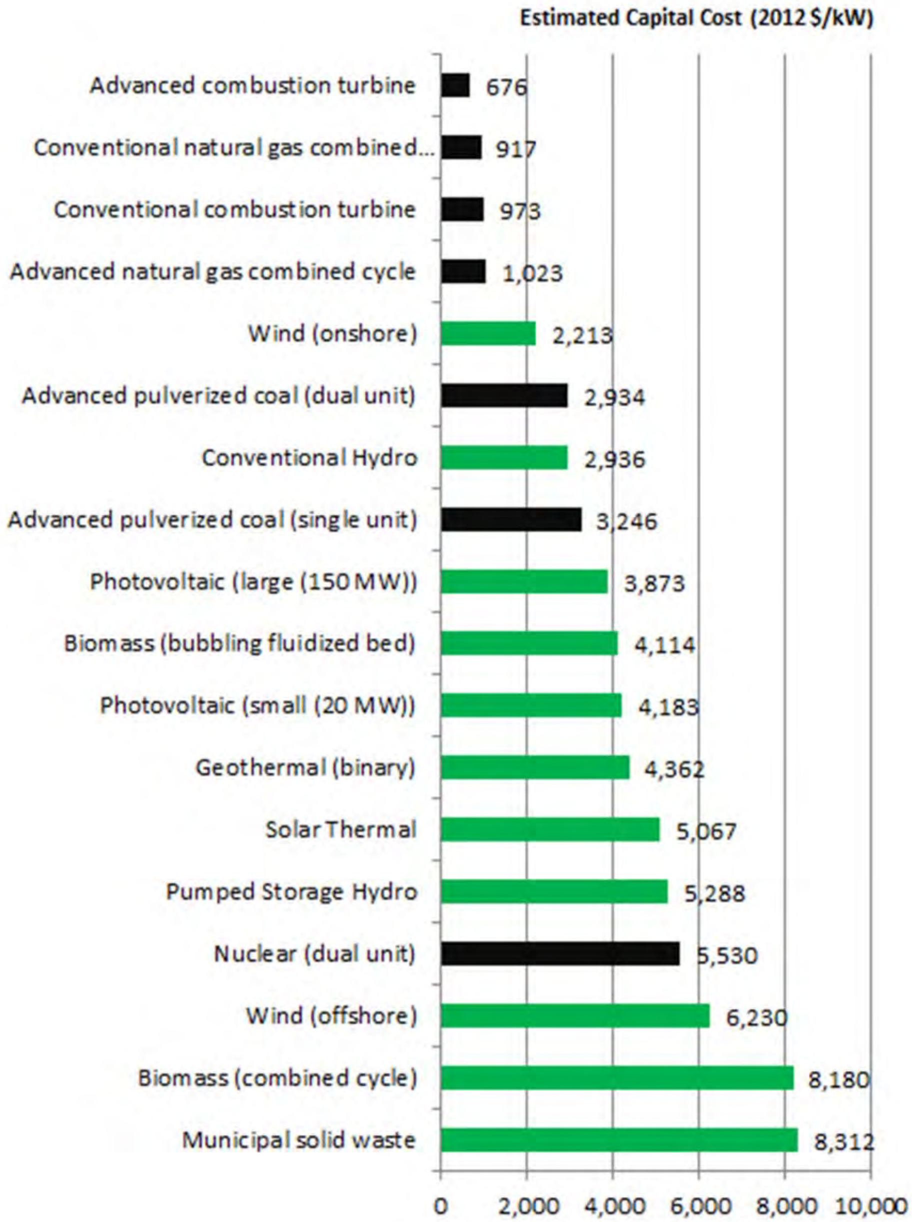


Figure 1-9: Estimated generating technologies capital cost (Data source EIA [18])

Figure 1-10 shows the EIA estimated operating and maintenance (O&M) costs. As can be seen from the figure, renewable resources do not have a clear advantage over conventional generating technologies in terms of O&M costs. But renewables such as solar, wind, hydro and geothermal have the obvious advantage of virtually free fuel.

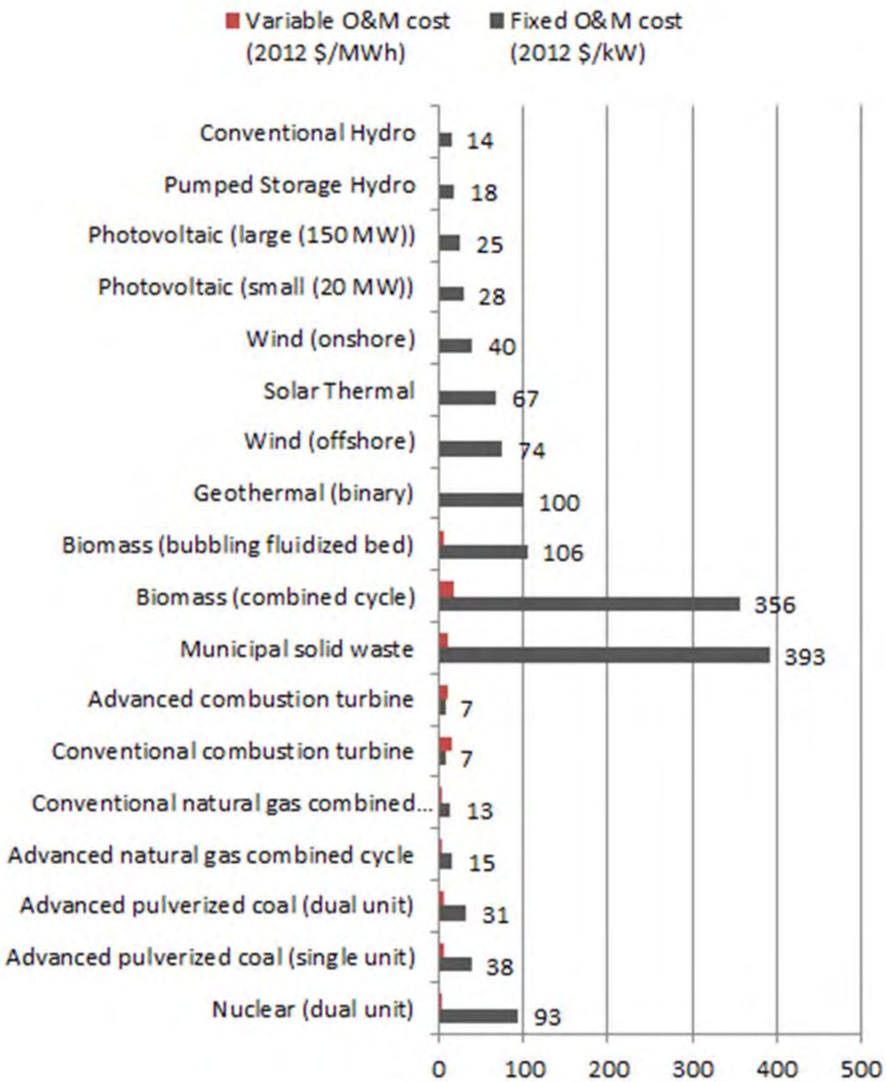


Figure 1-10: Estimated generating technologies O&M cost (Data source EIA [18])

1.4 References

1. Energy Information Administration (EIA). May 2015 Monthly Energy Review Table 10.1. http://www.eia.gov/totalenergy/data/monthly/#renewable
2. EIA. May 2015 Monthly Energy Review Table 1.1 http://www.eia.gov/totalenergy/data/monthly/#summary
3. EIA. May 2015 Monthly Energy Review Table 1.3 http://www.eia.gov/totalenergy/data/monthly/#summary
4. EIA. Renewable. April 2015 Monthly Energy Review, Table 7.2a. http://www.eia.gov/totalenergy/data/monthly/#electricity www.eia.gov/totalenergy/data/browser/xls.cfm?tbl=T07.02A&freq=m
5. EIA. State Energy Data System (SEDS), Table CT2. Primary Energy Consumption Estimates, 1960-2012, Indiana http://www.eia.gov/state/seds/data.cfm?incfile=/state/seds/sep_use/total/use_tot_INcb.html&sid=IN
6. EIA. Indiana Electricity Profile 2012, Table 5, Release date: July 8, 2014. http://www.eia.gov/electricity/state/indiana/ www.eia.gov/electricity/state/indiana/xls/sept05in.xls
7. George Stevens. Indiana Utility Regulatory Commission.
8. Performance Services Corporation. http://www.performanceservices.com/services/wind_power/Community_wind_project
9. DOE, Wind Powering America Program. School wind project locations. http://www.windpoweringamerica.gov/schools/projects.asp
10. Cascade Renewable Energy. City Bus Headquarters Wind Project. http://www.cascaderenewableenergy.com/projects/citybus-wind
11. National Renewable Energy Laboratory. The open PV Project. http://openpv.nrel.gov/
12. Database of State Incentives for Renewables & Efficiency (DSIRE). http://www.dsireusa.org/
13. Indianapolis Power & Light Company. http://www.iplpower.com/uploadedFiles/iplpowercom/Business/Programs_and_Services/Rate%20REP-Apr%2010.pdf
14. NIPSCO. https://www.nipsco.com/docs/default-source/our-services-docs/feedin-faq.pdf
15. NIPSCO. February 2015. https://www.nipsco.com/docs/default-source/our-services-docs/feed-in-tariff-faqs.pdf
16. NIPSCO. March 4, 2015. http://www.nipsco.com/docs/default-source/electric-tariffs-122711-docs/rate-665
17. NIPSCO. https://www.nipsco.com/our-services/renewable-energy-projects/feed-in-tariff-program
18. EIA. Updated capital cost estimates for utility scale electricity generation plants. April 2013. http://www.eia.gov/forecasts/capitalcost/pdf/updated_capcost.pdf

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.

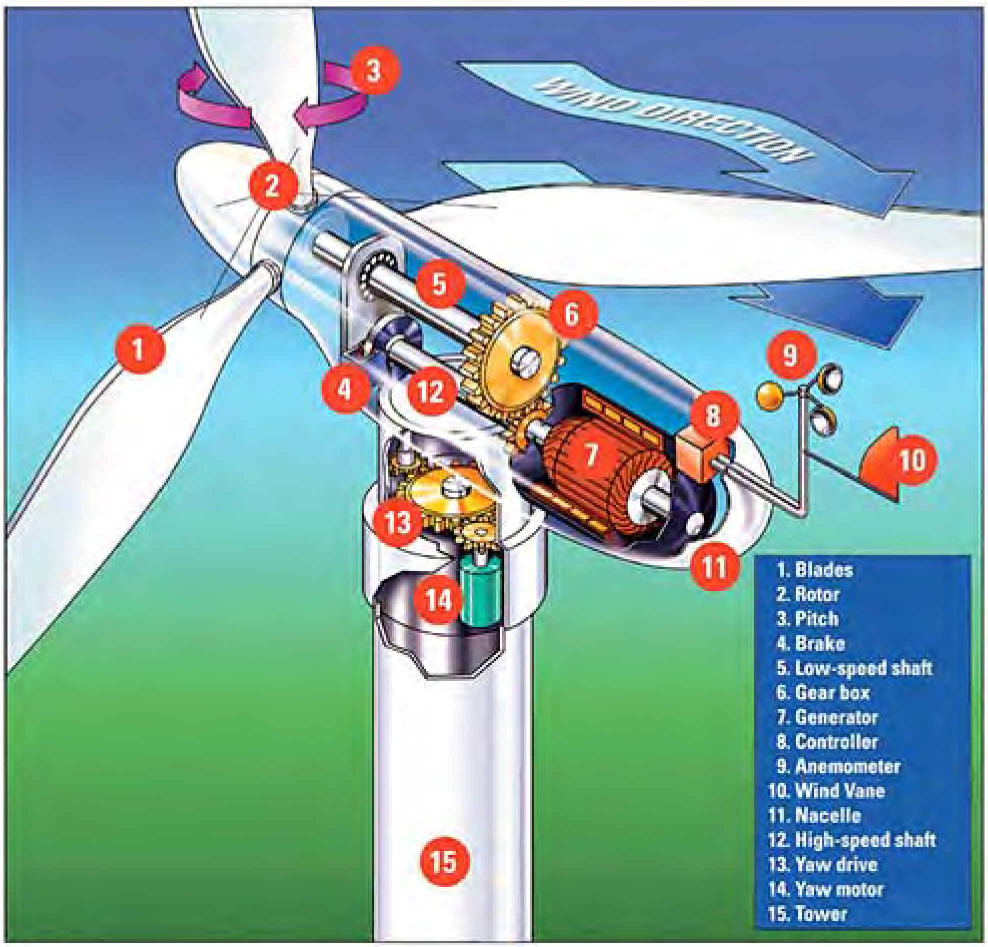


Figure 2-1: Horizontal wind turbine configuration (Source: Alternative Energy News [1])

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, 3].

Although wind farms' capacities have grown to be comparable to fossil fueled generators, the total electricity that can be produced from a 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[4] 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 [4].

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" [5]. 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 - 1000	7.0 – 9.4 (15.7 – 21.1)	> 800	8.8-11.9 (19.7-26.6)

<u>Table 2-1:</u> <u>Wind resource classification</u> (Data source: NREL [6])

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

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. 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 which is very difficult to predict. This intermittency of intensity 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[5] on people living in close proximity.

2.2 Economics of wind energy

Figure 2-2 shows capital cost estimates released by the EIA in April 2013. According to these estimates, onshore utility scale wind power plants have the lowest capital cost among the renewables at $2,213/kW. In addition wind has a lower capital cost than nuclear and pulverized coal power plants. Offshore wind power plants, on the other hand, have an estimated capital cost that is higher than all other generating technologies except municipal solid waste power plants and combined cycle biomass power plants.

[5]The shadow flicker is a pulse of shadows and reflections that is sometimes cast by the moving turbine blades.

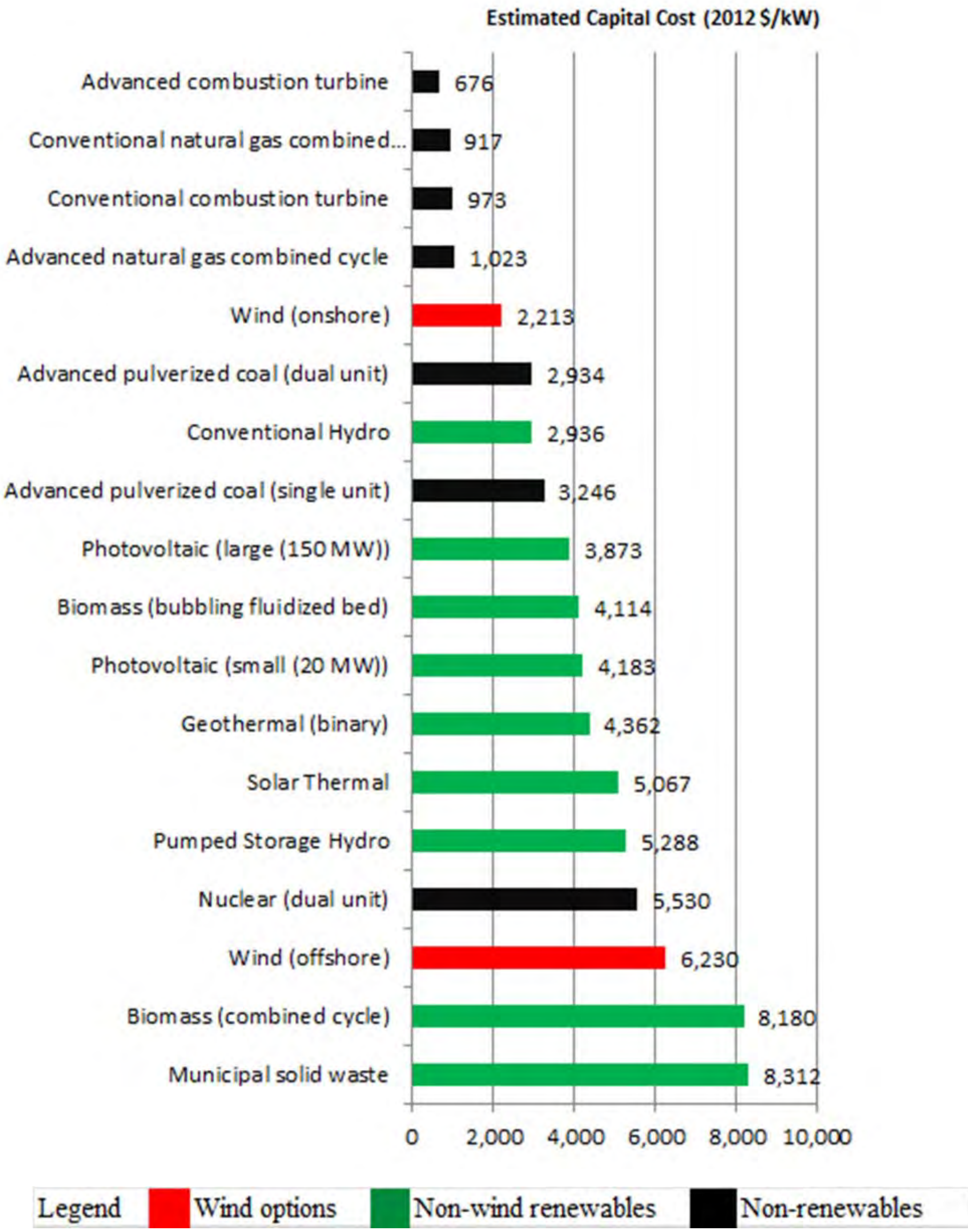
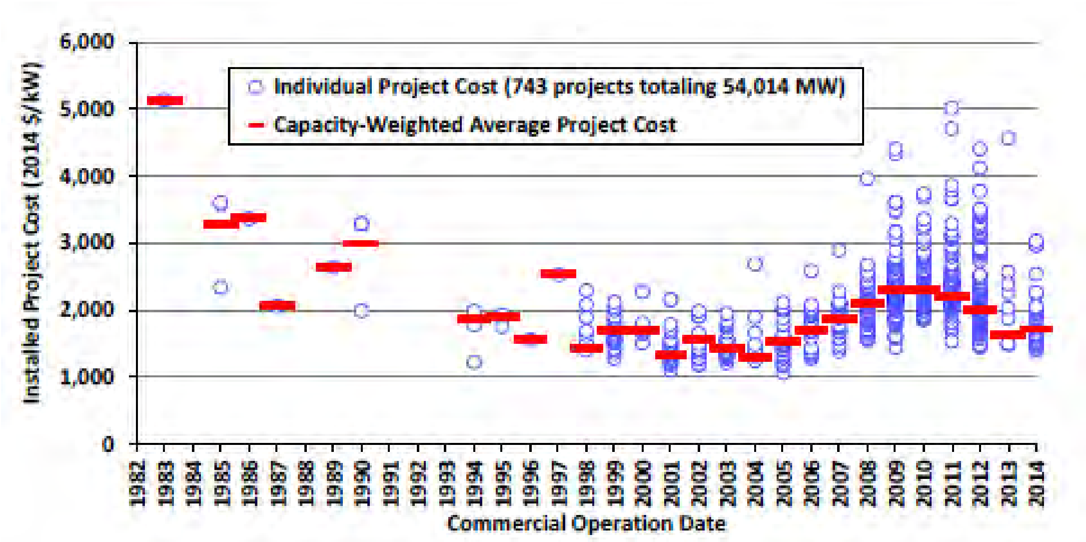


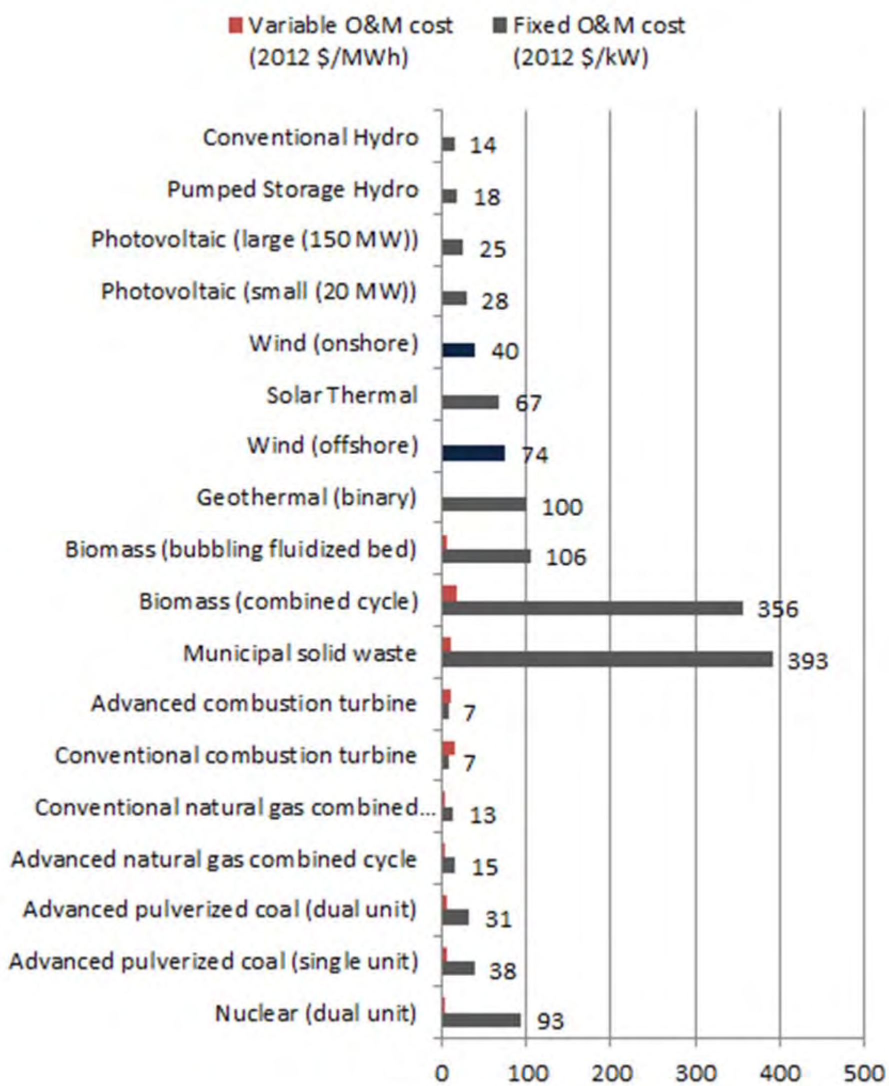
Figure 2-2: Estimated capital costs of various electric generation options (Source: EIA [7])

Figure 2-3 shows the trend in installed wind power plant costs for the projects installed from 1982 to 2014 contained in the 2014 DOE *Wind Technologies Market Report* [8]. As can be seen in the figure, after a period of increasing project cost between 2005 and 2009, the costs were on a steady decline up to 2013, decreasing by $683 from a high of $2,298/kW in 2009 to $1,615/kW in 2013. This declining cost was reversed in 2014 with the capacity-weighted cost for projects installed in 2014 being $92 higher than projects completed in 2013. The decline trend in installed costs of wind energy projects by approximately 20 to 40 percent from 2008 to 2013 reflects the reduction in turbine prices that has been occurring since 2008.



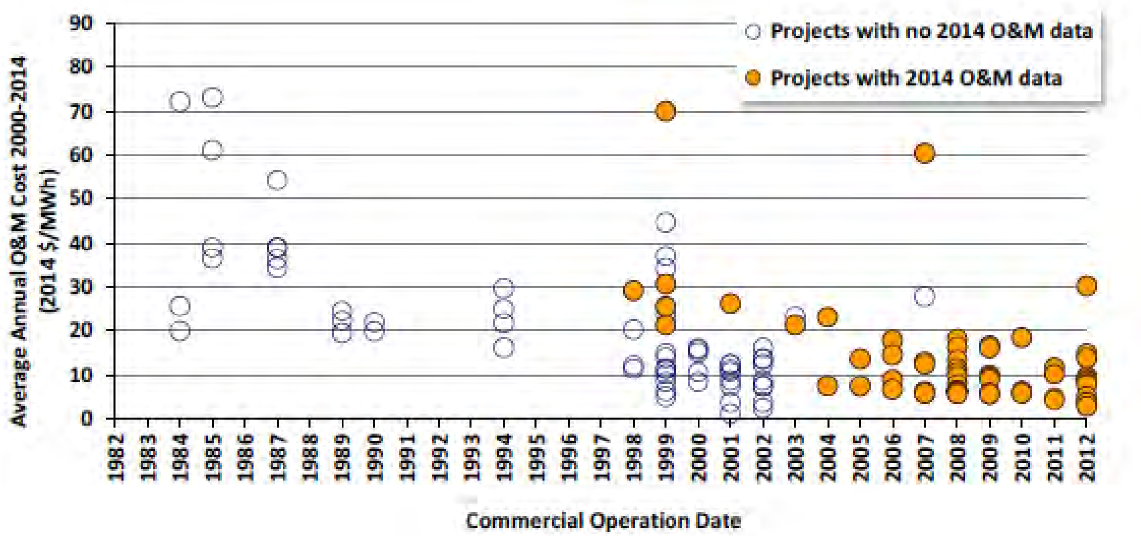
<u>Figure 2-3:</u> <u>Installed wind project costs over time</u> (Source: EERE [8])

Operation and maintenance (O&M) costs are a significant part of the overall cost of wind power plants. According to the *2014Wind Technologies Market Report,* unscheduled maintenance and premature component failure are key challenges to the wind industry. Figure 2-4 shows the O&M costs of electricity generating plants according to the EIA 2013 estimates. EIA estimates the variable O&M to be zero for both onshore and offshore wind farms while the fixed O&M cost is $74/kW for offshore wind and $40/kW for onshore wind farms. The $40/kW fixed O&M cost for the onshore wind farms is higher than that of all fossil-fuel power plants but lower than the $93/kW estimated fixed O&M cost of a nuclear power plant.



<u>Figure 2-4:</u> <u>Generating technologies O&M cost</u> (Data Source: EIA [7])

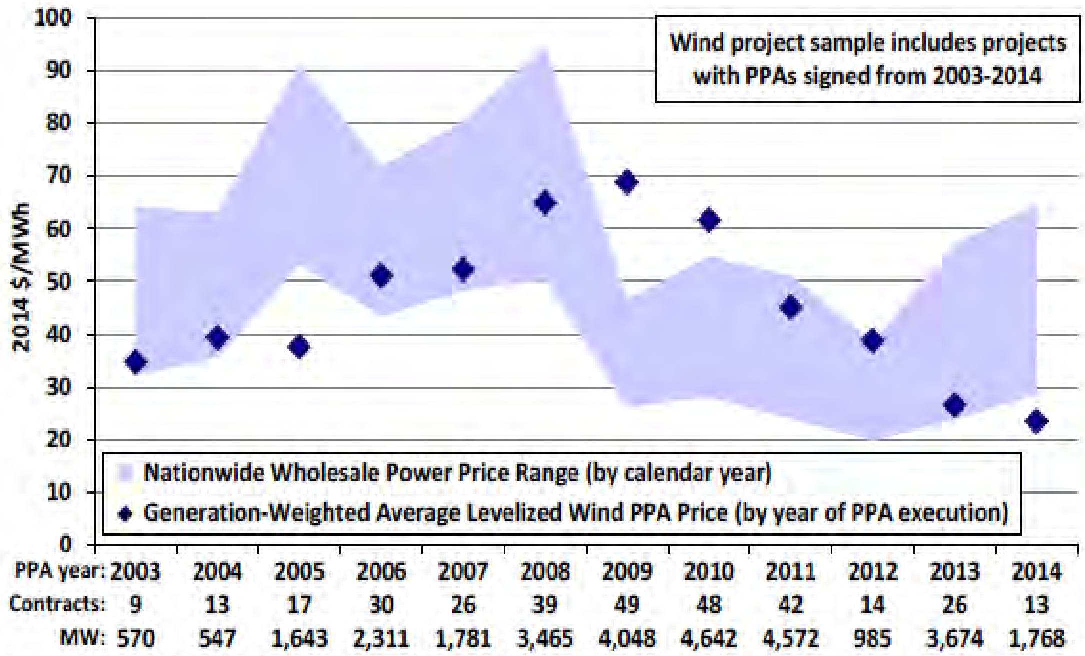
Figure 2-5 shows the O&M costs in the *2014 Wind Technologies Market Report.* According to the report consistent time-series O&M data is very difficult to obtain, and even when available, care must be taken in interpreting historical trends due to the very dramatic changes that have taken place in wind turbine technology in the last twenty years. Figure 2-5 shows the O&M costs in $/MWh for the 147 wind projects in the Lawrence Berkeley National Laboratory database for which O&M data was available. The graph 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 $34/MWh, which dropped to $24/MWh for the 37 projects installed in the 1990s, to $10/MWh for the 66 projects installed in the 2000s, and to $9/MWh for the 20 projects installed since 2010.



<u>Figure 2-5:</u> <u>Reported U.S. wind turbine O&M costs over time</u> (Source: EERE [8])

Figure 2-6 shows the range of national average annual wholesale electricity prices for a flat block of power and the average generation-weighted price in power purchase agreements (PPA) executed in each year from 2003 to 2014. As can be seen from the figure, average wind power prices compared favorably to wholesale power prices until the sharp drop in wholesale prices in 2009. This resulted in a couple of years, 2009 and 2010, when wind power prices were higher than the wholesale electricity prices on a nationwide basis. This condition changed in 2011 and 2012 when the wind power prices fell below the higher end of the wholesale power price range. In 2013, declining wind PPA prices, combined with a rise in wholesale power prices, put wind back in the lower range of the wholesale power price and in 2014 below the wholesale power price range. The wind energy prices in the Berkeley Lab data set reflect the price received 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 $23/MWh federal production tax credit (PTC). The PTC has since expired and is only available for projects whose construction had started before the end of 2014.

Figure 2-6: Average cumulative wind and wholesale electricity prices (Source: EERE [8])



2.3 State of wind energy nationally

In the wake of the 2008 financial crisis which drastically reduced access to capital, the annual wind capacity additions dropped from 10,000 MW in 2009 to 5,215 MW in 2010. This rate recovered to an annual addition of 6,647 MW in 2011 and a record high of 13,082 MW in 2012. This recovery did not last, with capacity additions of only 1,098 MW in 2014 and 1,767 in 2014. Figure 2-7 shows the capacity installation from 2001 through the first quarter of 2015. According to the American Wind Energy Association the cumulative installed wind capacity in the U.S. at the end April 2015 was 66,008 MW [9].

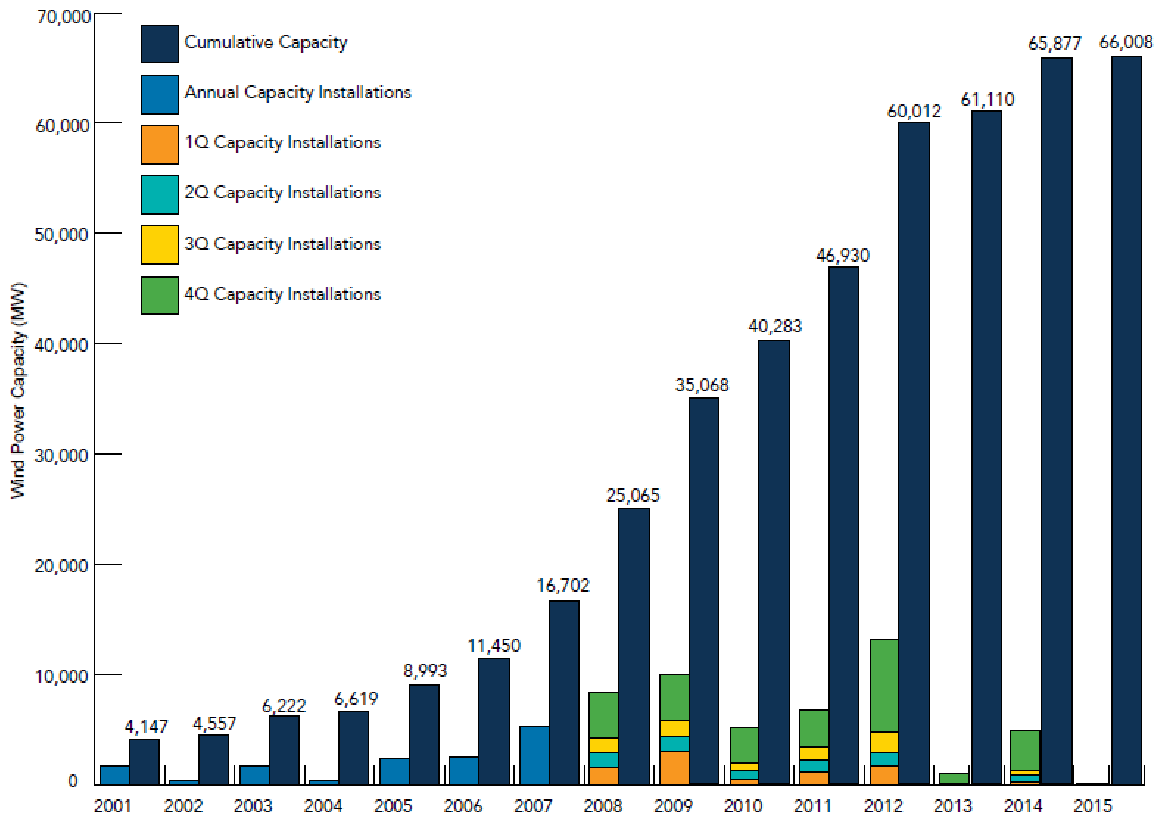


Figure 2-7: U.S. wind capacity growth (Source: AWEA [9])

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 for projects placed into service in 2009 and 2010 was a significant source of capital for the wind industry, offsetting the capital shortage caused by the 2008 financial crisis. The surge in capacity additions in 2012 is attributed to the then expected expiration of the $23/MWh federal renewable electricity production tax credit (PTC). The PTC has subsequently been extended to include all projects whose construction started before January 1, 2015.

Figure 2-8 is a map showing the states that have enacted some form of renewable portfolio standard or set a non-binding goal. Since the writing of the 2014 SUFG Indiana Renewable Resources Study the state of Vermont has enacted a renewable portfolio standard while West Virginia has discontinued their renewable portfolio standard. In addition several states, including Ohio, Colorado, Kansas and Oklahoma have legislative attempts to roll back their renewable portfolio standards [10].

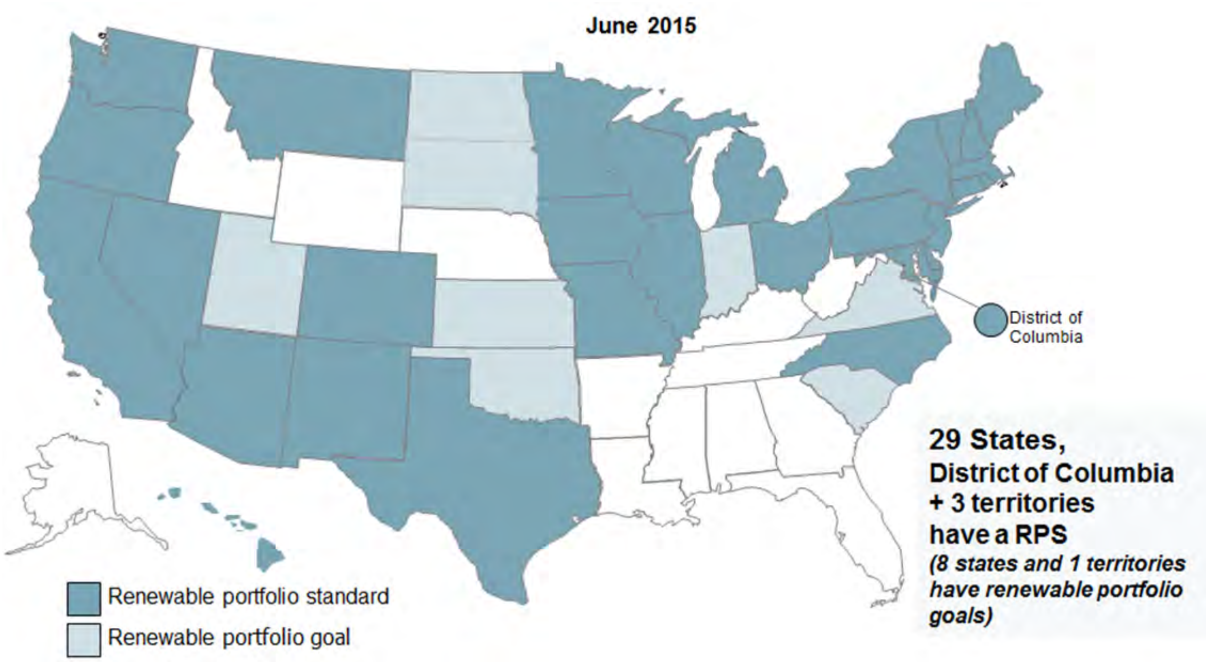


Figure 2-8: Renewable portfolio standards across the U.S. (Source: DSIRE [11])

Figure 2-9 shows the cumulative capacity of wind energy installed in states as of the end of March 2015. Texas continued to lead with a total capacity of 14,208 MW installed followed by California with 5,914 MW of cumulative capacity installed. Indiana ranked 13th overall with 1,745 MW of cumulative installed capacity at the end of March 2015. In terms of wind capacity added in 2014, Texas again led with 1,811 MW followed added by Oklahoma with 648 MW. The Headwaters Wind Farm in Randolph County accounted for the 200 MW capacity added in Indiana in 2014 [12].

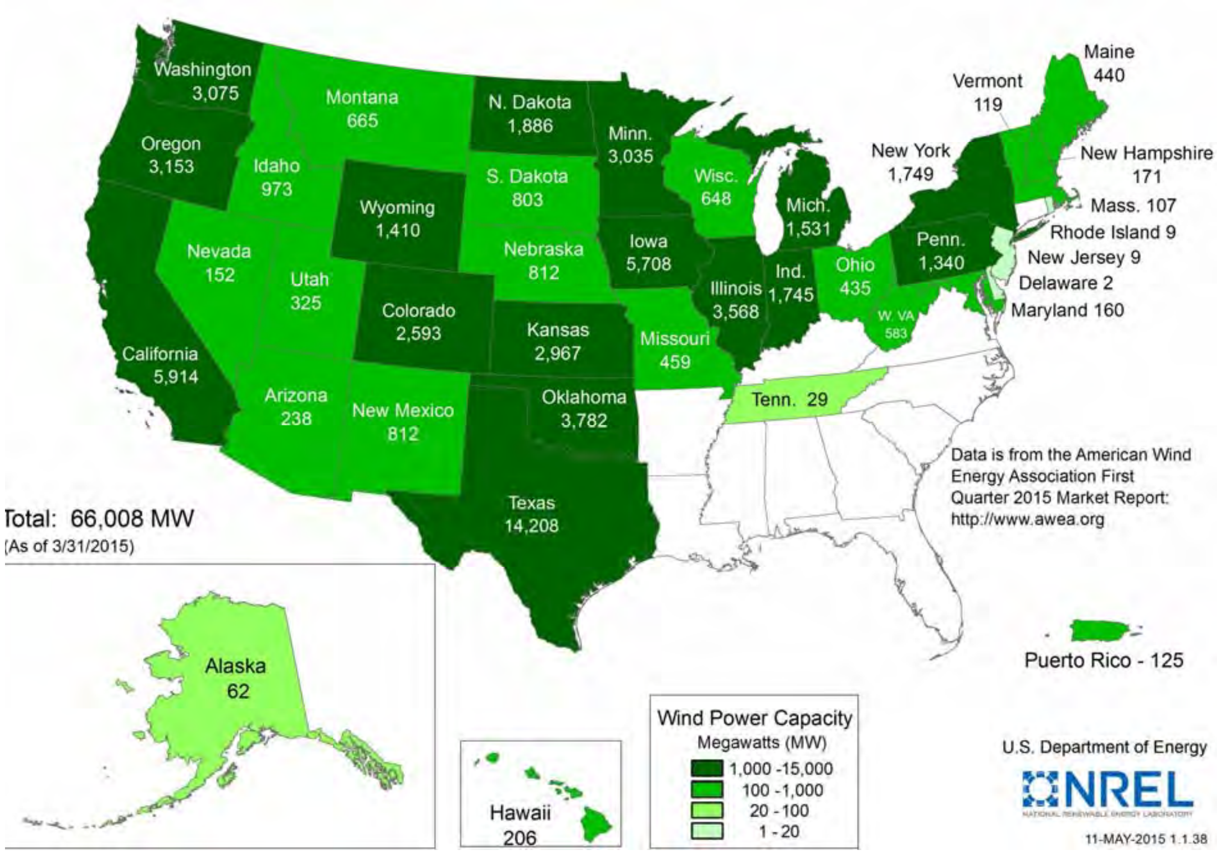


Figure 2-9: Wind power capacity by state at the end of March 2015 (MW) (Source: U.S. DOE [13])

With regard to the penetration of wind energy as a percent of the total electricity generated in 2013, the leading five states in wind energy penetration in 2013 were Iowa – 28.5 percent; South Dakota – 25.3 percent; Kansas – 21.7 percent; Idaho – 18.3 percent; North Dakota – 17.6 percent. Table 2-2 shows the top twenty states in capacity added in 2014, total cumulative capacity, and penetration of wind energy in 2014. The U.S. average penetration was 4.4 percent [8].

Installed Capacity (MW)					Percentage of In-State Generation	
Annual Addition 2014			Cumulative (end of 2014)		Actual (2014)	
Texas	1,811		Texas	14,098	Iowa	28.5%
Oklahoma	648		California	5,917	South Dakota	25.3%
Iowa	511		Iowa	5,688	Kansas	21.7%
Michigan	368		Oklahoma	3,782	Idaho	18.3%
Nebraska	277		Illinois	3,568	North Dakota	17.6%
Washington	267		Oregon	3,153	Oklahoma	16.9%
Colorado	261		Washington	3,075	Minnesota	15.9%
North Dakota	205		Minnesota	3,035	Colorado	13.6%
Indiana	201		Kansas	2,967	Oregon	12.7%
California	107		Colorado	2,593	Texas	9.0%
Minnesota	48		North Dakota	1,866	Wyoming	8.9%
Maryland	40		New York	1,748	Maine	8.3%
New Mexico	35		Indiana	1,745	New Mexico	7.0%
New York	26		Michigan	1,531	California	7.0%
Montana	20		Wyoming	1,410	Nebraska	6.9%
South Dakota	20		Pennsylvania	1,340	Montana	6.5%
Maine	9		Idaho	973	Washington	6.3%
Ohio	0.9		New Mexico	812	Hawaii	5.9%
Massachusetts	0.6		Nebraska	812	Illinois	5.0%
			South Dakota	803	Vermont	4.4%
Rest of U.S.	0		Rest of U.S.	4,941	Rest of U.S.	0.9%
TOTAL U.S.	4,854		TOTAL U.S.	65,877	TOTAL U.S.	4.4%

Table 2-2: U.S. wind power rankings: Top 20 states (Source: EERE [8])

The U.S. has significant wind energy potential. The National Renewable Energy Laboratory estimates the potential rated capacity that could be installed on available windy land areas across the U.S. is approximately 11 million MW, and the annual wind energy that could be generated from these potential installed capacities is approximately 39 million gigawatt hours (GWh). This is more than seven times the electricity generated from all sources in the U.S. in 2014. Figure 2-10 shows the distribution of the wind resource [14, 15].

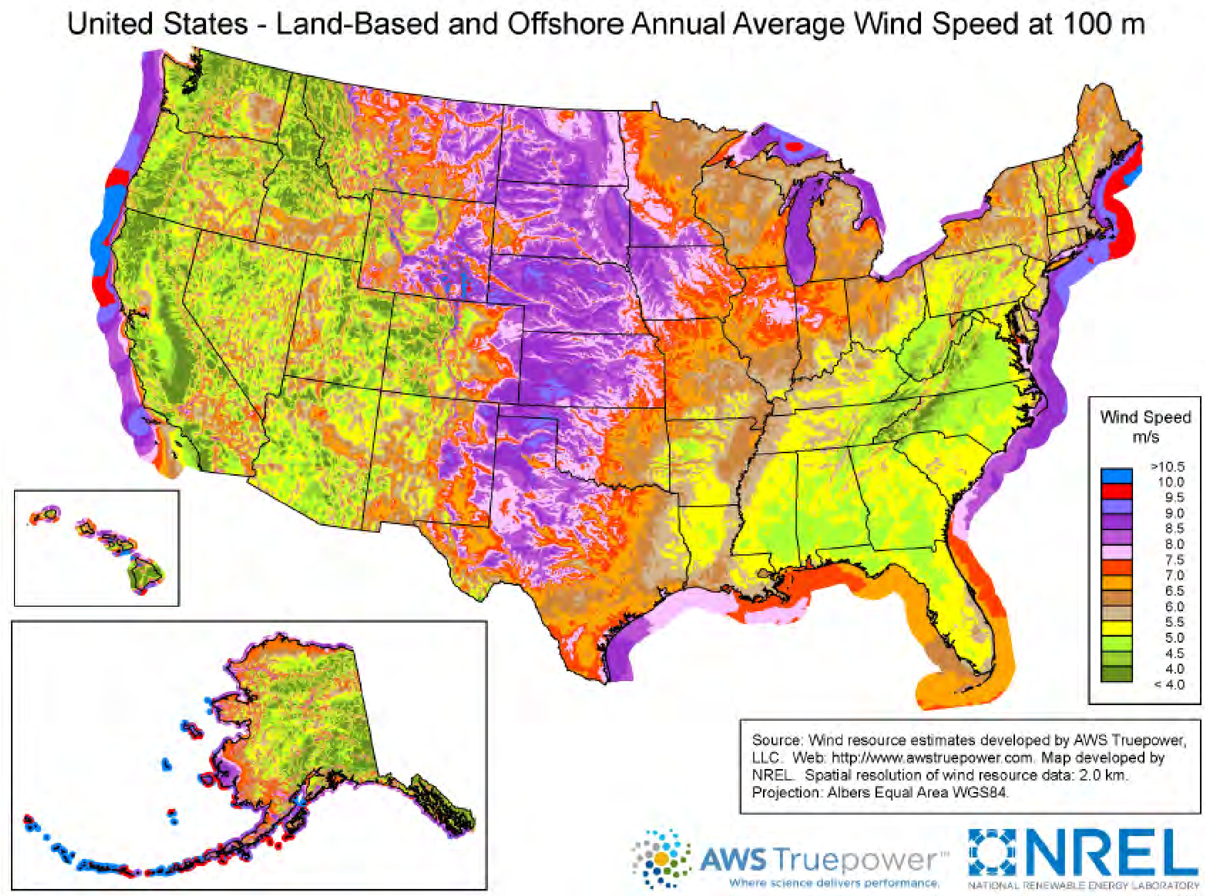


Figure 2-10: 80-meter U.S. wind resource map (Source: NREL [16])

As can be seen in Figure 2-10 there is an abundance of wind energy resources along the U.S. coast lines and in the Great Lakes. Offshore winds tend to be of higher speed and steadier. So far there has been no offshore wind energy project established in the U.S. The proposed 1,500 MW Cape Wind project in Cape Cod, Massachusetts whose construction was planned to start in the Fall of 2014 suffered a major setback in January 2015 when its two utility customers, National Grid and Northeast Utilities, terminated the power purchase agreements to buy 77.5% of the projects output [17, 18].

In addition to resistance from local communities as demonstrated by the Cape Wind project, other factors hindering the development of offshore wind energy include its relatively higher cost and the technical challenges associated with installing wind turbines in a marine environment and connecting the electricity to the onshore power grid.

The federal government, in a combined effort between DOE and the U.S. Department of the Interior, is trying to lower these barriers and expedite the deployment of substantial offshore wind generation. This effort is explained in *A National Offshore Wind Strategy: Creating an Offshore Wind Energy Industry in the United States* released in 2012 [19] and the *Wind Energy Vision* report released in April 2015 [20].

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 908 MW annual capacity addition in 2009 fell to additions of 302 MW in 2010 and virtually no capacity additions in 2011 outside small, stand-alone community wind turbines. Figure 2-11 shows the annual and cumulative capacity additions in Indiana. The 205 MW capacity added in 2014 reflects the completion of the Headwaters wind farm in Randolph County and the addition of several small wind turbines under the net metering and feed-in tariffs of Indiana Utilities.

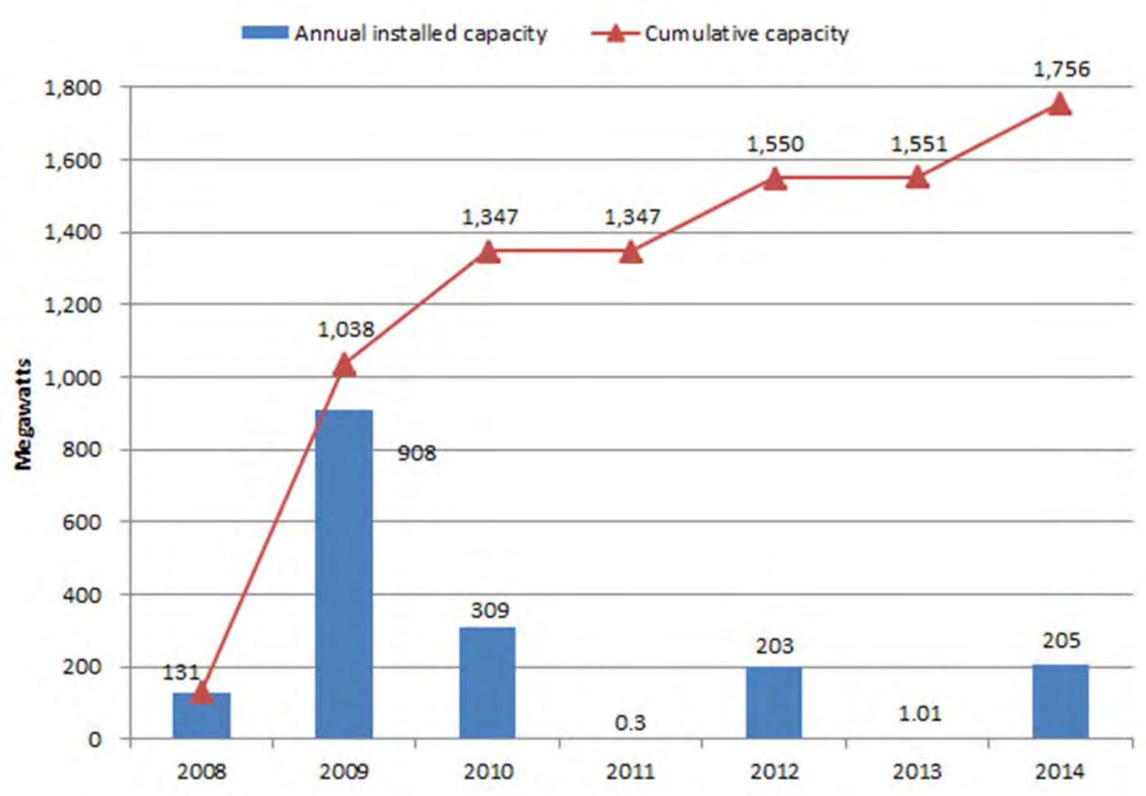


Figure 2-11: Annual wind energy capacity installation in Indiana (Data source: IURC, DOE [21 – 24]

Table 2-3 shows a list of utility scale wind farms in Indiana. It includes the eleven operational wind farms with a combined capacity of 1,744 MW. One wind farm, the 150 MW Amazon Wind Farm in Benton County, is currently under construction while five wind farms with a combined capacity of 768 MW have been approved for construction by the Indiana Regulatory Commission (IURC) but construction had not started at the writing of this report. Project completed.

Project Name	County	Capacity (MW)	Developer	Date Completed
Benton County Wind Farm	Benton	131	Orion	2008
Fowler Ridge I Wind Farm	Benton	301	BP/Dominion	2009
Fowler Ridge II-A Wind Farm	Benton	200	BP/Dominion	2009
Fowler Ridge III Wind Farm	Benton	99	BP/Dominion	2009
Hoosier Wind Farm	Benton	106	EDF Renewable Energy	2009
Meadow Lake Wind Farm I	White	200	Energias de Portugal (EDP)	2009
Meadow Lake Wind Farm II	White	99	EDP	2010
Meadow Lake Wind Farm III	White	110	EDP	2010
Meadow Lake Wind Farm IV	White	99	EDP	2010
Wildcat Wind Farm I	Madison/ Tipton	200	E.ON	2012
Headwaters Wind Farm	Randolph	200	EDP	2014
Project under construction				**Construction start**
Amazon Wind Farm	Benton	150	Pattern Energy	2015
Proposed projects				
Meadow Lake Wind Farm V	White	101	EDP	
Spartan Wind Farm	Newton	198	Apex Clean Energy	
Bluff Point	Jay/ Randolph	119	NextEra	
Fowler Ridge IV Wind Farm	Benton	150	BP/Dominion	
Wildcat Wind Farm II	Grant/ Howard	200	E.ON	

Table 2-3: Utility Scale Wind Farms in Indiana (Data source: IURC [24], Performance Services [25], WLFI News18 [26])

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 with a combined capacity of 6.9 MW of which SUFG was aware at the writing of this report.

Project Name	County	Capacity (kW)	Developer	Date Completed
Randolph Eastern School Corporation	Randolph	1,000	Performance Services	2009
Union City	Randolph	1,000	Performance Services	2009
Tippecanoe Valley Schools	Kosciusko	900	Performance Services	2010
Lafayette City Bus	Tippecanoe	300	Cascade Renewable	2011
North Newton School Corporation	Newton	900	Performance Services	2012
West Central School Corporation	Pulaski	900	Performance Services	2012
Northwestern School Corporation	Howard	900	Performance Services	2012
Taylor University	Grant	100	ECI Wind and Solar	2013
Goshen College	Elkhart	10	Performance Services	2013
Shenandoah School Corporation	Henry	900	Performance Services	2013
City of Winchester	Randolph	850	Performance Services	2014

Table 2-4: Community wind projects in Indiana (Data source: [21 - 23])

Indiana utilities have a total 1,152.5 MW of wind power contracted on power purchase agreements, 747.1 MW from wind farms in Indiana and 405.4 MW from out of state wind farms in Iowa, Minnesota and South Dakota. Table 2-5 shows the wind power capacity contracted to Indiana utilities.

Utility	Project	State	Power Purchase Agreement (MW)
Duke Energy	Benton County Wind Farm	Indiana	110.7
Duke Energy	Benton County Wind Farm	Indiana	110.7
Vectren	Benton County Wind Farm	Indiana	30
Vectren	Fowler Ridge Wind Farm II	Indiana	50
IPL	Hoosier Wind	Indiana	106
Indiana Michigan Power (I&M)	Fowler Ridge Wind Farm I	Indiana	100.4
I&M	Fowler Ridge II Wind Farm	Indiana	50
I&M	Wildcat I Wind Farm	Indiana	100
I&M	Headwaters Wind Farm	Indiana	200
IPL	Lakefield Wind	Minnesota	201
NIPSCO	Buffalo Ridge	South Dakota	50.4
NIPSCO	Barton Wind Farm	Iowa	50
Hoosier Energy	Rail Splitter	Illinois	25
Wabash Valley	Various sources	Various sources	29
Indiana Municipal Power Agency	Hancock County	Iowa	50

Table 2-5: Wind energy purchase agreements by Indiana utilities (Data source: IURC [24])

Figure 2-12 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 2-13 shows the distribution of the wind resource at 50m, a height at which smaller scale community wind projects operate.

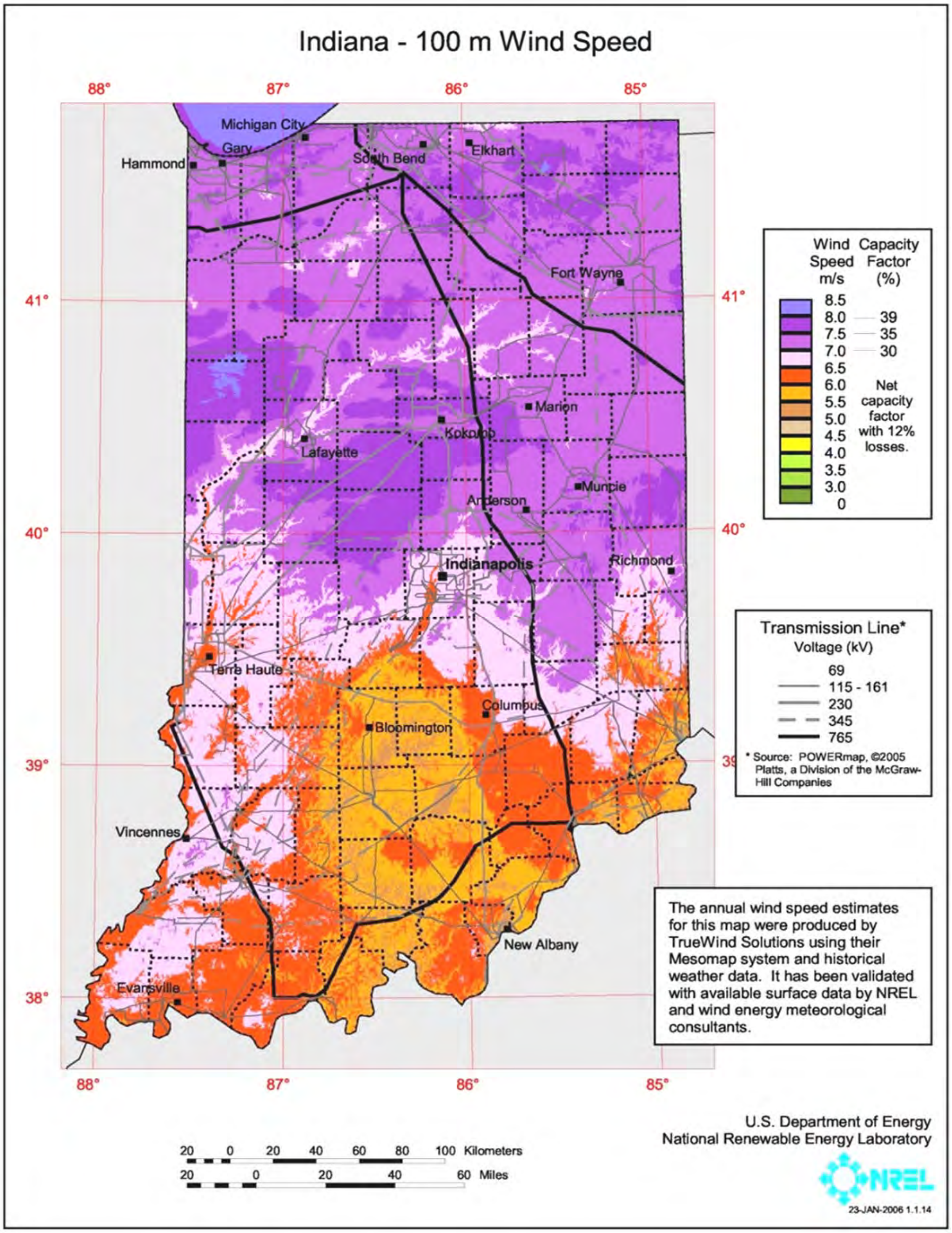
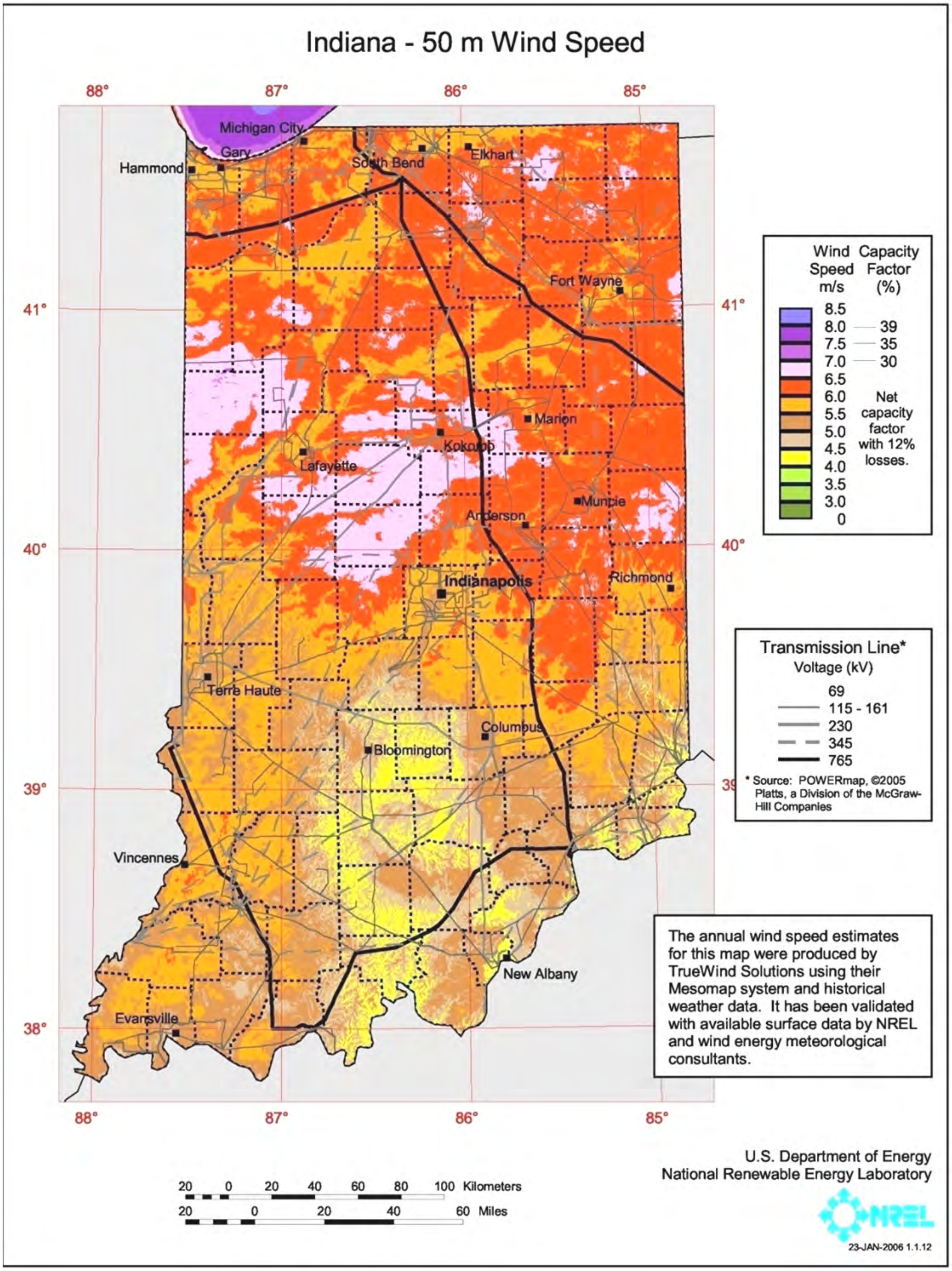


Figure 2-12: Indiana wind speed at 100 meters height (Source: OED/NREL [27])



<u>Figure 2-13:</u> <u>Indiana wind speed at 50 meters height</u> (Source: OED/NREL [27])

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 2009 to allow producers who would qualify for the PTC to opt to take the federal business energy investment tax credit (ITC). The PTC expired in December 2014 but projects under construction in 2015 are eligible for the credit if they began construction before the end of 2014 [11].
- U.S. DOE Loan Guarantee Program (Section 1703, Title IV of Energy Policy Act of 2005 provides loan guarantees for large scale innovative renewable energy projects that reduce the emission of pollutants, including renewable energy projects [11].
- Business Energy Investment Tax Credit (ITC) credits up to 30 percent of expenditures, with no maximum credit, on qualifying wind energy installations. Eligible small wind property includes wind turbines up to 100 kW in capacity [11].
- Modified Accelerated Cost-Recovery System (MACRS) allows businesses to recover investments in qualified renewable energy technologies through depreciation deductions. A provision for a 50 percent first year bonus depreciation added by the Economic Stimulus Act of 2008 expired at end of 2014 [11].
- USDA 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].
- Clean Renewable Energy Bonds (CREBs) are tax credit bonds designed to offset the tax liability of not-for-profit entities such as public utilities, and local and state governments that because of their structure do not benefit from the traditional renewable energy production tax credit (PTC). In February 2015 the IRS announced the allocation of nearly $1.4 billion for new CREBS available from March 2015 [11].
- 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 [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 [11, 28].
- 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 20 percent of energy used by federal agencies must be obtained from renewable resources by 2020 [11].

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 [11].
- Clean Energy Credit Program (Energy Efficiency and Renewable Energy Set-aside) allocates nitrogen oxides (NOx) allowances for renewable energy and energy efficiency projects that displace utility electricity generation. These NOx credits can then be traded in the regional NOx market that covers 21 states in the eastern United States. One NOx allowance is allocated for each ton of NOx emissions displaced. Several projects may be combined in one application to meet the one ton minimum requirement [29].
- Renewable Energy Property Tax Exemption provides property tax exemptions for solar thermal, PV, wind, hydroelectric and geothermal systems [11].
- 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. At the writing of this report winners for 2015 had been selected and the challenge closed for the year [11, 30].
- 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, which includes electricity, from state gross retail tax. However, only wind energy has clearly specified rules from the Department of Revenue [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].

- 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 wind turbines between from 3kW and 10kW is $0.25/kWh for the first batch to be selected in the first capacity allocation lottery (*allocation 1*) and $0.23/kW for subsequent ones (*allocation 2*). The payment for wind turbines larger than 10kW up to 200kW is $0.15/kWh for projects in *allocation 1* and $0.138 for those in *allocation 2* [11, 31, 32].

2.6 References

1. Alternative Energy News. http://www.alternative-energy-news.info/technology/wind-power/wind-turbines/
2. National Renewable Energy Laboratory (NREL). Wind Powering America. Wind energy update, January 2012. http://www.windpoweringamerica.gov/pdfs/wpa/wpa_update.pdf
3. U.S. Department of Energy (U.S. DOE). Wind vision: a new era for wind in the United States. http://www.energy.gov/windvision, http://www.energy.gov/sites/prod/files/WindVision_Report_final.pdf
4. 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.leg.state.vt.us/jfo/envy/Wind%20Power%20Fact%20Sheet.pdf
5. NREL. Renewable Resource Data Center. Wind energy resource atlas of the United States. http://rredc.nrel.gov/wind/pubs/atlas/appendix_A.html#wind
6. 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
7. 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
8. U.S. DOE Office of Energy Efficiency and Renewable Energy (EERE). 2014 Wind technologies market report. http://www.energy.gov/eere/wind/downloads/2014-wind-technologies-market-report www.energy.gov/sites/prod/files/2015/08/f25/2014_WTMR_Data_File_0.xls
9. AWEA. U.S. Wind industry first quarter 2015market report. plus.com/FileDownloads/pdfs/1Q2015%20AWEA%20Market%20Report%20Public%20Version.pdf
10. GRIST. http://grist.org/news/score-one-for-alec-west-virginia-is-first-state-to-repeal-a-renewable-energy-standard/
11. Database of State Incentives for Renewables & Efficiency (DSIRE). http://www.dsireusa.org/
12. EERE. WINDExchange. Installed wind capacity by state apps2.eere.energy.gov/wind/windexchange/docs/installed_wind_capacity_by_state.xls

13. EERE. WINDExchange. Installed Wind Capacity. http://apps2.eere.energy.gov/wind/windexchange/wind_installed_capacity.asp
14. NREL. Estimates of windy land area and wind energy potential, by State, for areas >= 30% capacity factor at 80m. apps2.eere.energy.gov/wind/windexchange/docs/wind_potential_80m_30percent.xlsx
15. EIA. May 2015 Electric Power Monthly Table 1.1 http://www.eia.gov/electricity/monthly/ www.eia.gov/electricity/monthly/xls/table_1_01.xlsx
16. NREL. Wind maps. http://www.nrel.gov/gis/wind.html http://www.nrel.gov/gis/images/100m_wind/awstwspd100onoff3-1.jpg
17. Cape Wind. http://www.capewind.org/
18. The Boston Globe, January 7, 2015. https://www.bostonglobe.com/metro/2015/01/06/major-setback-for-cape-wind-project/kggnYeAXRj03PyfIUn2iIM/story.html
19. 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
20. U.S. DOE. Wind vision: a new era for wind power in the United States http://energy.gov/eere/wind/wind-program http://www.energy.gov/sites/prod/files/WindVision_Report_final.pdf
21. Cascade Renewable Energy. City Bus Headquarters Wind Project. http://www.cascaderenewableenergy.com/projects/citybus-wind
22. Performance Services Corporation. http://www.performanceservices.com/services/wind_power/Community_wind_project
23. U.S. DOE, Wind Powering America Program. School wind project locations. http://www.windpoweringamerica.gov/schools/projects.asp
24. George Stevens. Indiana Utility Regulatory Commission.
25. Performance Services. www.performanceservices.com/files/Project%20Profiles/PEP_Project%20Profile%204-2013.pdf
26. WLFI News 18. http://wlfi.com/2015/07/29/amazon-wind-farm-begins-construction/
27. Indiana Office of Energy Development. Indiana wind maps & reports. http://www.in.gov/oed/2425.htm
28. U.S. Department of Agriculture, Rural Development. Grants http://www.rd.usda.gov/programs-services/high-energy-cost-grants
29. Indiana Department of Environmental Management. Clean Energy Credit. http://www.in.gov/idem/airquality/2553.htm www.in.gov/oed/files/Presentation_Letterman.ppt
30. Indiana Office of Energy Development. Community Conservation Challenge. https://secure.in.gov/oed/2645.htm
31. NIPSCO. February 2015. https://www.nipsco.com/docs/default-source/our-services-docs/feed-in-tariff-faqs.pdf
32. NIPSCO. March 4, 2015. http://www.nipsco.com/docs/default-source/electric-tariffs 122711-docs/rate-665

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. Information on the use of 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 research, development, demonstration and deployment effort, led by the U.S. Department of Energy (DOE) Bioenergy Technologies Office, is under way to build a national bioenergy industry with the objective to reduce U.S. dependence on imported oil. Biomass is unique among renewable resources in that it can also be used as feedstock to produce liquid transportation fuels and industrial chemicals. This characteristic is the primary motivation behind the research on energy crops and organic waste biomass and the associated conversion technologies [1]. This research effort is detailed in the DOE report titled *U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry* [2] and the Bioenergy Technologies Office March 2015 *Multi-Year Program Plan* [3]. 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 in the University of Vermont extension program.

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 varieties suited to given regions of the country.

Figure 3-1: Switchgrass (Source: Farm Energy [4])

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 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 bark and the paper processing byproduct *black liquor* are used to produce energy in pulp and paper mills. The 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 [2].

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 [5].
- 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 [6].
- 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 [7].

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 feed stocks 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. Fifteen of these are small scale pilot projects with a capacity of one dry metric ton of biomass per day. These pilot plants screen and validate promising bio-processing technologies. Four of the biorefineries are demonstration plants where the technologies validated at the pilot plants are scaled up to produce at the scale of 10 to 50 dry metric tons of feedstock a day. The technologies validated at the pilot scale are to be scaled up to commercial level at the four "pioneer" plants. Table 3-1 is a list of integrated biorefinery projects [8].

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

*Discussion of algae as a source of energy is included in Section 4 of report

Table 3-1: DOE funded integrated biorefinery projects (Data source: DOE [8])

Three of the commercial scale pioneer projects are now complete and producing biofuels as shown in Table 3-2. The fourth project is Mascoma Biorefinery at Kinross, Michigan. It was proposed to convert aspen trees into cellulosic ethanol with a design output capacity of 20 million gallons per year. In 2013 the project suffered a major setback when one of the project partners, Valero Energy Corporation, pulled out leaving the project short of financing [9].

	INEOS (Vero Beach FL)	Abengoa (Hugoton KS)	POET-DSM (Emmetsburg IA)
Began production	2013	2013	2014
Feedstock (tons per year)	Yard and wood waste (250,000)	Agricultural crop residues (325,000)	Corn stover (285,000)
Primary Process	Gasification	Enzymatic hydrolysis	Two step biotechnological process
Biofuel Output (million gallons per year)	Cellulosic ethanol (8)	Cellulosic ethanol (25)	Cellulosic ethanol (20-25)
Electricity Output	6 MW gross 2 MW net	21 MW Gross	Thermal energy output supplies plant needs

Table 3-2: Completed DOE funded integrated biorefineries (Data source: DOE [10])

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[6] (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 woody crop 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 farm-gate prices $40, $50 and $60 per dry ton[7] 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

[6] 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.

[7] Dry ton is the weight in tons of the biomass material after all the moisture has been removed.

$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.

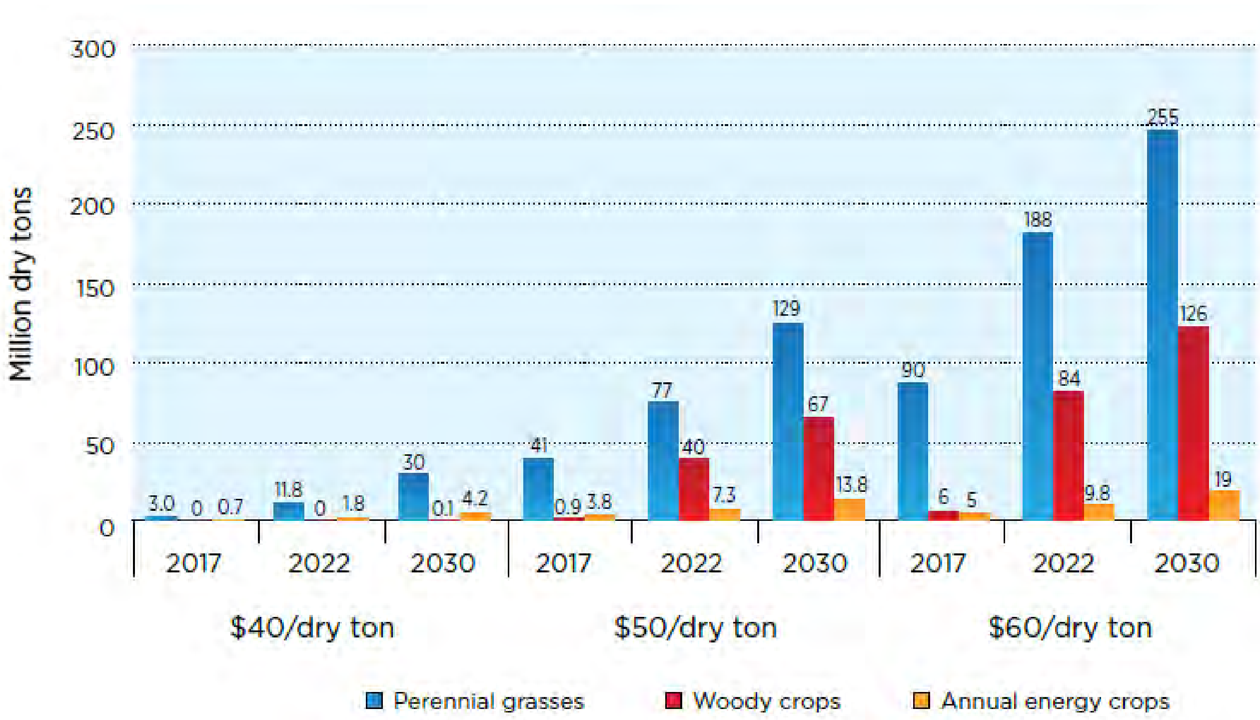


Figure 3-2: Potential production of energy crops at various years and farm-gate prices (Source: DOE [2])

In addition to the *Billion-Ton* study DOE has developed a spatial web-accessible database, the *Bioenergy Knowledge Discovery Framework* (KDF), which brings together data from the various DOE supported bioenergy research efforts across the U.S. The research projects whose data is integrated into the KDF include

- Biomass Resource Potential research prepared by the Oak Ridge National Laboratory whose results are presented in the *Billion-Ton Update* report referred to above,
- The Sun Grant Initiative Resource Assessment project that collects data from the energy crops field trials,
- The Feedstock Supply and Logistics Analysis research being conducted at the Idaho National Laboratory,
- The Microalgae Biofuel Potential project taking place at the Pacific Northwestern National Laboratory,
- The Regional Land-Use Change Modeling project based at the Great Lakes Bioenergy Center,

- The International Projects Partnership based at the Oak Ridge National Laboratory that is working to identify areas of biodiversity concern to be avoided when planting energy crops,
- The National Biorefinery Siting Model that seeks to develop a geographical information system (GIS) based biomass supply and biorefinery location model of the U.S.
- The Alternative Fuels and Advanced Vehicles Data Center at the National Renewable Energy Laboratory that is intended to provide interactive maps of alternative fuels infrastructure [11]

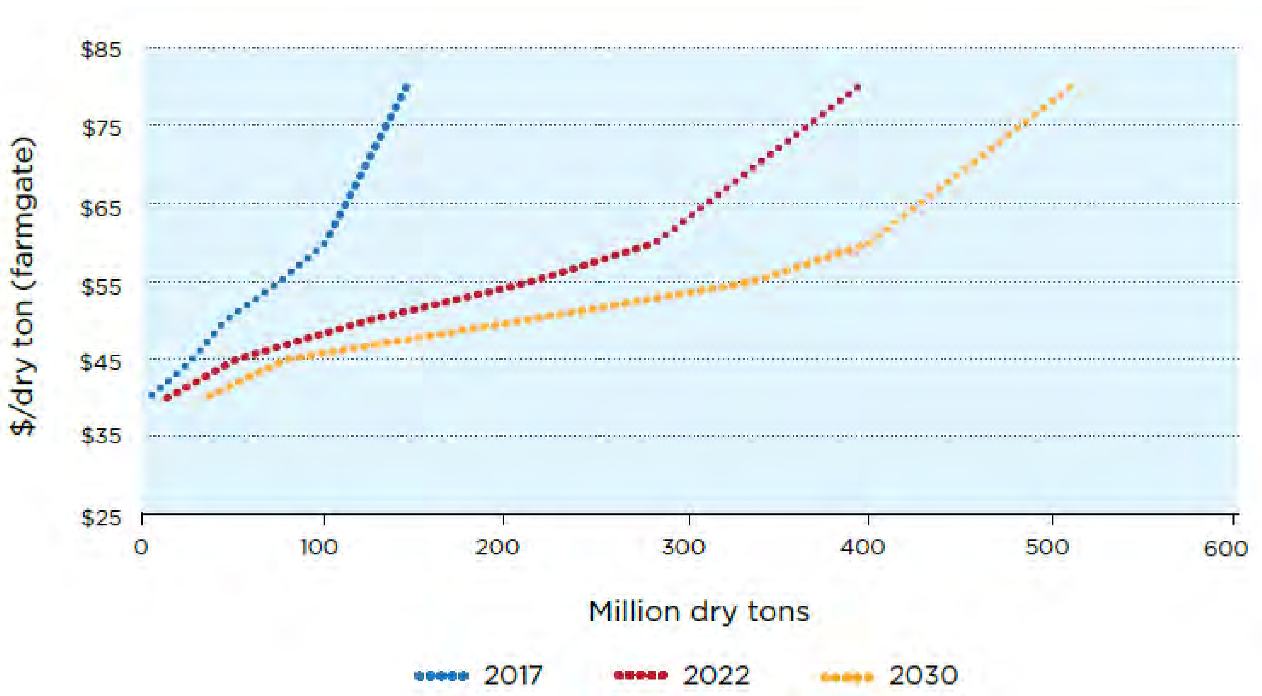


Figure 3-3: Supply curves for all energy crops at selected years (Source: DOE [2])

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 the fact that they are 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 1,068 MGY have been constructed, bringing the total corn-ethanol capacity to 1,168 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 of at least one plant, the 102 MGY Noble Americas plant in South Bend, reducing the producing capacity to 1,066 MGY. Table 3-3 shows the location and capacities of ethanol plants in Indiana.

Table 3-4 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 93 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 it being associated with ground water pollution. The replacement of MTBE was mandated both by states and the 2005 Energy Policy Act [12].
- The renewable fuel standard first enacted in 2005 and then expanded in 2007 requires that 36 million gallons of renewable fuel (15 billion gallons from corn-ethanol and the balance from advanced biofuels) must be blended into gasoline by 2022 [13].
- 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	Location	Nameplate Capacity (MGY*)	Operating Production (MGY*)
Abengoa Bioenergy Corp.	Mt. Vernon	90	90
Cardinal Ethanol	Union City	100	100
Central Indiana Ethanol	Marion	50	50
Grain Processing Corp.	Washington	20	20
Green Plains Renewable Energy	Bluffton	120	120
Iroquois Bio-Energy Company	Rensselaer	50	50
Noble Americas South Bend Ethanol	South Bend	102	0
POET Biorefining - Alexandria	Alexandria	68	68
POET Biorefining - Cloverdale	Cloverdale	92	92
POET Biorefining - North Manchester	North Manchester	68	68
POET Biorefining - Portland	Portland	68	68
The Andersons Clymers Ethanol	Clymers	110	110
Valero Renewable Fuels	Linden, IN	120	120
Valero Renewable Fuels	Mount Vernon	110	110

*MGY denotes million gallons per year.

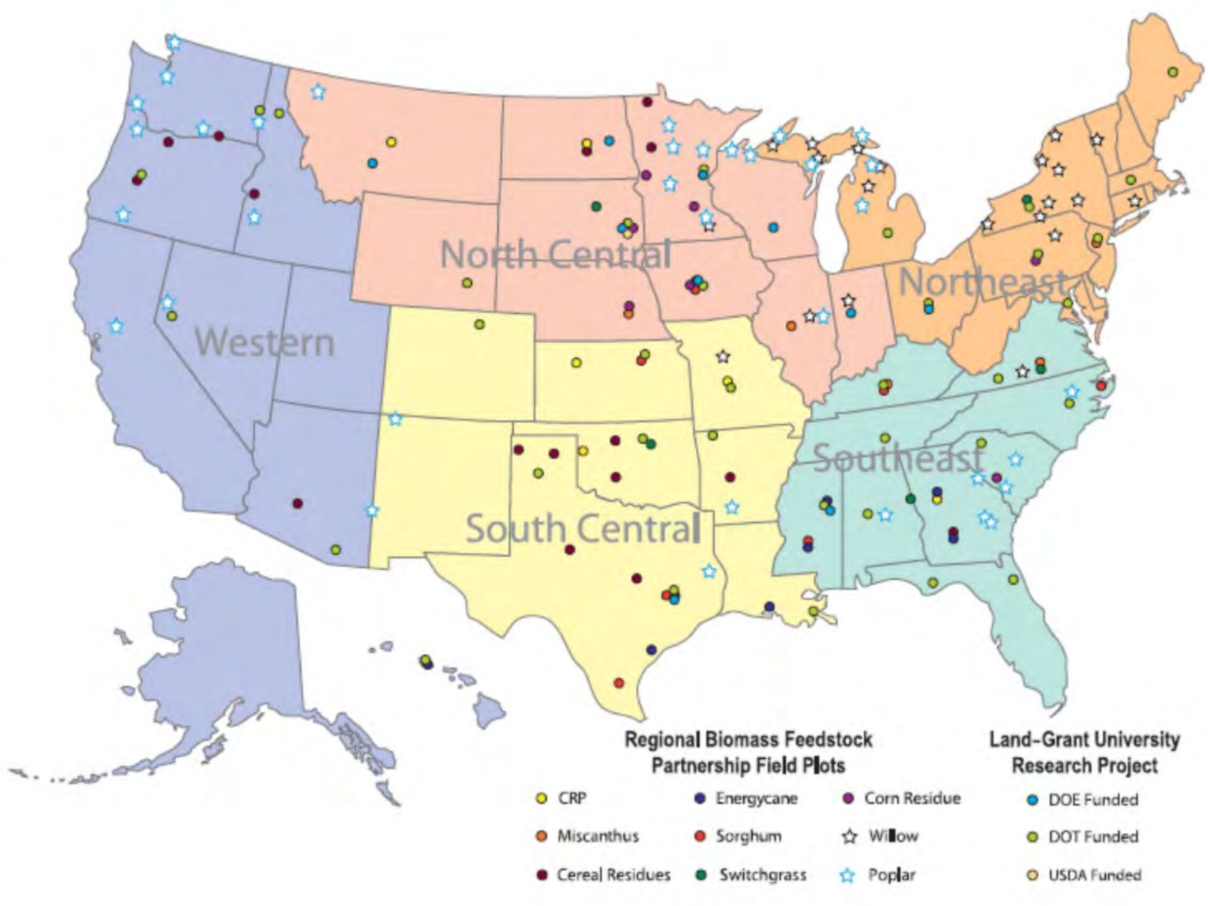
Table 3-3: Ethanol plants in Indiana (Data source: Ethanol Producers Magazine [14])

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 3-4: Biodiesel plants in Indiana (Data source: Indiana State Department of Agriculture [15])

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*.



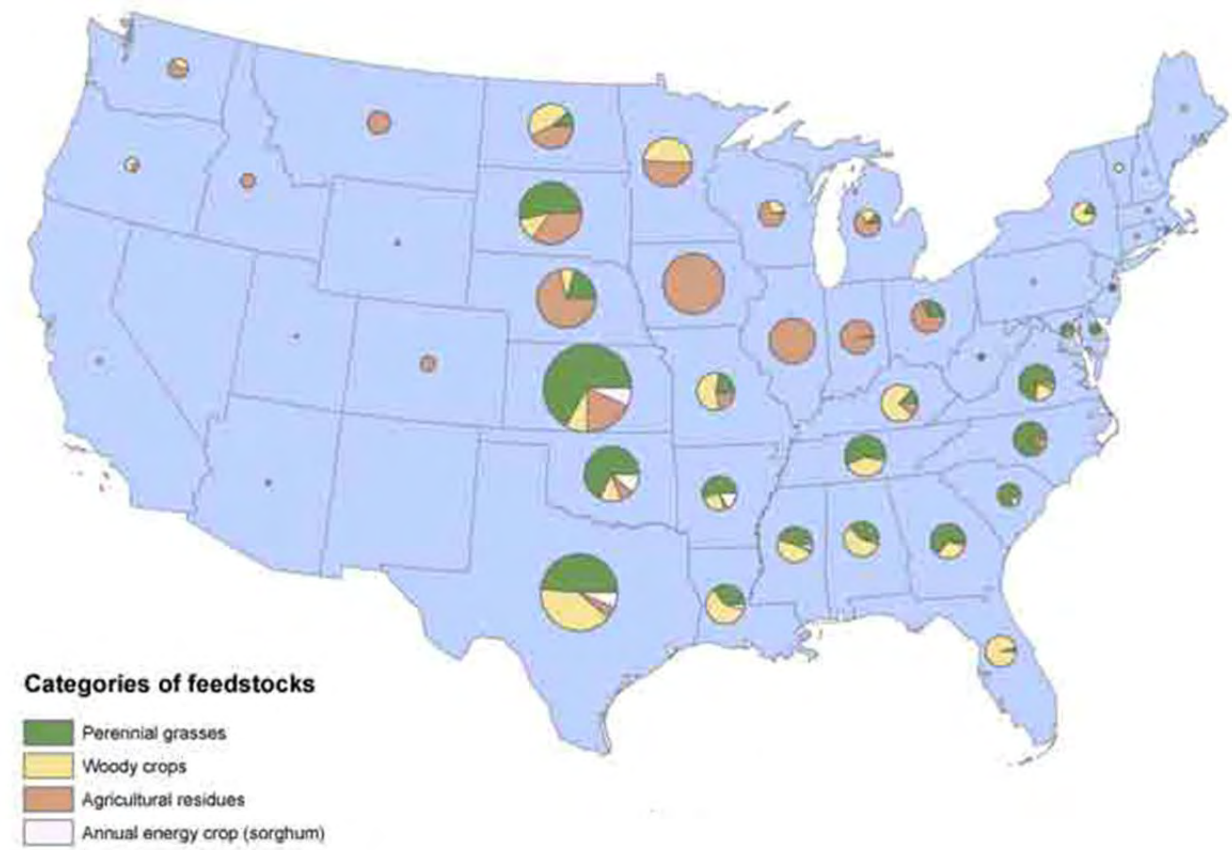
<u>Figure 3-4:</u> <u>Bioenergy crop trial stations</u> (Source DOE [16])

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 [17]. At the March 2015 project peer review conference the following progress was reported on the feedstock research [18].

- The completion of field trials for seven crop years (2008 to 2014),
- Making the yield and plot treatment data publicly available by uploading it onto the DOE Knowledge Discovery Framework,
- Collecting of soil samples for sustainability analysis at multiple locations,
- Collecting of biomass samples from the field plots and sending them to the Idaho National Laboratory (INL) for composition analysis and archiving in the biomass resource library housed at INL.

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 a biomass farm-gate price of $60 per dry ton.



<u>Figure 3-5:</u> <u>Estimated shares of energy crops and agricultural residues supplied at $60 per dry ton in 2030</u> (Source: DOE [2])

Figure 3-6 shows the quantities of energy crops projected to be produced in Indiana in 2030 at biomass farm-gate prices 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.

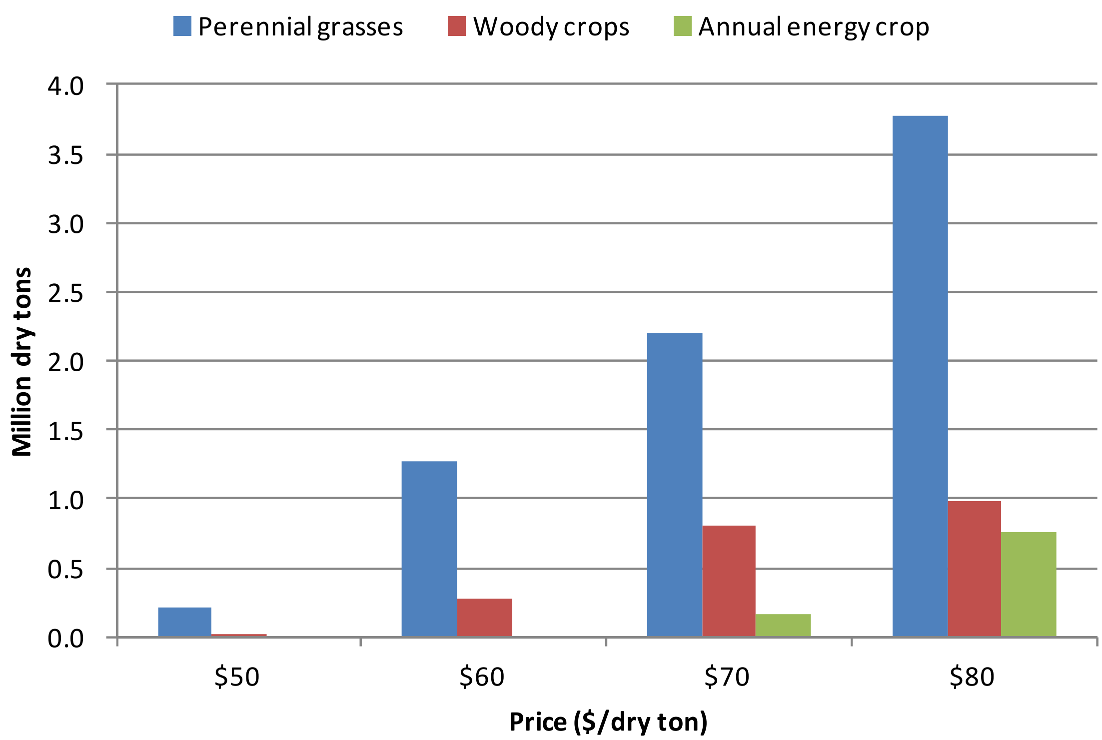


Figure 3-6: Projected production of energy crops in Indiana in 2030 (Data source: DOE [19])

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 3-5 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 3-5: Average cost ($/ton) for producing switchgrass in Indiana (Data source: Brechbill & Tyner [20])

Allen, in his December 2011 Master's Thesis, estimated the cost of producing and transporting biomass from woody crops to be between $43 and $52 per dry ton [21].

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 energy technologies. Dedicated energy crops fall under the closed-loop biomass category. The PTC expired in December 2014 but projects under construction in 2015 are eligible for the credit if they began construction before the end of 2014 [22].
- U.S. DOE Loan Guarantee Program (Section 1703, Title IV of Energy Policy Act of 2005 provides loan guarantees for large scale innovative renewable energy projects that reduce the emission of pollutants, including renewable energy projects [22].
- Modified Accelerated Cost-Recovery System (MACRS) allows businesses to recover investments in qualified renewable energy technologies through depreciation deductions. A provision for a 50 percent first year bonus depreciation added by the Economic Stimulus Act of 2008 expired at the end of 2014 [22].
- USDA 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 [22].

- USDA Biorefinery Assistance Program offers loan guarantees for the development, construction or retrofitting of commercial-sized biorefineries. The program finances 80 percent of the cost of the biorefinery up to a maximum of $250 million [22].
- Clean Renewable Energy Bonds (CREBs) are tax credit bonds designed to offset the tax liability of not-for-profit entities such as public utilities, and local and state governments that because of their structure do not benefit from the traditional renewable energy production tax credit (PTC). In February 2015 the IRS announced the allocation of an approximately $1.4 billion for new CREBS available from March 2015 [22].
- 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 [22].
- 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 [22].
- Green Power Purchasing Goal requires 20 percent of energy used by federal agencies must be obtained from renewable resources by 2020 [22].

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 [22].
- Clean Energy Credit Program (Energy Efficiency and Renewable Energy Set-aside) allocates nitrogen oxides (NOx) allowances for renewable energy and energy efficiency projects that displace utility electricity generation. These NOx credits can then be traded in the regional NOx market that covers 21 states in the eastern United States. One NOx allowance is allocated for each ton of NOx emissions displaced. Several projects may be combined in one application to meet the one ton minimum requirement [23].
- 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. At the writing of this report winners for 2015 had been selected and the challenge closed for the year [22, 24].

- 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, which includes electricity, from state gross retail tax. However, only wind energy has clearly specified rules from the Department of Revenue [22].
- 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].
- 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 projects that are selected in the first lot in the capacity allocation process is $0.0918/kWh [22, 25, and 26].

3.6 References

1. U.S. Department of Energy (DOE). Biotechnology Office fact sheet. Reshaping American energy – a look back at BETO's accomplishments in 2013. http://www.energy.gov/sites/prod/files/2014/03/f14/accomplishments_two_pager.pdf
2. DOE. U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry, 2011. 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/bioenergy/pdfs/billion_ton_update.pdf
3. DOE Energy Efficiency and Renewable Energy Office (EERE). Biotechnology office multi-year program plan. March 2015. http://www.energy.gov/sites/prod/files/2015/03/f20/mypp_beto_march2015.pdf
4. FarmEnergy. http://farmenergymedia.extension.org/tags/switchgrass
5. EERE. Biopower technical strategy workshop summary report. http://www.energy.gov/eere/bioenergy/downloads/biopower-technical-strategy-workshop-summary-report http://www.energy.gov/sites/prod/files/2014/04/f14/biopower_workshop_report_december_2010.pdf
6. EERE. Processing and conversion http://www.energy.gov/eere/bioenergy/processing-and-conversion
7. National Renewable Energy Laboratory (NREL). Thermochemical Thermochemical Conversion Capabilities http://www.nrel.gov/biomass/thermochemical_conversion.html
8. EERE. Integrated biorefineries fact sheet. http://www.energy.gov/eere/bioenergy/integrated-biorefineries http://www1.eere.energy.gov/bioenergy/pdfs/ibr_portfolio_overview.pdf
9. Midwest Energy News. August 6, 2013. http://midwestenergynews.com/2013/08/06/as-key-partner-departs-future-dims-for-michigan-cellulosic-biofuel-plant/

10. EERE. Integrated biorefineries.
http://www.energy.gov/eere/bioenergy/integrated-biorefineries
http://www.energy.gov/eere/bioenergy/ineos-new-planet-indian-river-bioenergy-center
http://www.energy.gov/eere/bioenergy/abengoa
http://www.energy.gov/eere/bioenergy/poet-dsm-project-liberty
11. EERE. The bioenergy knowledge discovery framework. KDF fact sheet.
http://www.energy.gov/eere/bioenergy/downloads/bioenergy-knowledge-discovery-framework-kdf
http://www.energy.gov/sites/prod/files/2014/03/f14/kdf_fact_sheet.pdf
12. EIA. U.S. ethanol production and the Renewable Fuel Standard RIN bank
http://www.eia.gov/todayinenergy/detail.cfm?id=11551
13. EPA. Renewable Fuel Standard.
http://www.epa.gov/otaq/fuels/renewablefuels/index.htm
14. Ethanol producer's magazine. U.S. ethanol plants. Updated June 9, 2015.
http://www.ethanolproducer.com/plants/listplants/US/Existing/Sugar-Starch/
15. Indiana State Department of Agriculture. Fact Sheet: Biofuels plants in Indiana. May 2013. http://www.in.gov/isda/biofuels/factsheet.pdf
16. Sun Grant Initiative. http://www.sungrant.org/Feedstock+Partnerships/Research+Plots/
17. Sun Grant Initiative. Feedstock partnerships. http://www.sungrant.org/Regional+Centers/
18. EERE. DOE Bioenergy Technologies Office. 2015 Project Peer Review. SunGrant/DOE Regional Biomass Feedstock Partnership (Award # GO85041; WBS 7.6.2.5).
http://www.energy.gov/sites/prod/files/2015/04/f21/terrestrial_feedstocks_owens_7625.pdf
19. DOE. Bioenergy Knowledge Discovery Framework. https://www.bioenergykdf.net/
20. 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
http://www.agecon.purdue.edu/papers/biofuels/Working_Paper_Fina.pdf
21. 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. http://gradworks.umi.com/15/02/1502105.html
22. Database of State Incentives for Renewables & Efficiency (DSIRE).
http://www.dsireusa.org/
23. Indiana Department of Environmental Management. Indiana Clean Energy Credit Program. http://www.in.gov/idem/airquality/2553.htm
www.in.gov/oed/files/Presentation_Letterman.ppt
24. Indiana Office of Energy Development. Community Conservation Challenge.
https://secure.in.gov/oed/2645.htm

25. NIPSCO. February 2015. https://www.nipsco.com/docs/default-source/our-services-docs/feed-in-tariff-faqs.pdf
26. NIPSCO. March 4, 2015. http://www.nipsco.com/docs/default-source/electric-tariffs-122711-docs/rate-665

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. 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 bio digesters; and
- Municipal wastewater, or sewage, which is used to produce gas in bio digesters.

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 feed stocks 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 the 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; or is fed directly to a combustion turbine or an internal combustion engine to produce 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 over 20 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 make 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 long. 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 - 4]:

- 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 emissions is achieved. Such an experiment was conducted at the Arizona Public Service Red Hawk power plant in 2006 and 2007 [5].

The production of algae for energy is still in the development stage. The federal government through the DOE biotechnologies research office is continuing to invest in funding the research and development to develop technologies needed to economically and sustainably produce, harvest, and convert algae into biofuels with a goal of producing 5 billion gallons of algal biodiesel per year by the year 2030 [4].

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 the 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. In the 2013 Energy Information Administration (EIA) plant cost estimates, the MSW power plant was listed as having the highest capital cost at over $8,300/kW among the technologies considered and the highest fixed O&M cost at over $390/kW [6].

Similarly, other organic waste streams such as animal waste, wastewater treatment and landfills generate methane-rich biogas. The reduction of greenhouse gas emissions is an added benefit to the process of converting the biogas 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. However, it is expected that biomass, including agricultural crop residues, will play a substantial role in the national effort to diversify the transportation fuel supply away from petroleum. 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 and an associated online database of the results of the study, the *Bioenergy Knowledge Discovery Framework* (KDF) was released. In the 2011 update to this *billion-ton* study the amount of crop residue that would be produced at various farm-gate 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 five different farm-gate prices ranging from $40 to $60 per dry ton [8].

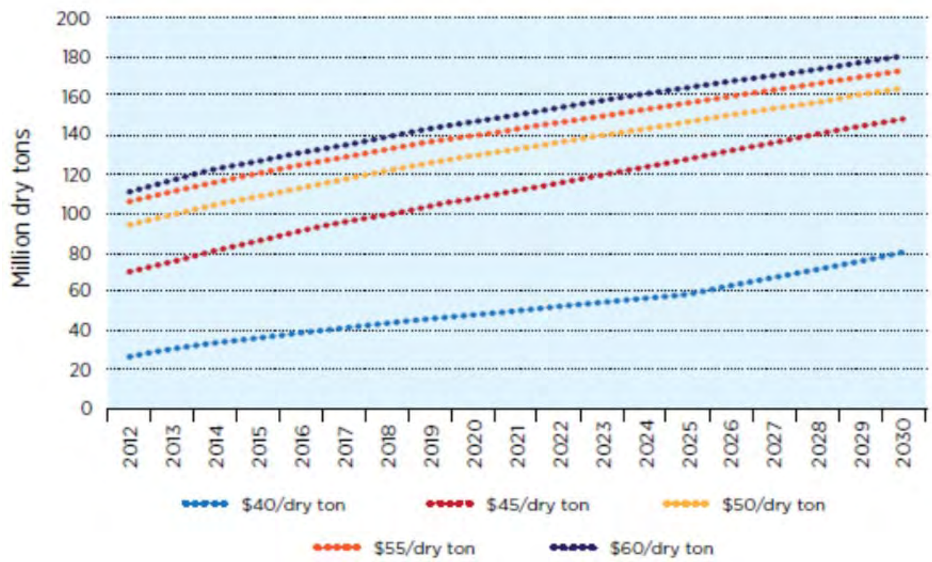


Figure 4-1 Supply of crop residues at various prices under DOE base-case assumptions (Source: DOE [8])

Most of the potential crop residue supplied, over 80 percent, is corn stover. Figure 4-2 shows the potential crop residue supplied with corn stover separated from other residues in 2012, 2017, 2022 and 2030 under three different price scenarios.

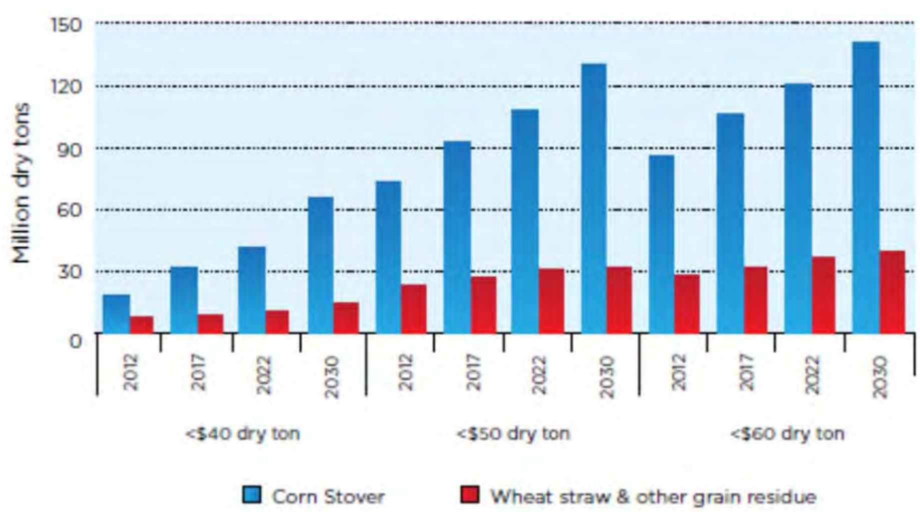


Figure 4-2: Corn stover and other grain residue supply at selected prices and years under DOE base-case assumptions (Source: DOE [8])

In a USDA funded study at Iowa State University published in 2012 [9], the U.S. wide supply curve for corn stover was estimated. Unlike the USDA/DOE *billion-ton* study which estimated the stover price at the farm gate, the price in this study estimates the price at the bioenergy plant gate. That is, it includes the cost of handling, storage and shipping costs associated with getting the stover to the bioenergy processing plant. According to this study the minimum price at which stover would be available for the bioenergy industry is $37.5 per ton, which is lower than the $40/ton minimum price modeled for corn stover in the *billion-ton* study. Figure 4-3 shows the U.S. wide corn stover supply curve from the Iowa State University study.

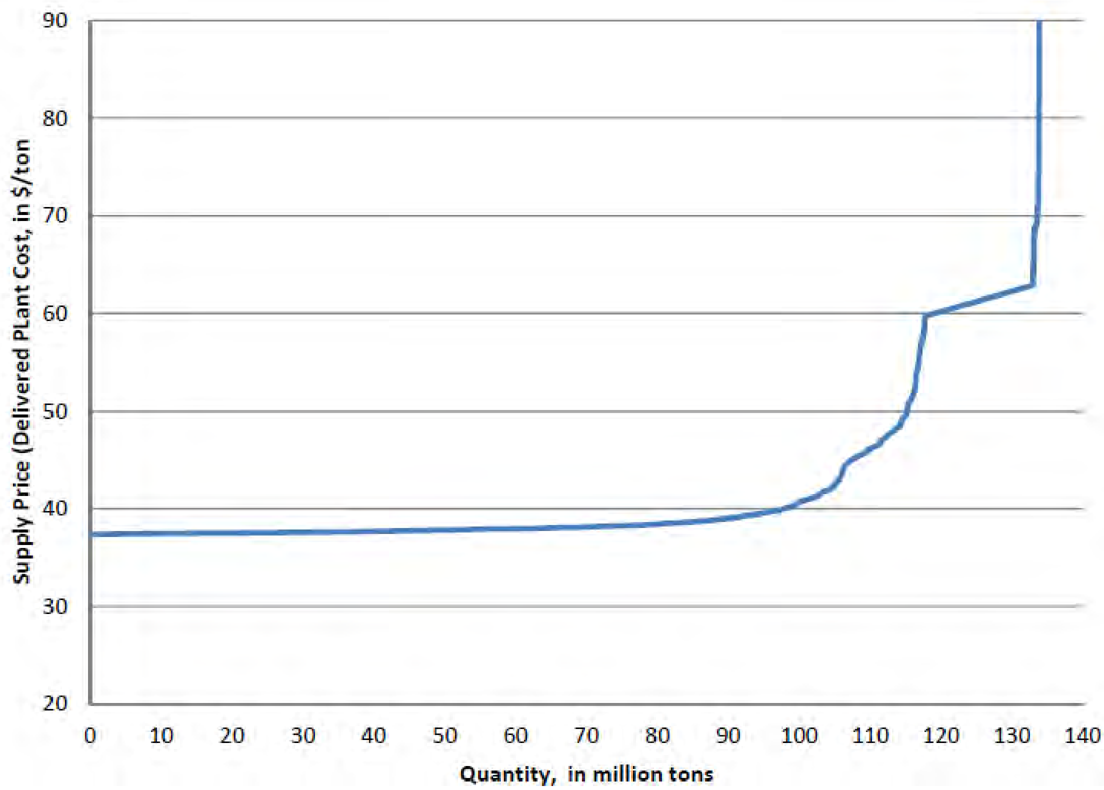


Figure 4-3: U.S. corn stover supply curve (Source: USDA [9])

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 yet. In 2009 DOE, using funds provided for by the *American Recovery and Reinvestment Act* of 2009, established the *National Alliance for Advanced Biofuels and Bioproduct*s (NAABB), a consortium of industry, universities and national laboratories to advance research in various facets of the algal biofuels industry [10]. According to the NAABB final report, the consortium has developed and demonstrated, at a pilot level, technology improvements which when combined can reduce the cost of producing algal biodiesel from approximately $200/gallon to $7.50/gallon. It still remains for this technology to be applied at a commercial scale [11].

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 4-4, wood and wood-derived fuels have been second only to hydroelectricity as a source of renewable energy. 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 2014 wood and wood-derived fuels supplied 23 percent of the renewable energy while other organic wastes contributed 5 percent. This was second to hydroelectricity's share of 26 percent and slightly higher than biofuels share of 21 percent.

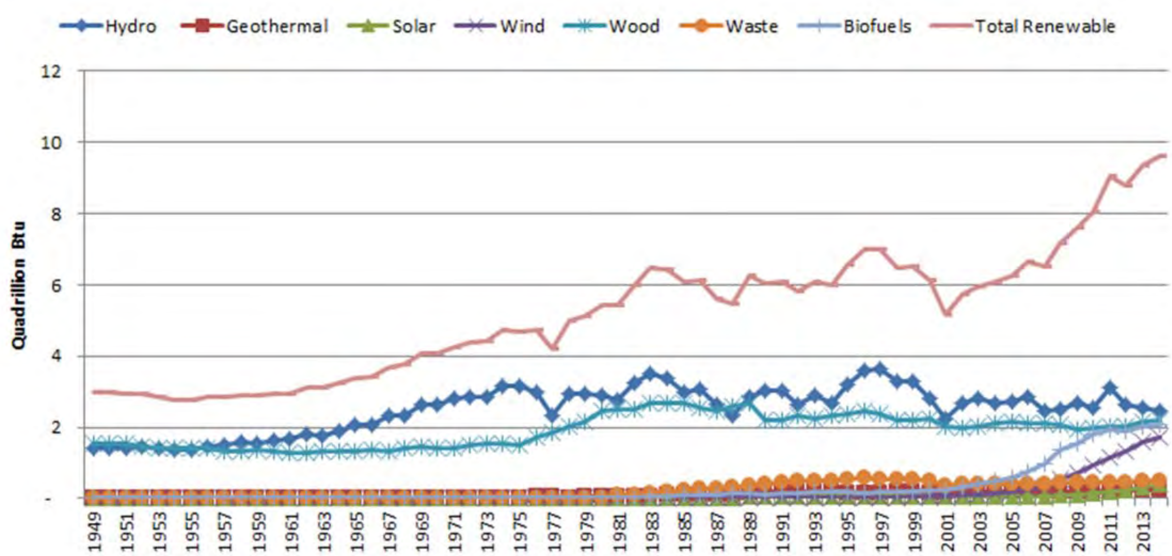


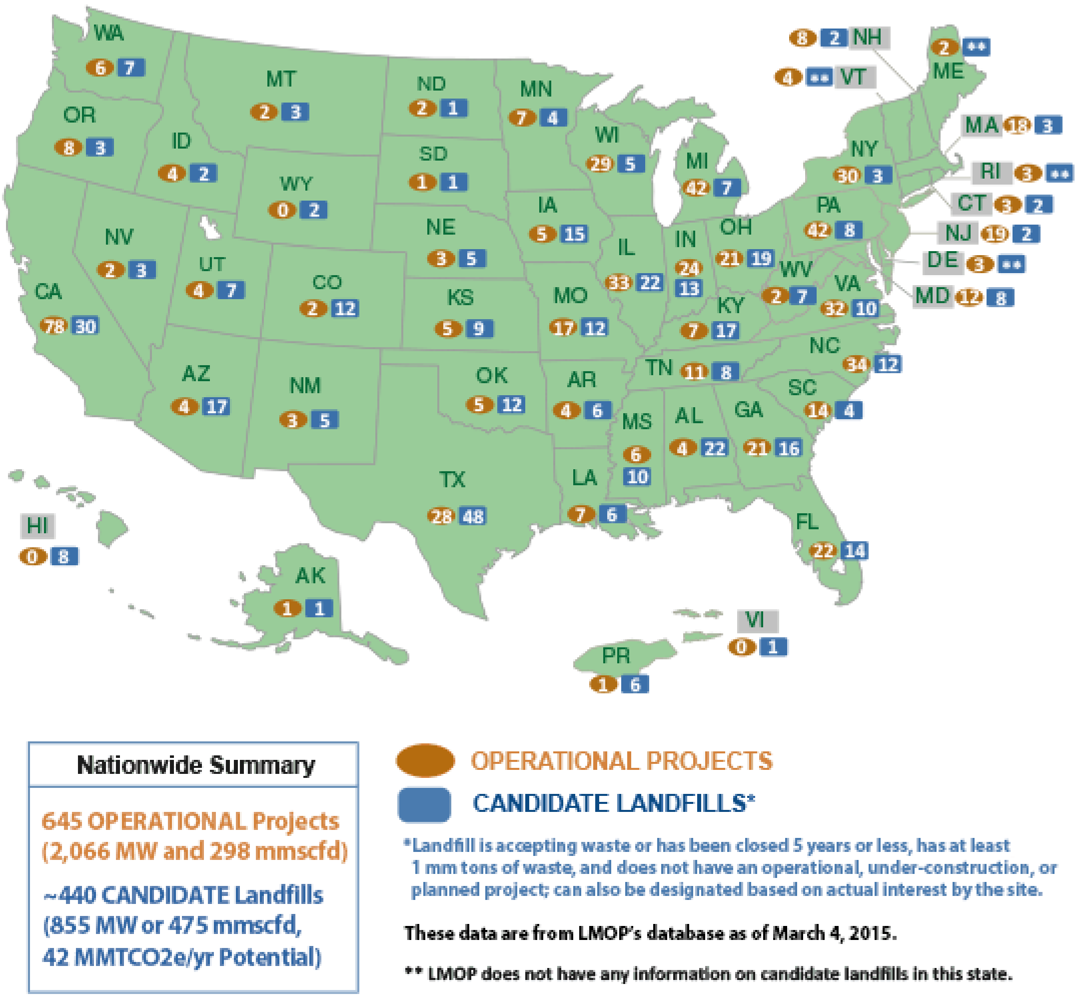
Figure 4-4: U.S. renewable energy consumption 1949-2014 (Source: EIA [12, 13])

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 national association of the waste to energy industry (the Energy Recovery Council) there were 84 MSW to energy plants operating in 23 states in the U.S. and one under construction in Palm Beach Florida. Of these plants, 62 had electricity as their only energy product; eighteen generated both electricity and steam, while four plants produced only steam. The combined electricity generating capacity installed in these plants was 2,554 MW. If the steam generated from the 22 steam-only and cogenerating plants were to be converted to electricity the Energy Recovery Council estimated that the total electricity generating capacity would increase to 2,769 MW. Table 4-1 shows the locations of MSW energy conversion plants in the U.S. Details about Indiana's one MSW energy conversion facility are given in Section 4.4.

State	Number of facilities	State	Number of facilities
Alabama	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	3	Utah	1
Maryland	3	Virginia	5
Massachusetts	7	Washington	1
Michigan	3	Wisconsin	2
Minnesota	9	Total U.S.	84

Table 4-1: States with solid waste to energy plants (Data source: Energy Recovery Council [14])

The other organic waste stream in use as a source of energy is landfill gas. According to the EPA there were 645 landfills with operational energy conversion projects as of March 2015 with a combined capacity of 2,066 MW electricity generation and 298 million standard cubic feet per day (mmscfd) of gas for thermal energy production. In addition there were 440 'candidate' landfills that have the size and capacity necessary to support energy projects. These candidate landfills have the potential for 855 MW of electricity generation and 475 mmscfd of gas for thermal energy conversion. Figure 4-5 shows the location of operational and candidate landfill gas energy projects in the U.S [15].



Legend mmscfd – million standard cubic feet per day; MMTCO2e/yr – million metric ton of carbon dioxide-equivalent per year

Figure 4-5: Landfill gas projects (Source: EPA [15])

Livestock manure is in use currently as an energy source with 247 anaerobic digester biogas recovery systems in operation on livestock farms in the U.S. as of the January 2014. The majority of these digesters (202) were on dairy farms, but there were also 39 on swine farms, 8 on beef farms, 7 on poultry farms, and 8 on mixed cattle/swine farms [16]. In a 2011 report *Market Opportunities for Biogas Recovery Systems at U.S. Livestock Facilities* EPA estimated that there were 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 [17]. 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 ft^3/ 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 [17])

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 2011 study there were 104 waste treatment facilities 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 [18]. 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)
AR	1	1.73
AZ	1	0.29
CA	33	62.67
CO	2	7.07
CT	2	0.95
FL	3	13.50
IA	2	3.40
ID	2	0.45
IL	2	4.58
IN	1	0.13
MA	1	18.00
MD	2	3.33
MI	1	0.06
MN	4	7.19

State	Number of Sites	Capacity (MW)
MT	3	1.09
NE	3	5.40
NH	1	0.37
NJ	4	8.72
NY	6	3.01
OH	3	16.29
OR	10	6.42
PA	3	1.99
TX	1	4.20
UT	2	2.65
WA	5	14.18
WI	5	2.02
WY	1	0.03
Total	104	189.8

Table 4-3: Wastewater treatment combined heat and power systems in the U.S. (Data source: EPA [18])

Although crop residues are not in use today as a source of energy, they are the most readily available biomass feedstocks. 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.   In the 2011 update of the billion ton study, the total amount of agricultural residues produced at a farm-gate 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].

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 consumed in Indiana contributing over 80 percent of the renewable energy up to the 1980s, and over 60 percent in the 1990s. It was not until the rapid growth in corn ethanol production in the 2000s that biomass was overtaken by ethanol as the leading source of renewable energy consumed in Indiana. Figure 4-6 shows the contribution of the various renewable resources to the total annual energy consumed in Indiana since 1960. 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 waste 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 [19].

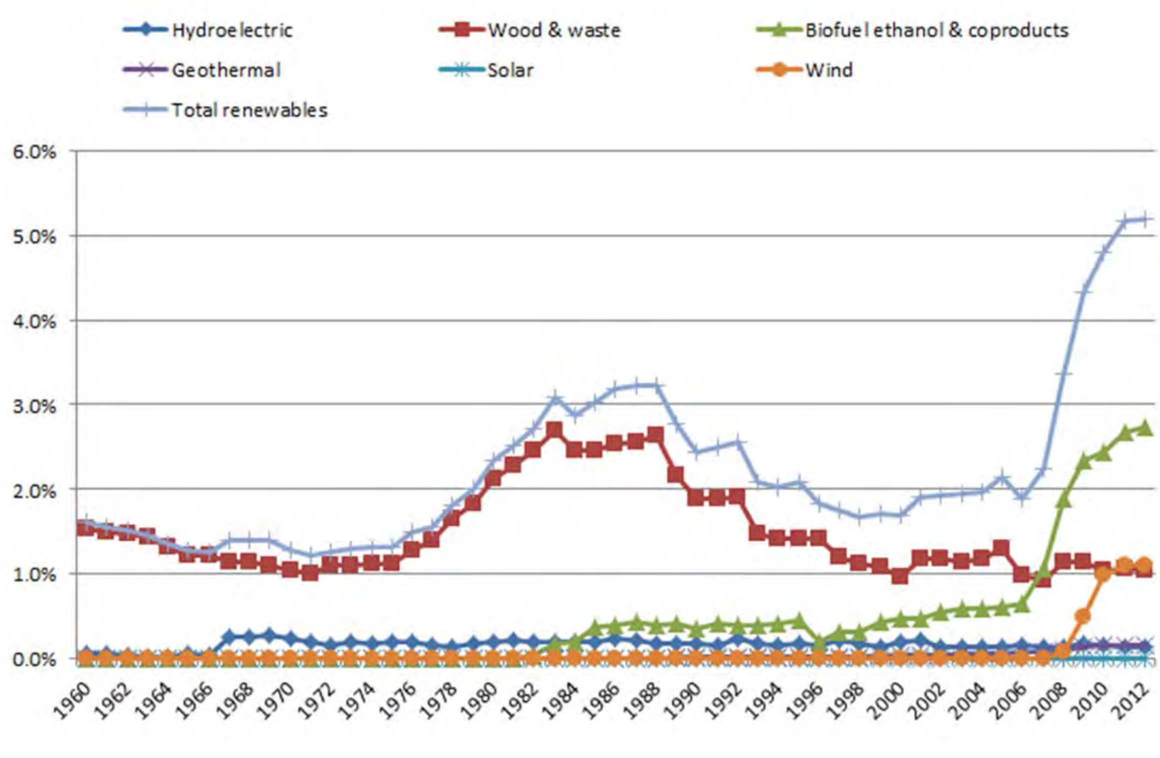


Figure 4-6: Renewables share of Indiana total energy consumption (1960-2012) (Source EIA [20])

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 (WVPA) which has a total of 56 MW of electricity generating capacity from eighteen power plants on nine landfills. Table 4-4 provides a list of landfill gas electricity generating plants in Indiana.

Project Developer	**Landfill Name**	**County**	**Generating Capacity (MW)**	**End User**
	National Serv-All	Allen	6.4	General Motors
Aria Energy; Republic Services	County Line	Fulton	6	
Energy Systems Group	Blackfoot	Pike	3.2	Vectren Energy
Energy Systems Group	Munster	Lake	1.1	NIPSCO
Granger Energy	South Side	Marion	4	Rolls-Royce
Hoosier Energy	Clark-Floyd	Clark	2.14	Hoosier Energy
Hoosier Energy	Clark-Floyd	Clark	1.4	Hoosier Energy
WVPA	Deercroft	LaPorte	3.2	WVPA
WVPA	Deercroft	LaPorte	3.2	WVPA
WVPA	Earthmovers	Elkhart	4	WVPA
WVPA	Jay County	Jay	3.2	WVPA
WVPA	Jay County	Jay	2.4	WVPA
WVPA	Liberty	White	3.2	WVPA
WVPA	Liberty	White	3.2	WVPA
WVPA	Oak Ridge	Cass	3.2	WVPA
WVPA	Prairie View	St. Joseph	3.2	WVPA
WVPA	Prairie View	St. Joseph	3.2	WVPA
WVPA	Twin Bridges	Hendricks	3.2	WVPA
WVPA	Twin Bridges	Hendricks	3.2	WVPA
WVPA	Twin Bridges	Hendricks	3.2	WVPA
WVPA	Wheeler	LaPorte	2.4	WVPA
WVPA	Wheeler	LaPorte	1.6	WVPA
WVPA	Wheeler	LaPorte	0.8	WVPA
WVPA; Waste Management	Twin Bridges	Hendricks	3.2	WVPA

Table 4-4: Electricity generating plants in Indiana landfills (Data source: EPA [21])

Giraldo in his 2013 Master's Thesis [22] 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 (kW)**
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
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 [22])

Another source of biomass fuel used for electricity generation in Indiana is the anaerobic digestion of animal manure. There are 10 anaerobic digester projects installed in Indiana as shown in Table 4-6. The Culver Duck Farm project is unique in that it does not process the animal manure, but rather the by-products (offal and blood) from a duck processing plant. Table 4-6 shows the locations and electricity generating capacities of anaerobic digesters in Indiana farms arranged in decreasing installed electricity generating capacity. The combined installed generating capacity of these digesters is 17.25 MW. In addition, the Fair Oaks Dairy Farm has installed purification and compression equipment to produce biogas to run milk delivery trucks [23, 24]. The potential to expand biogas production from livestock farms is substantial given that 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 [17].

Farm/ Project Name	County	Year Operational	Animal Type	Population Feeding Digester	Biogas End Use(s)	Installed Capacity (kW)
Biotown Ag, Inc.#	White	2011	Swine, Cattle	800; 4500	Cogeneration	9,450
Culver Duck Farm (processing plant)*	Elkhart	2013	Ducks	105,000 gallons duck blood & offal per week	Electricity	1,200
Bos Dairy	Jasper	2005	Dairy	3600	Electricity	1,050
Waste No Energy	White	2013	Swine, Cattle	4000; 300	Cogeneration	1,050
Fair Oaks Dairy - Digester 2	Jasper	2008	Dairy	9000	Cogeneration; CNG	1,050
Homestead Dairy#	Marshall	2013	Dairy	2100	Electricity	1,000
Hidden View	Jasper	2007	Dairy	3500	Cogeneration	950
Herrema Dairy	Jasper	2002	Dairy	3750	Cogeneration	800
Fair Oaks Dairy - Digester 1	Jasper	2004	Dairy	3000	Electricity	700
Windy Ridge Dairy	Jasper	2006	Dairy	7000	Flared Full Time	0

*Data from Culver Duck from a 2013 site visit; #Data from Biotown Ag and Homestead Dairy websites [25, 26]

Table 4-6: Operational Anaerobic Digesters in Indiana (Data source EPA [16])

It is estimated that 144 concentrated animal feeding operations (CAFO) had the size and manure handling processes necessary to support an additional 20 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)	Potential electrical generation capacity per category (kW)
Dairy (500-999)	17	175	2,975
Dairy (1000-2499)	12	365	4,380
Dairy (2500 or more)	3	1,204	3,612
Hog farrow-to-wean (1000-1999)	4	22	88
Hog farrow-to-wean (2000-4999)	2	53	106
Hog farrow-to-wean (5000 or more)	2	184	368
Hog farrow-to-finish (1000-1999)	14	20	280
Hog farrow-to-finish (2000-4999)	14	43	602
Hog farrow-to-finish (5000 or more)	16	194	3,104
Hog finish only (1000-1999)	18	28	504
Hog finish only (2000-4999)	22	68	1,496
Hog finish only (5000 or more)	14	181	2,534
Hog nursery (1000-1999)	2	12	24
Hog nursery (2000-4999)	3	18	54
Hog nursery (5000 or more)	1	38	38
Total	144		20,165

Table 4-7: Potential electricity generating capacity in Indiana concentrated animal feeding operations (Data source: Giraldo [22])

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 [27]. It is estimated that wastewater 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 WWTP	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 [22])

Figure 4-7, obtained from the DOE *Billion-Ton* study referred to earlier in the section, 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.

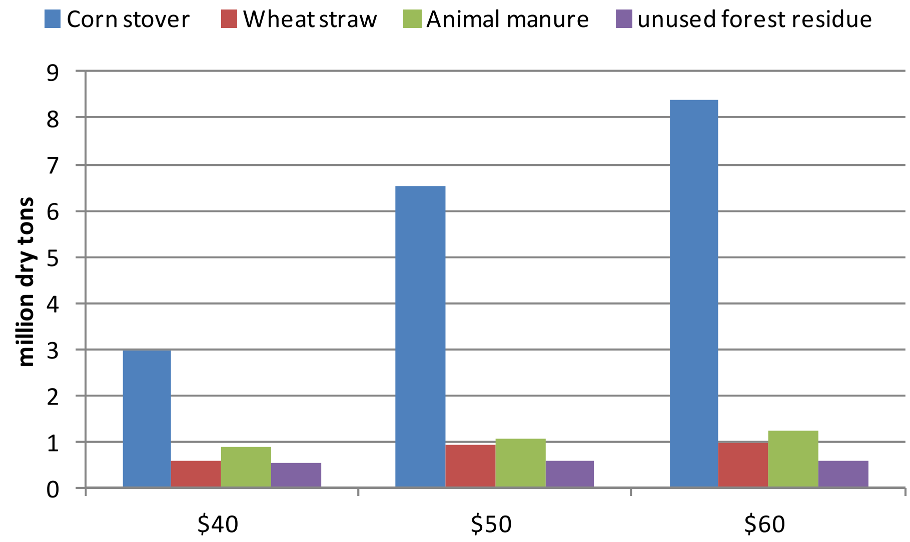


Figure 4-7: Estimated biomass production potential in Indiana (Data source: DOE [8])

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 Btu/lb 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 9 percent of Indiana's 116,000 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. The algae based system improves the waste treatment facility's energy efficiency by replacing the mechanical aeration system with an algae wheel that utilizes the symbiotic relationship between the algae and the waste treatment bacteria. Oxygen produced by algae serves as food for the bacteria while the bacteria in turn converts the wastewater bio-solids into food for the algae. In addition the algae produced is a biofuel that can be used in-house to supplement the facility's energy needs or sold to provide a revenue stream [28]. Stellarwind, on the other hand, is focused on producing oil from algae that has the potential for use in producing transportation fuels [29].

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 1.1 cents/kWh for open-loop biomass, landfill gas and municipal solid waste energy technologies. Organic waste biomass falls under the open-loop category. The PTC expired in December 2014 but projects under construction in 2015 are eligible for the credit if they began construction before the end of 2014 [30].
- U.S. DOE Loan Guarantee Program (Section 1703, Title IV of Energy Policy Act of 2005 provides loan guarantees for large scale innovative renewable energy projects that reduce the emission of pollutants, including renewable energy projects [30].
- Business Energy Investment Tax Credit (ITC) credits up to 30 percent of expenditures on qualified renewable energy systems. Municipal solid waste is the only biomass that qualifies for the ITC [30].
- Modified Accelerated Cost-Recovery System (MACRS) allows businesses to recover investments in qualified renewable energy technologies through depreciation deductions. A provision for a 50 percent first year bonus depreciation added by the Economic Stimulus Act of 2008 expired at the end of 2014 [30].
- USDA 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 [30].
- USDA Biorefinery Assistance Program offers loan guarantees for the development, construction or development of commercial-sized biorefineries. The program finances 80 percent of the cost of the biorefinery up to a maximum of $250 million [23].
- Clean Renewable Energy Bonds (CREBs) are tax credit bonds designed to offset the tax liability of not-for-profit entities such as public utilities, and local and state governments that because of their structure do not benefit from the traditional renewable energy production tax credit (PTC). In February 2015 the IRS announced the allocation of an approximately $1.4 billion for new CREBS available from March 2015 [30].
- 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 bonds are allocated to states in proportion to the state’s percentage of the U.S. population [30].

- 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 [30].
- Green Power Purchasing Goal requires 20 percent of energy used by federal agencies must be obtained from renewable resources by 2020 [30].

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 [30].
- Clean Energy Credit Program (Energy Efficiency and Renewable Energy Set-aside) allocates nitrogen oxides (NOx) allowances for renewable energy and energy efficiency projects that displace utility electricity generation. These NOx credits can then be traded in the regional NOx market that covers 21 states in the eastern United States. One NOx allowance is allocated for each ton of NOx emissions displaced. Several projects may be combined in one application to meet the one ton minimum requirement [31].
- 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. At the writing of this report winners for 2015 had been selected and the challenge closed for the year [30, 32].
- 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, which includes electricity, from state gross retail tax. However, only wind energy has clearly specified rules from the Department of Revenue [30].
- 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 [30].
- 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 projects that are selected in the first lot in the capacity allocation process is $0.0918/kWh [30, 33, and 34].

4.6 References

1. U.S. Environmental Protection Agency (EPA). Overview of Greenhouse Gases. http://epa.gov/climatechange/ghgemissions/gases/ch4.html
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. DOE Biotechnologies Office. Algal biofuelsfact sheet. September 2014 http://energy.gov/sites/prod/files/2014/09/f18/algal_biofuels_factsheet.pdf
5. Greentechmedia. http://www.greentechmedia.com/articles/read/aps-gets-70.5m-to-feed-captured-carbon-to-algae
6. 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
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. USDA. Biomass supply from corn residues: estimates and critical review of procedures http://www.usda.gov/oce/reports/ http://www.usda.gov/oce/reports/energy/Biomass%20Supply%20From%20Corn%20Residues-Nov-2012.pdf
10. DOE Biotechnologies Office. National Alliance for Advanced Biofuels and Bioproducts Synopsis (NAABB) Final Report. June 2014 http://www.energy.gov/eere/bioenergy/downloads/national-alliance-advanced-biofuels-and-bioproducts-synopsis-naabb-final
11. National Alliance for Advanced Biofuels and Bioproducts (NAABB). Synopsis. June 2014. http://www.energy.gov/eere/bioenergy/downloads/national-alliance-advanced-biofuels-and-bioproducts-synopsis-naabb-final
12. EIA. 2012 Annual Energy Review. Table 10.1. http://www.eia.gov/totalenergy/data/annual/index.cfm#renewable
13. EIA. May 2013 Monthly Energy Review Table 10.1 http://www.eia.gov/totalenergy/data/monthly/#renewable
14. Energy Recovery Council. http://www.energyrecoverycouncil.org/userfiles/files/ERC_2014_Directory.pdf

15. EPA. Landfill Methane Outreach Program. http://www.epa.gov/lmop/projects-candidates/index.html#map-area
16. EPA, AgStar. Operating Anaerobic Digester Projects. http://www.epa.gov/agstar/projects/index.html
17. AgStar. Market opportunities for biogas recovery systems at U.S. livestock facilities. http://www.epa.gov/agstar/documents/biogas_recovery_systems_screenres.pdf.
18. EPA Combined Heat and Power Partnership, Opportunities for combined heat and power at wastewater treatment facilities: market analysis and lessons learned. http://www.epa.gov/chp/markets/wastewater.html
19. Covanta Energy Corporation. http://www.covantaenergy.com/en/facilities/facility-by-location/indianapolis.aspx
20. 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
21. EPA. Landfill Methane Outreach Program (LMOP). http://www.epa.gov/lmop/projects-candidates/index.html
22. 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. http://docs.lib.purdue.edu/dissertations/AAI1544326/ http://www.purdue.edu/discoverypark/energy/assets/pdfs/SUFG/publications/SUFG_Biogas.pdf
23. U.S. Dairy Sustainability Committee. www.usdairy.com/~/media/usd/public/dairypowercasestudy_renewableenergy.pdf.ashx
24. EPA. Fair Oaks Dairy - Digester 2. http://www.epa.gov/agstar/projects/profiles/fairoaksdairydigester2.html
25. Biotown Ag. http://biotownag.com/, http://www.americanbiogascouncil.org/projectProfiles/reynoldsIN.pdf
26. Homestead Green Energy. http://www.mbce.com/pdf/RRV4N4_Homestead%20Dairy.pdf
27. West Lafayette wastewater treatment plant. http://www.westlafayette.in.gov/department/division.php?fDD=11-185
28. AlgaeWheel North America. http://www.algaewheel.com/ https://www.purdue.edu/discoverypark/energy/assets/pdfs/energy-camp-presentations/Biotown%20Tour_AlgaeWheel__Presentation.pdf
29. Stellarwind Bio Energy LLC. http://www.oilgae.com/blog/2009/03/stellarwind-bioenergy-oil-from-algae.html
30. Database of State Incentives for Renewables and Efficiency (DSIRE). http://www.dsireusa.org/

31. Indiana Department of Environmental Management. Indiana clean energy credit program http://www.in.gov/idem/airquality/2553.htm. www.in.gov/oed/files/Presentation_Letterman.ppt
32. Indiana Office of Energy Development. Community Conservation Challenge. https://secure.in.gov/oed/2645.htm
33. NIPSCO. February 2015. https://www.nipsco.com/docs/default-source/our-services-docs/feed-in-tariff-faqs.pdf
34. NIPSCO. March 4, 2015. http://www.nipsco.com/docs/default-source/electric-tariffs-122711-docs/rate-665

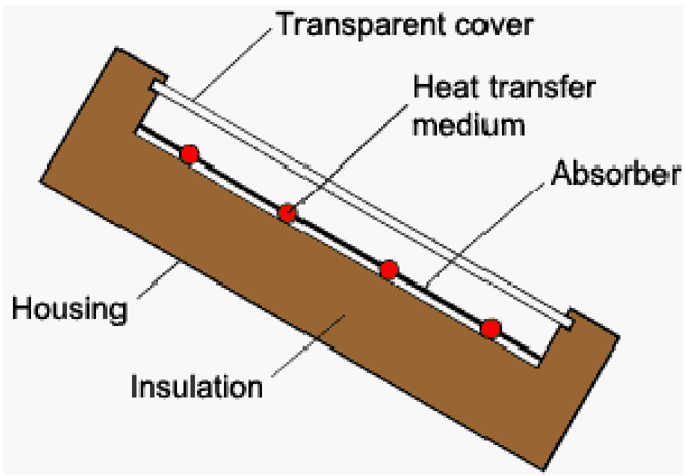
5. Solar Energy

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].



<u>Figure 5-1:</u> <u>Cross-section layout of a flat-plate collector</u> (Source: SolarServer [1])

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 parabolic trough CSP system has trough shaped collectors with a parabolic cross section and a receiver 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 1,287 MW out of the total 1,689 MW of installed CSP capacity in the U.S. being parabolic trough based.

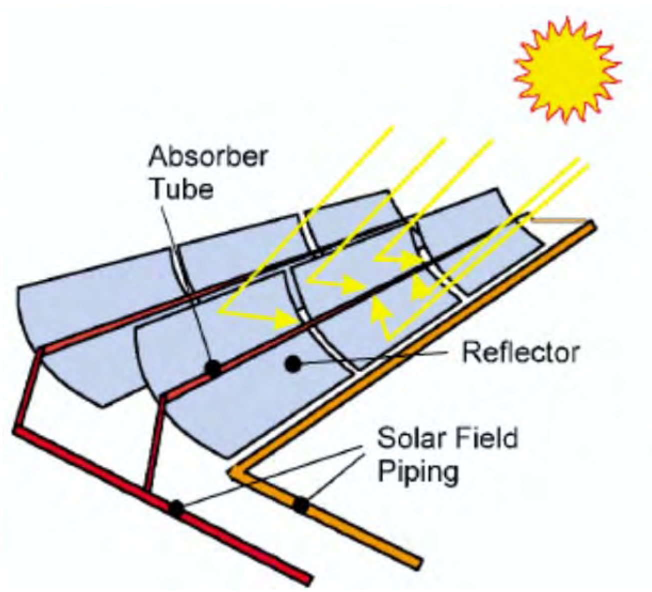


Figure 5-2: A parabolic trough CSP system (Source: NREL [2, 3])

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 currently one linear Fresnel project in operation and one under construction in the U.S. The operating one is the 5 MW Kimberlina plant in Bakersfield, California and the one under construction is the 5 MW Tucson Electric Power Sundt Boost project in Tucson, Arizona [4].

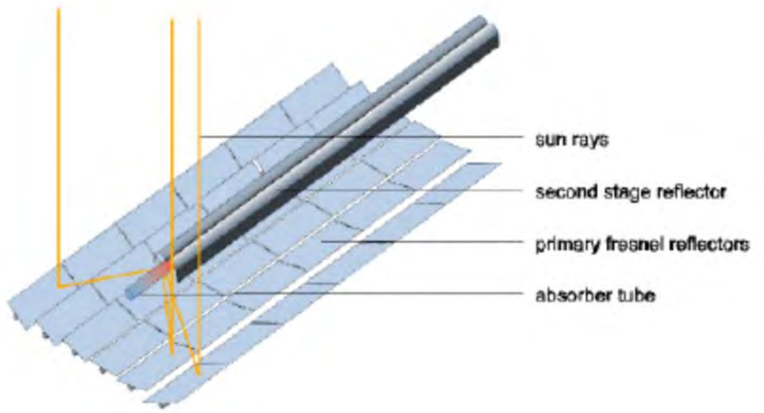


Figure 5-3: A linear Fresnel CSP system (Source: IEA [2, 3])

The power tower CSP system utilizes thousands of flat sun-tracking mirrors, or heliostats which 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]. There are two power tower projects in operation and one under construction in the U.S. at the time this report was written. The two in operation are the 392 MW Ivanpah project in the Mojave Desert in California and the 5 MW Sierra Sun Tower plant in Lancaster, California. The 110 MW Crescent Dunes project has been under construction since 2011 and is expected to be completed in 2015 [4].

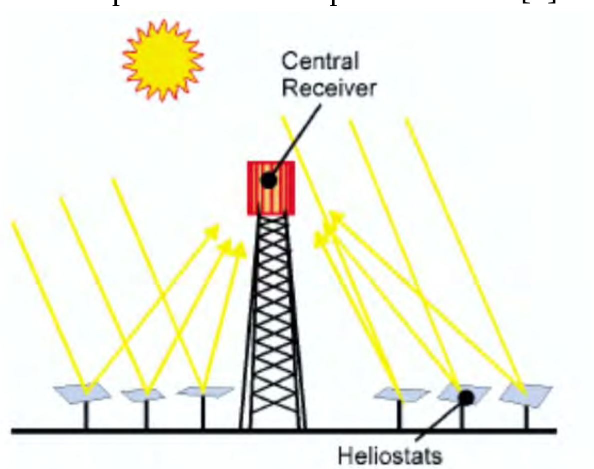


Figure 5-4: A power tower CSP system (Source: NREL [2, 3])

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 [2]. The dish/engine system does not use any cooling water which puts it at an advantage over the other three 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. There are only two dish/engine projects in the U.S., the 1.5 MW Tooele Army Depot project currently under construction and the 1.5 MW Maricopa project which is no longer operational. The Maricopa project was commissioned in 2009 and then decommissioned in 2011. The construction of the Tooele Army Depot project was started in 2012 and partial production started in 2013 [3].

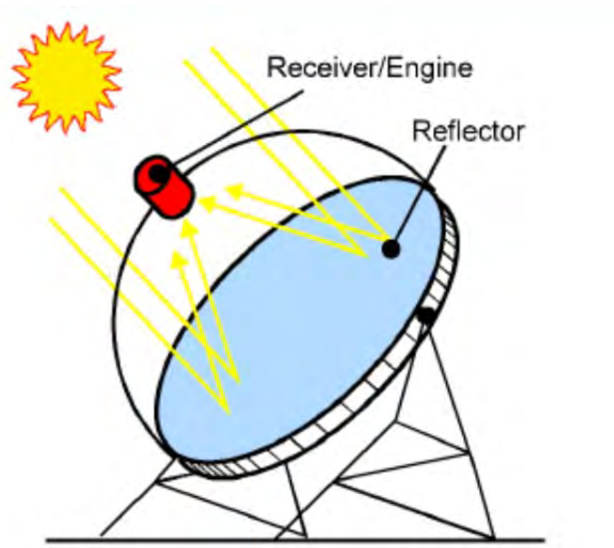


Figure 5-5: A dish/engine CSP system (Source: NREL [2, 3])

5.2 Economics of solar technologies

Table 5-1 shows the overnight capital cost[8] estimates for CSP power plants currently in operation world-wide for which capital cost was available from the National Renewable Energy Laboratory (NREL) [4]. As can be seen in the table, which is ordered in decreasing capital cost, the top six plants have thermal storage facilities installed with the highest capital cost plant, the Gemasolar plant in Spain having 15 hours-worth of thermal storage capacity.

[8] 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.

The capacity-weighted average capital cost for the plants in the table is $6,405/kW.

Project Name	Developer, Owner	Location	Capacity (MW)	Technology	Online Date	Capital cost ($/kW)	Thermal storage (hours)
Gemasolar Thermosolar Plant	Torresol, Masdar, Sener	Andalucía, Spain	20	Power Tower	2011	13,060*	15
Kasur Solar One	Abengoa	Poffader, South Africa	100	Parabolic Trough	2015	8,600	2.5
Solana Generating Station	Abengoa	Phoenix, Arizona	250	Parabolic Trough	2013	8,000	6
La Africana	Ortiz/TSK/ Magtel	Posadas, Spain	50	Parabolic Trough	2012	7,740*	7.5
Arcosol 50	Torresol	Cádiz, Spain	49.9	Parabolic Trough	2011	7,246*	7.5
Termesol 50	Torresol	Cádiz, Spain	49.9	Parabolic Trough	2011	7,246*	7.5
Borges Termosolar	Abantia	Lleida, Spain	25	Parabolic Trough	2012	6,916*	None
Morón	Ibereólica Solar	Seville, Spain	50	Parabolic Trough		6,667*	None
Olivenza 1	Ibereólica Solar	Olivenza, Spain	50	Parabolic Trough		6,418*	None
Martin Next Generation Solar	Florida Power & Light	Indian Town, Florida	75	Parabolic Trough	2010	6,351	None
Shams 1	Abengoa, Masdar,Total	United Arab Emirates	100	Parabolic Trough	2013	6,000	None
Ivanpah Solar Electric Generating System	BrightSource Energy	Primm, CA	377	Power Tower	2013	5,836	None
Mojave Solar Project	Abengoa	Harper Lake, California	280	Parabolic Trough	2014	5,714	None
Orellana	Acciona	Orellana, Spain	50	Parabolic Trough		5,424*	None
Dahan Power Plant	IEE, China	Beijing, China	1	Power Tower	2012	5,120*	1
Ibersol Ciudad Real	Iberdrola Renewables	Puertollano, Spain	50	Parabolic Trough	2009	4,520*	None
Nevada Solar One	Acciona	Boulder City, Nevada	64	Parabolic Trough	2007	4,156	0.5
Megha Solar Plant	Megha Engineering	Andhra Pradesh, India	50	Parabolic Trough	2014	2,661*	None

*cost converted from Euros at $1.37 per Euro, from Chinese Yuan at $0.16 per Yuan, and from Indian Rupees at $0.02 per Rupee

Table 5-1: Estimated capital cost of CSP plants (Sources NREL [4])

Figure 5-6 shows the overnight capital cost estimates of utility scale electricity generating technologies given in the 2013 EIA update of generating plant costs [7] sorted in order of decreasing capital cost. 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.

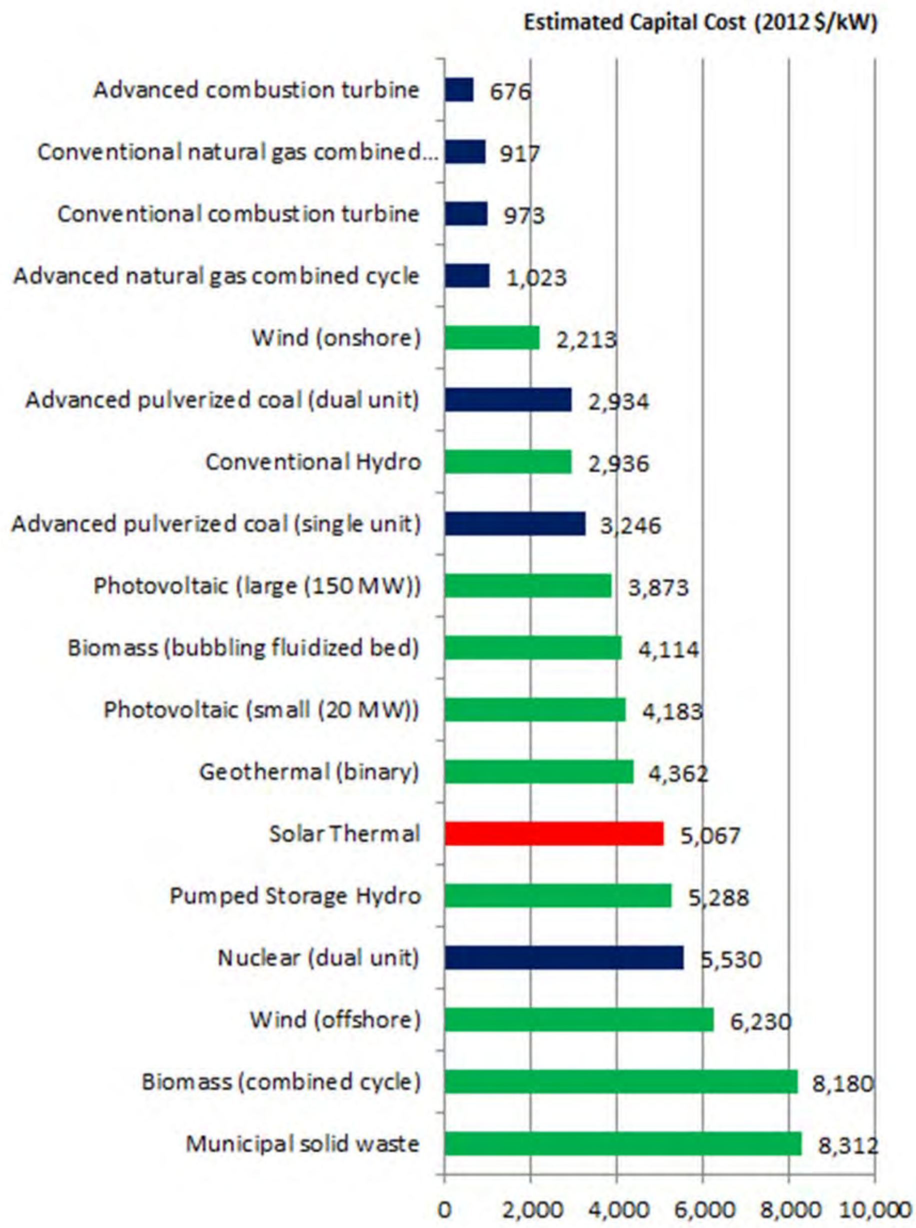


Figure 5-6: Estimated capital cost of generating technologies (Data source: EIA [7])

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.

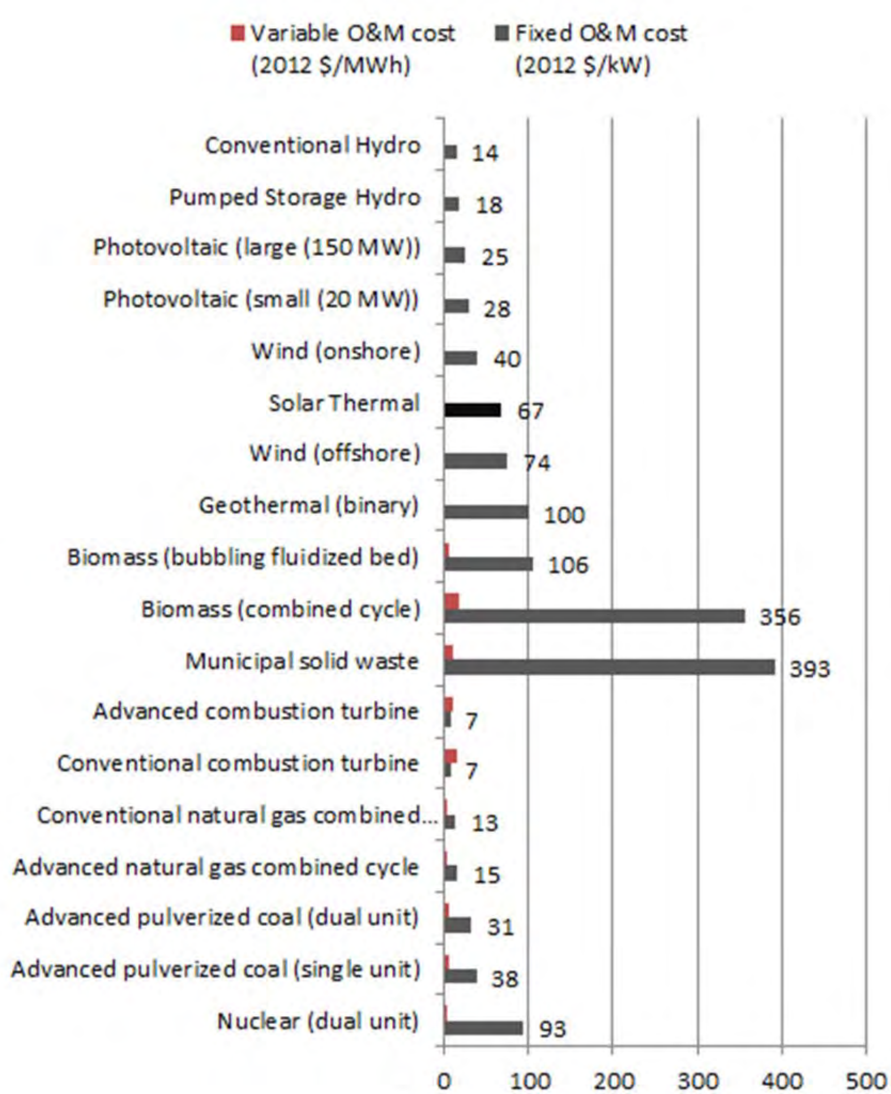


Figure 5-7: Operating and maintenance cost of generating technologies (Data source: EIA [7])

5.3 State of solar energy nationally

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

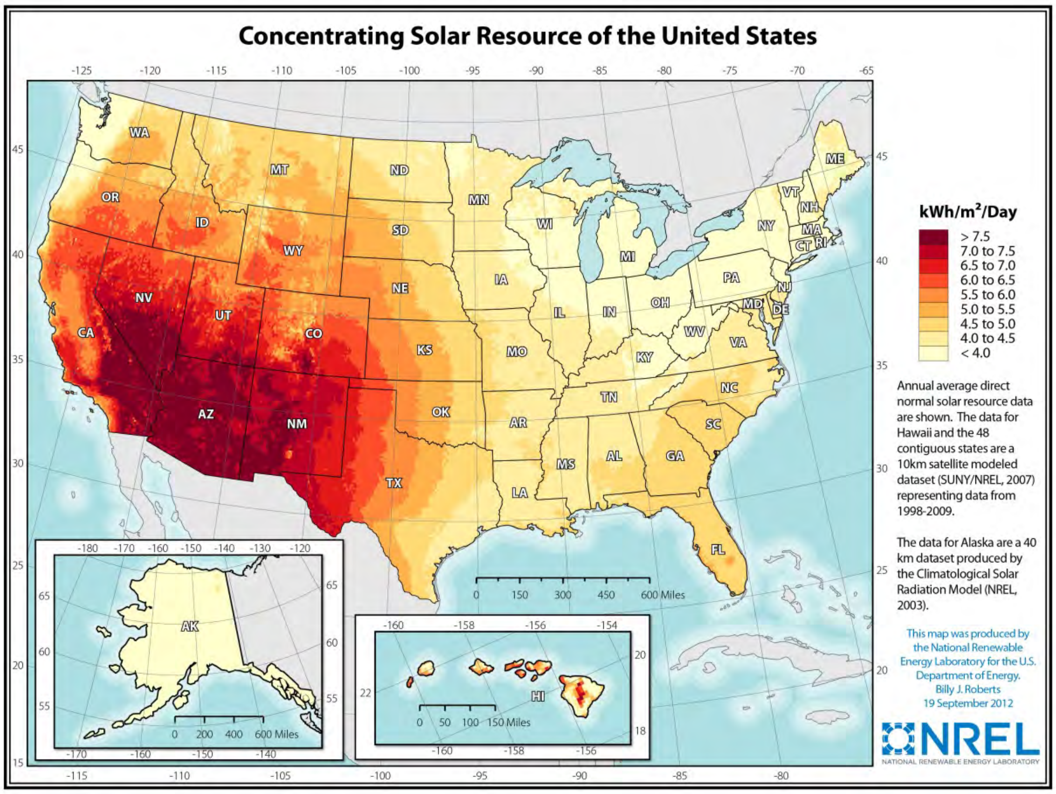


Figure 5-8: Concentrating solar power resource in the U.S. (Source: NREL [8])

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 10 years. After a period of approximately 15 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. Figure 5-9 shows the annual and cumulative capacity additions in the U.S.

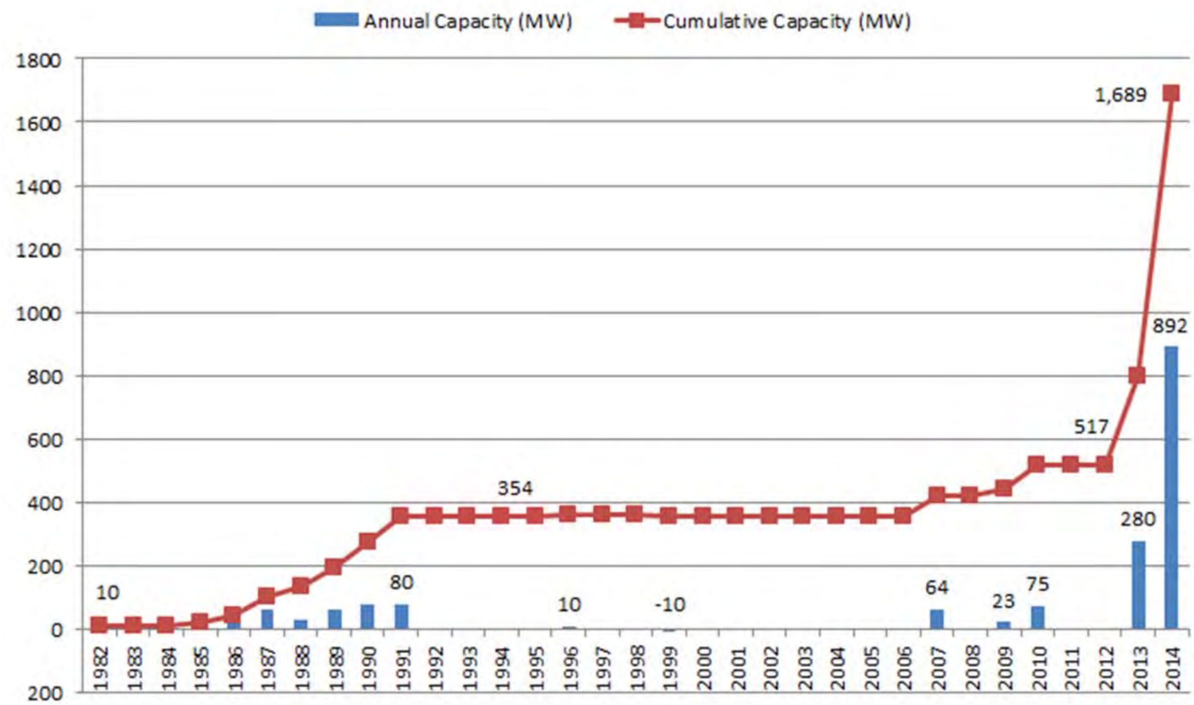


Figure 5-9: Solar thermal power capacity installed in the U.S. (Sources: NREL [4], SEIA [9], IREC [10], Go Solar [11])

Since 2005 a total of ten CSP projects with a combined installed capacity of 1,335 MW have been added, bringing the total CSP installed capacity in the U.S. to 1,689 MW. Four of these large projects with a combined capacity of 1,172 MW were completed in 2013 and 2014. The largest of these is the 392 MW Ivanpah power tower in the Mojave Desert in California. The other three are the 280 MW Solana project near Gila Bend Arizona, the 250 MW Genesis project in Riverside County California and the 250 MW Mojave solar project also located in the Mojave Desert of California. Table 5-2 contains a list of CSP projects in operation in the U.S. as of the writing of this report.

Developer/ Owner	Project Name	State	Capacity (MW)	Technology	Online Date
Luz	Solar Energy Generating Systems (SEGS) I	CA	14	Parabolic Trough	1985
Luz	SEGS II	CA	30	Parabolic Trough	1986
Luz	SEGS III	CA	30	Parabolic Trough	1987
Luz	SEGS IV	CA	30	Parabolic Trough	1987
Luz	SEGS V	CA	30	Parabolic Trough	1988
Luz	SEGS VI	CA	30	Parabolic Trough	1989
Luz	SEGS VII	CA	30	Parabolic Trough	1989
Luz	SEGS VIII	CA	80	Parabolic Trough	1990
Luz	SEGS IX	CA	80	Parabolic Trough	1991
Solargenix	Saguaro Solar Power Plant	AZ	1	Parabolic Trough	2005
Acciona	Nevada Solar One	NV	64	Parabolic Trough	2007
Acciona	Nevada Solar One Expansion	NV	11	Parabolic Trough	2009
Ausra	Kimberlina	CA	5	Linear Fresnel	2009
eSolar	Sierra SunTower	CA	5	Power Tower	2009
Sopogy	Holaniku at Keahole Point	HI	2	Parabolic Trough	2009
Florida Power & Light Co.	Martin Next Generation Solar Energy Center	FL	75	Parabolic Trough	2010
Abengoa	Solana	AZ	280	Parabolic Trough	2013
BrightSource Energy	Ivanpah Solar Energy Generating System	CA	392	Power Tower	2014
NextEra Energy Resources	Genesis Solar Energy Project Phase 1	CA	250	Parabolic Trough	2014
Abengoa	Mojave Solar	CA	250	Parabolic Trough	2014

Table 5-2: CSP plants in the U.S. (Data sources: NREL [4], SEIA [9])

Table 5-3 shows the three CSP projects currently under construction in the U.S. The main one is the 110 MW Crescent Dunes power tower in Tonopah, Nevada. The Crescent Dunes power tower project has been under construction since 2011 and is expected to be completed in 2015.

Project Name	**Developer/ Owner**	**City/County**	**State**	**Capacity (MW)**	**Technology**	**Construction Start Date**
Crescent Dunes Solar Energy Project	SolarReserve	Nye County	NV	110	Power Tower	2011
Tooele Army Depot	Solar PACES, Infinia	Tooele	UT	1.5	Dish/Engine	2012
Tucson Electric Power Sundt Boost Project	Areva	Tucson	AZ	5	Linear Fresnel	2014

Table 5-3 CSP plants under construction in the U.S. (Data sources: NREL [4], SEIA [9])

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 comparably low annual average solar radiation. This combined with the relatively low retail electricity rates makes Indiana a less than ideal location for multi-megawatt CSP plants compared to such states as California, Arizona, Nevada, and Florida. The 1,689 MW of solar thermal power plants in the U.S. are located in five states as follows: California – 1,256 MW, Arizona – 281 MW, Florida – 75 MW, Nevada – 75 MW, and Hawaii – 2 MW. The 116.5 MW of capacity under construction are in Nevada (110 MW), Arizona (5 MW) and Utah (1.5 MW). However there is some potential for water heating applications of solar thermal technologies in Indiana.

Figure 5-10 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 5-10: Direct normal solar radiation (flat-plate collector) in Indiana (Source: NREL [12])

5.5 Incentives for solar energy

The following incentives are available for solar thermal energy projects:

Federal Incentives

- U.S. DOE Loan Guarantee Program (Section 1703, Title IV of Energy Policy Act of 2005 provides loan guarantees for large scale innovative renewable energy projects that reduce the emission of pollutants, including renewable energy projects [13].
- Business Energy Investment Tax Credit (ITC) credits up to 30 percent of expenditures on solar systems [13].
- Modified Accelerated Cost-Recovery System (MACRS) allows businesses to recover investments in qualified renewable energy technologies through depreciation deductions. A provision for a 50 percent first year bonus depreciation added by the Economic Stimulus Act of 2008 expired at the end of 2014 [13].
- USDA 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 [13].
- Clean Renewable Energy Bonds (CREBs) are tax credit bonds designed to offset the tax liability of not-for-profit entities such as public utilities, and local and state governments that because of their structure do not benefit from the traditional renewable energy production tax credit (PTC). In February 2015 the IRS announced the allocation of nearly $1.4 billion for new CREBS available from March 2015 [13].
- 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 [13].
- USDA High Energy Cost Grant Program 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 [13, 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 [13].
- Green Power Purchasing Goal requires 20 percent of energy used by federal agencies must be obtained from renewable resources by 2020 [13].

- 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 the Federal Housing Authority or the Department of Veterans Affairs [13].

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 [13].
- 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 [13].
- Renewable Energy Property Tax Exemption provides property tax exemptions for solar thermal, PV, wind, hydroelectric and geothermal systems [13].
- Clean Energy Credit Program (Energy Efficiency and Renewable Energy Set-aside) allocates nitrogen oxides (NOx) allowances for renewable energy and energy efficiency projects that displace utility electricity generation. These NOx credits can then be traded in the regional NOx market that covers 21 states in the eastern United States. One NOx allowance is allocated for each ton of NOx emissions displaced. Several projects may be combined in one application to meet the one ton minimum requirement [15].
- 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. At the writing of this report winners for 2015 had been selected and the challenge closed for the year [12, 16].
- 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 [13].
- 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 solar systems from 5kW to under 10kW is $0.17/kWh for the first batch to be selected in the first capacity allocation lottery (*allocation 1*) and $0.1564/kW for subsequent ones (*allocation 2*). The payment for solar systems larger than 10kW up to

200kW is $0.15/kWh for projects in *allocation 1* and $0.138 for those in *allocation 2* [13, 17, 18].

5.6 References

1. Solar Server, Online Portal to Solar Energy. http://www.solarserver.com/knowledge/basic-knowledge/solar-collectors.html
2. National Renewable Energy Laboratory (NREL). Fuel from the sky: solar energy's potential for Western energy supply. www.nrel.gov/csp/pdfs/32160.pdf
3. International Energy Agency. SolarPACES solar thermal power systems network. http://www.solarpaces.org/csp-technology
4. NREL. Concentrating solar projects. http://www.nrel.gov/csp/solarpaces/
5. U.S. Department of Energy, Energy Efficiency and Renewable Energy (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://energy.gov/eere/energybasics/articles/concentrating-solar-power-dishengine-system-basics
7. 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
8. NREL. http://www.nrel.gov/gis/solar.html
9. Solar Energy Industries Association (SEIA), Major projects list. August 19, 2014; February 23, 2015; May 28, 2015 http://www.seia.org/research-resources/major-solar-projects-list
10. Interstate Renewable Energy Council (IREC). 2011 updates and trends http://www.irecusa.org/2012/08/irec-releases-its-solar-market-trends-report-for-2011/
11. Go Solar California. History of Solar Energy in California http://www.gosolarcalifornia.ca.gov/about/gosolar/california.php
12. NREL. MapSearch. http://www.nrel.gov/gis/ http://en.openei.org/w/index.php?title=File:NREL-eere-pv-h-indiana.pdf
13. Database of State Incentives for Renewables and Efficiency (DSIRE). http://www.dsireusa.org/
14. U.S. Department of Agriculture, Rural Development, Electric Programs. http://www.rurdev.usda.gov/UEP_Our_Grant_Programs.html
15. Indiana Department of Environmental Management. Indiana clean energy credit program. http://www.in.gov/idem/airquality/2553.htm www.in.gov/oed/files/Presentation_Letterman.ppt
16. Indiana Office of Energy Development. Community Conservation Challenge. https://secure.in.gov/oed/2645.htm

17. NIPSCO. February 2015. https://www.nipsco.com/docs/default-source/our-services-docs/feed-in-tariff-faqs.pdf
18. NIPSCO. March 4, 2015. http://www.nipsco.com/docs/default-source/electric-tariffs-122711-docs/rate-665

6. Photovoltaic Cells

6.1 Introduction

Unlike the 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].

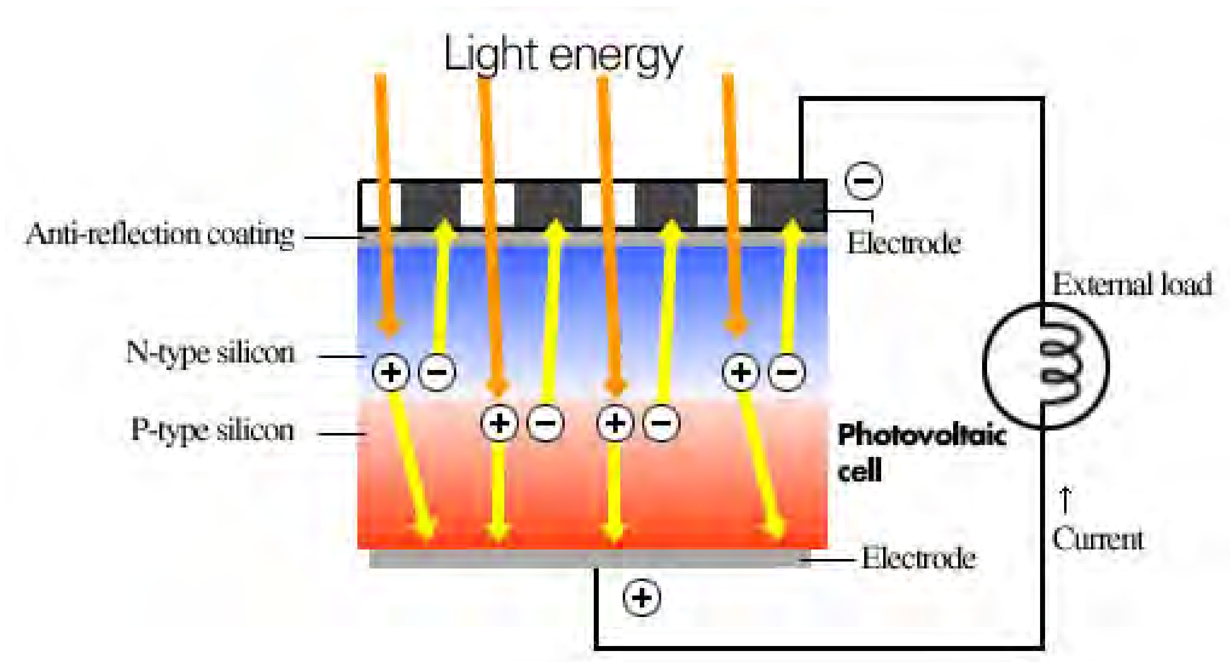


Figure 6-1: Photovoltaic cell operation (Source: EIA [2])

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 [1, 3].

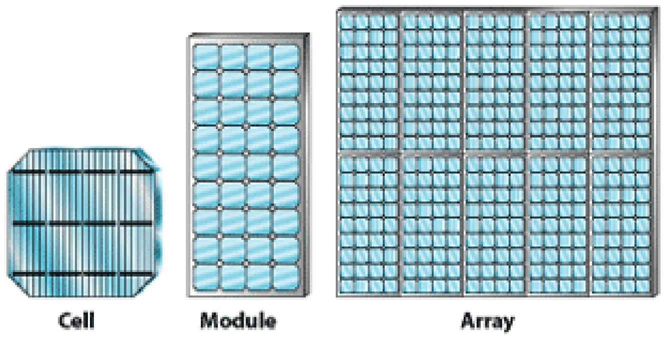


Figure 6-2: Illustration of a cell, module and array of a PV system (Source: EERE [3])

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 over 100,000 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

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 the SUFG was aware of twelve CPV systems in operation in the U.S. with a combined capacity of 60 MW [6, 7]. The largest of these is the 30 MW Alamosa Solar Generating Station installed in Alamosa, Colorado in 2012. Figure 6-3 shows the layout of a CPV cell.

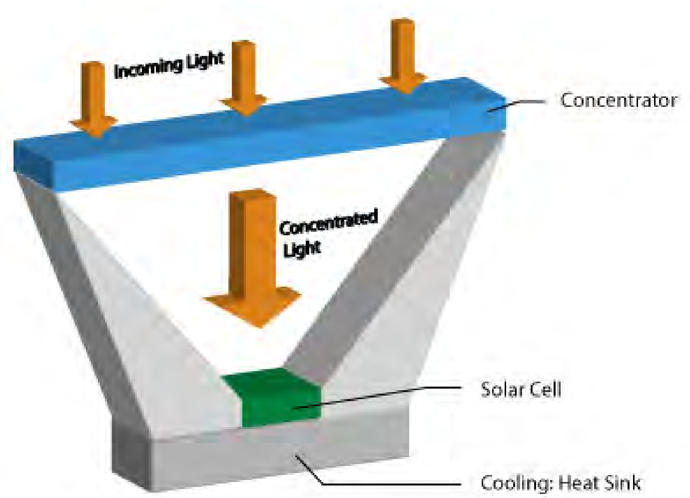
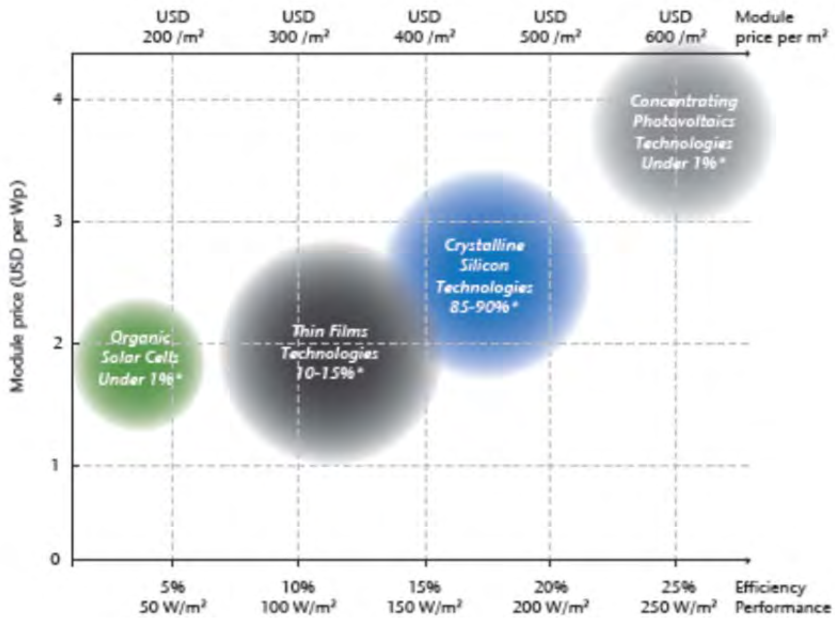


Figure 6-3: Illustration of concentrating photovoltaic cell (Source: Green Rhino Energy [8])

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. According to the U.S. Department of Energy limitations in their efficiency and their long-term reliability remain significant barriers to their commercial deployment [9]



*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

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. Starting 2013 the report was split into two with one dedicated to utility-scale systems (ground-mounted with capacity greater than 5 MW) and the other to residential and non-residential systems (roof-mounted and all ground-mounted up to 5 MW). Figure 6-5 shows the price trends for the residential and non-residential systems up to 5 MW while Figure 6-5 shows the price trends for utility-scale systems. The system installed price shown in the figures is the upfront cost not including any financial incentives.

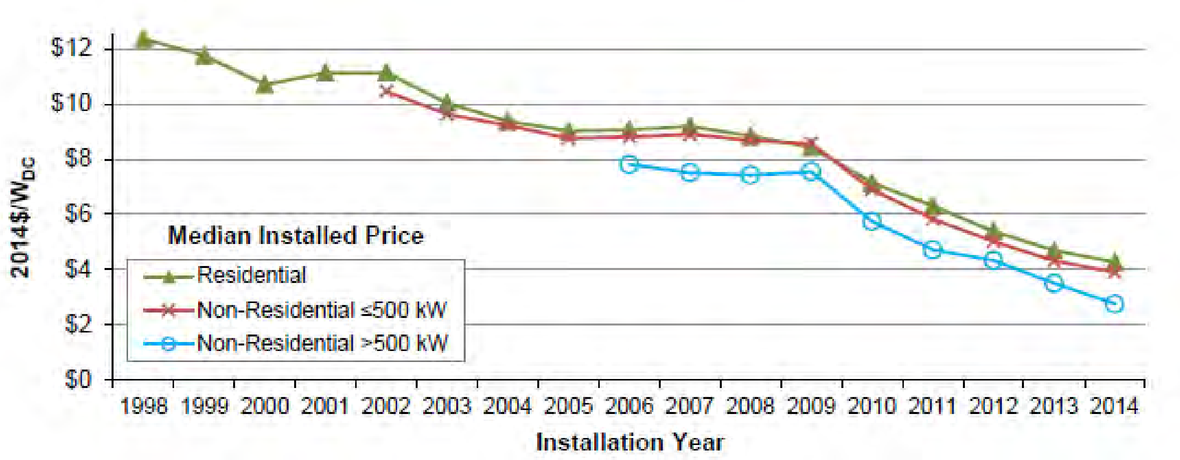
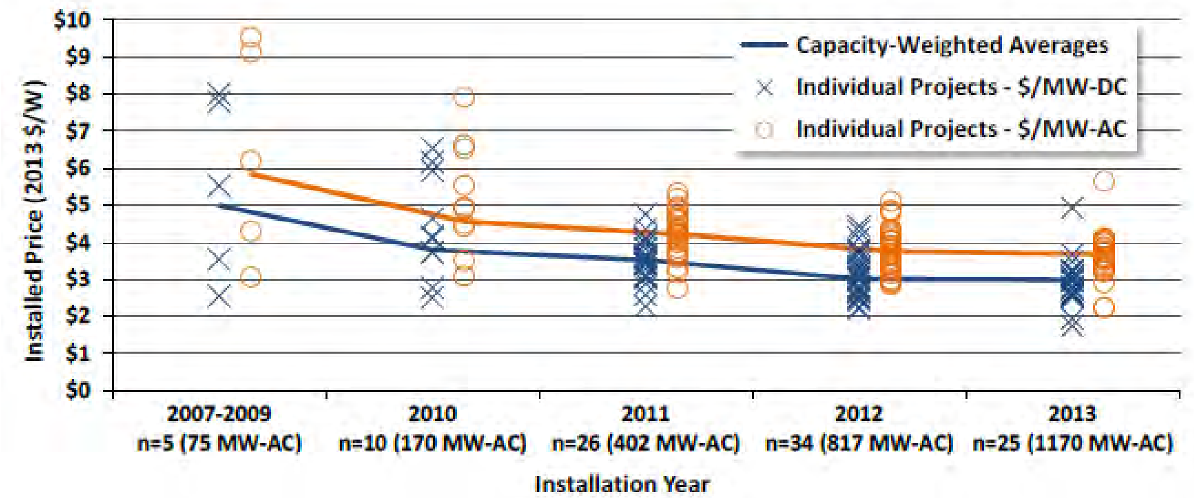


Figure 6-5: Installed price ($\$/W_{DC}$[9]) trends for residential and commercial PV systems (Source: Berkeley National Lab. [10])

As can be seen in Figure 6-5 the installed price for residential and commercial systems has been in steady decline over the entire period represented in the sample. According to the Berkeley Lab report the halt in the declining trend between 2005 and 2009 is attributed to a supply shortage as the PV suppliers struggled to keep pace with the rapid growth in PV installations worldwide. The steady decline in installed price resumed in 2010 dropping from approximately $8/W in 2009 to $4.3/W in 2014 for residential systems, $3.9/W for non-residential systems up to 500kW and $2.8/W for non-residential systems greater than 500 kW.

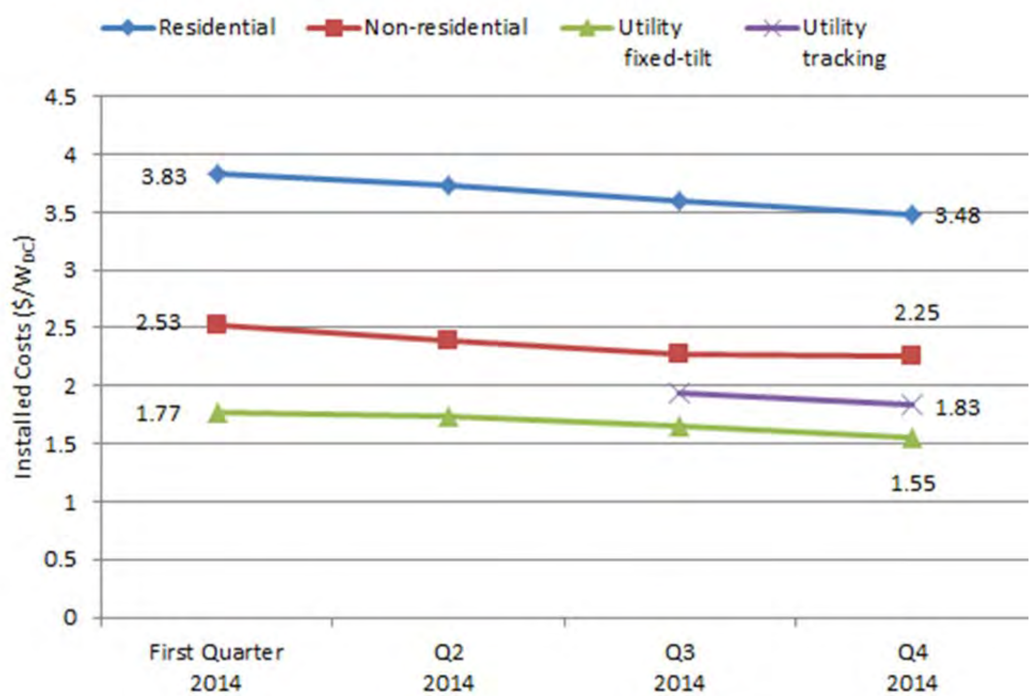
Figure 6-6 shows the installed price of the utility-scale PV projects in the Berkeley Labs database based on the year of the projects' commissioning. Over the time frame in the graph the capacity-weighted average price has dropped from $5.8/W for the projects commissioned in the 2007-2009 period to $3.8/W for the projects commissioned in 2013. Although there was an overall decline in installed prices, there is wide spread in prices between individual projects, ranging from $2.2/W to $5.6/W for projects commissioned in 2013.

[9] The direct current (DC) subscript in $\$/W_{DC}$ denotes that the price of the PV unit does not include the cost of the equipment needed to convert the electricity generated into alternating current mode (AC) mode used in the electric grid.



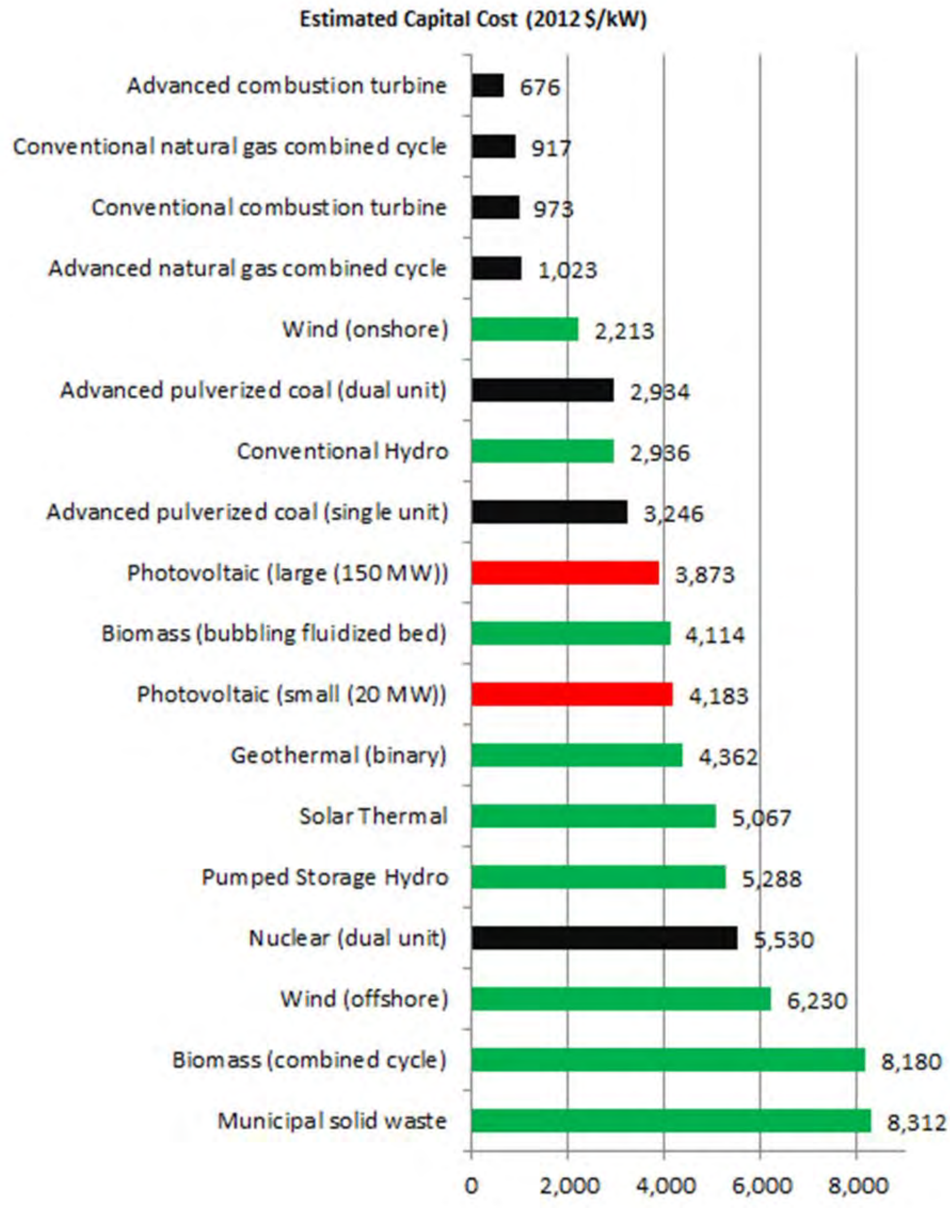
<u>Figure 6-6:</u> <u>Installed price of utility-scale PV systems over time</u> (Source: Berkeley National Lab. [11])

Figure 6-7 shows the estimates of the total cost of installing PV systems in the U.S. in each quarter of 2014 by the Solar Industries Energy Association (SEIA). The SEIA cost is obtained in a "bottom-up" approach that involves adding up the wholesale prices of individual components and the cost of installation obtained from major installers. The resulting estimated prices for the last quarter of 2014 are 3.48 $/W for residential systems, 2.25 $/W for non-residential systems, 1.55 $/W for fixed-tilt utility-scale systems, and 1.83 $/W for utility-scale with sun tracking capability [12].



<u>Figure 6-7:</u> <u>Bottom-up installed cost for PV system prices in 2014</u> (Data Source: SEIA [13])

Figure 6-8 shows EIA's estimates of the capital cost of utility scale photovoltaic electricity generating plants 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 estimated capital cost of $3,873/kW and the smaller plant (50 MW) having an estimated capital cost of $4,183/kW. Onshore wind has the lowest estimated capital cost among the renewables at $2,213/kW and municipal solid waste has the highest at $8,312/kW.



<u>Figure 6-8:</u> <u>Estimated capital cost of generating technologies</u> (Data source: EIA [14])

6.3 State of PV systems nationally

PV installed capacity in the U.S. has been increasing rapidly in the last fourteen years, growing from a mere 4 MW in 2000 to 19,598 MW at the end of first quarter of 2015. Figure 6-9 shows the annual and the cumulative installed capacity of grid-connected PV systems in the U.S.

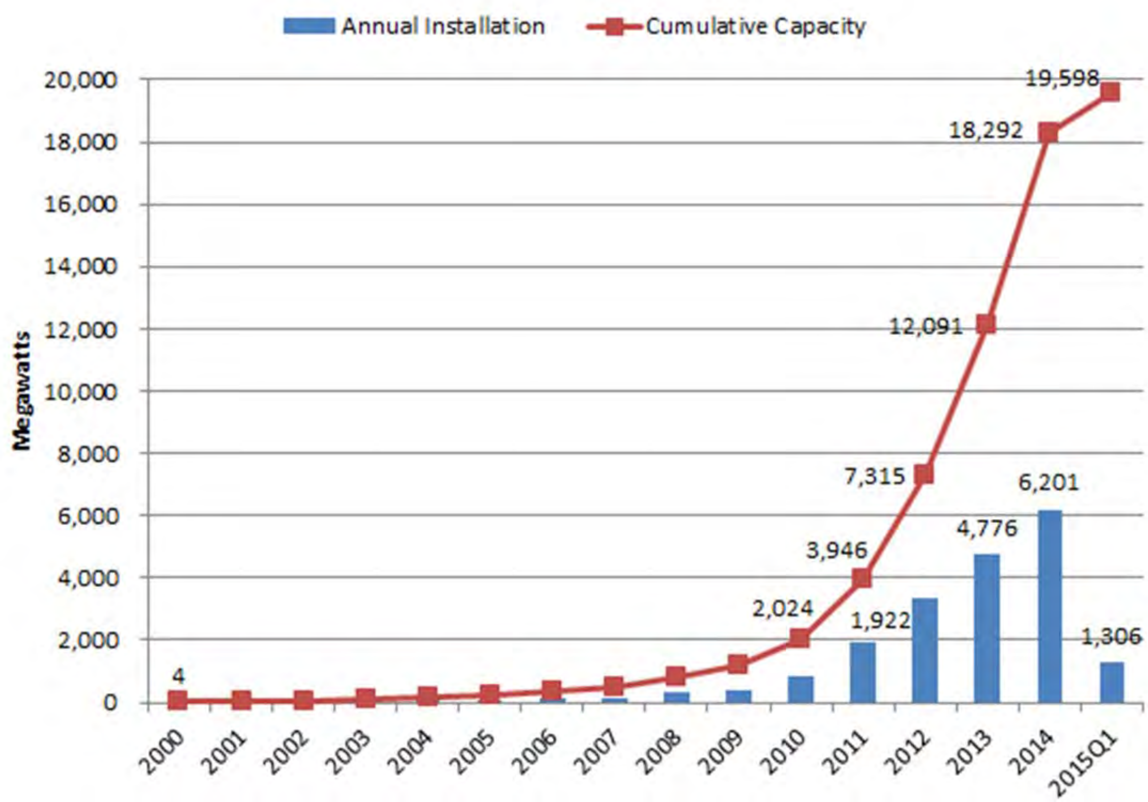
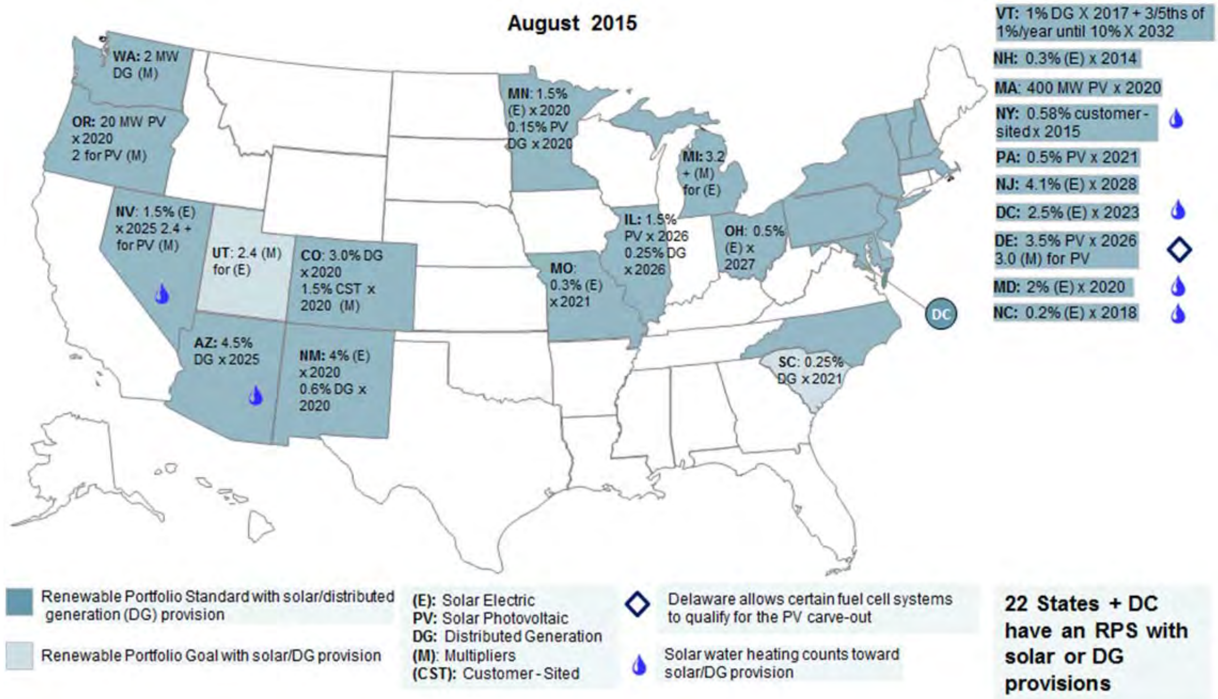


Figure 6-9: Grid-connected U.S. PV installed 2000 to first quarter 2015 (Data source SEIA [13, 15])

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, 21 states and the District of Columbia have a RPS with a 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 6-10 shows the various forms of solar provisions in state RPS. Sixteen states and the District of Columbia offer rebates for PV projects and 46 states offer some form of financial incentive for PV projects [16]



<u>Figure 6-10:</u> <u>Renewable portfolio standards with solar carve-outs</u> (Source DSIRE [16])

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 [16];
- 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, commonly known as the *1603 Treasury Grant Program* [17], 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 commonly referred to as the Energy Policy Act *Section 1705 Program* [18].

The two ARRA funded programs, the 1603 Treasury Grant Program and the Energy Policy Act *Section 1705 Program*, are no longer active having been retired at the end of 2011. However DOE still has the authority issue the loan guarantees under the older Section 1703 program.

Table 6-1 lists PV projects in the U.S. having a capacity 30 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 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**	**City/County**	**State**
Desert Sunlight	First Solar	550	2013	Desert Center	CA
Desert Topaz	First Solar	550	2014	San Luis Obispo	CA
Copper Mountain	Sempra/First Solar	482	2010- 2015	Boulder City	NV
Agua Caliente	First Solar	290	2013	Yuma	AZ
California Valley Solar	SunEdison	250	2013	San Luis Obispo	CA
Imperial Valley Solar	AES Solar	200	2013	Imperial Valley	CA
Mount Signal	8minutenergy	200		Imperial Valley	CA
Centinela Solar Energy	LS Power	170	2013	Imperial Valley	CA
SolarGen 2	First Solar	150	2014	Calapatria	CA
Catalina Solar Project	EDF Renewables	143.2	2013	Kern	CA
Campo Verde	First Solar	139	2013	Imperial	CA
Arlington Valley Solar Project II	LS Power	125	2013	Arlington	AZ
AV Solar Ranch One	First Solar	115	2013	Antelope Valley	CA
Mesquite Solar	Sempra Generation	150	2011, 2013	Arlington	AZ
Regulus Solar	SunPower	75	2015	Kern	CA
Lotus Solar Farm	8minutenergy	67	2014	Madera	CA
Alpine Solar Project	First Solar	66	2013	Lancaster	CA
Solar Star	SunPower	57	2014	Rosamond	CA
Alpaugh	Quanta	70	2012	Alpaugh	CA
Macho Springs	First Solar	50		Deming	NM
Silver State North Solar	First Solar	50	2012	Primm	NV
Alamo Solar Farm 1	OCI Solar Power	41	2013	San Antonio	TX
Alamo Solar Farm 4	OCI Solar Power	39	2014	Bracketville	TX
Avalon Solar Park	Star Harvest Solar	35	2015	Tucson	AZ
Long Island Solar Farm	BP Solar	32	2011	Brookhaven	NY
Alamosa Solar Generating Project	Cogentrix	30	2012	Alamosa	CO
Austin Energy PV	Standard /PPC	30	2011	Webberville	TX
Centinela Solar	LS Power	30	2014	Imperial Valley	CA
Cimarron I Solar Project	First Solar	30	2010	Cimarron	NM
Simon Solar Farm	Silicon Ranch	30	2013	Social Circle	GA
Spectrum Solar	SunPower	30	2013	Clark	NV
San Luis Valley Solar	Iberdrola	30	2011	Alamosa y	CO
McKenzie Road Solar	Recurrent Energy	30	2013	Galt	CA

Table 6-1: PV systems with capacity of 30 MW and above 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 in the last five years. According to the *Open PV Project* database maintained by the National Renewable Energy Laboratory (NREL) [19], there were 610 PV installations in Indiana totaling 120 MW at the time this report was written. Ninety four percent of that capacity (113 MW) was installed in 2013 and 2014. Figure 6-11 shows the annual and cumulative PV capacity installations in Indiana as reported to the NREL *Open PV Project* database as of July 2015.

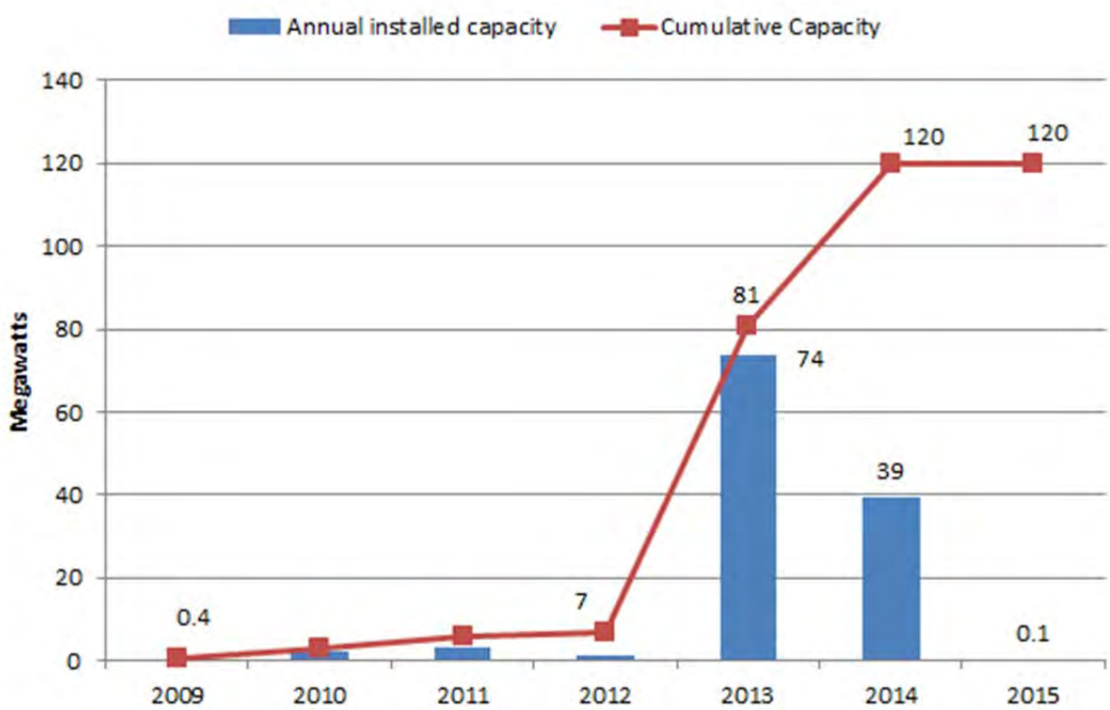


Figure 6-11: Indiana installed PV capacity in NREL *Open PV Project* database (Data source NREL [19]

Five projects in Marion County commissioned in 2013 and 2014 contributed 68 percent of Indiana's 120 MW of PV capacity installed. They are the 26.2 MW Indy Solar I and II solar farm located in Franklin Township, the 21.9 MW Indianapolis International Airport solar farm, the 11.3 MW Indy Solar III project in Decatur Township, the 11.2 MW project at the Indianapolis Motor Speedway, and the 10.9 MW Maywood Solar farm at the Reilly Superfund site in Indianapolis. Table 6-2 lists the PV installations with a capacity of 20 kW and above.

Owner/Developer	Rated Capacity (kW)	Location	Date Installed
Dominion Resources	26,209	Franklin, Marion County	2013
Johnson Melloh Solutions, Telemon Corporation, General Energy Solutions	21,944	Indianapolis International Airport	2013
Dominion Resources	11,275	Decatur, Marion County	2013
Unwire Technology and Blue Renewable Energy	11,204	Indianapolis Motor Speedway	2014
Maywood Solar Farm	10,860	Reilly Tar and Chemical Superfund Site, Indianapolis	2014
REC Group, Melink Corp.	3,189	Indianapolis	2014
Melink Corp	3,102	Rexnord Industries, Indianapolis	2014
groSolar	2,693	Griffith, Lake County	2013
groSolar	2,693	East Chicago	2013
U.S. General Services Administration	2,012	Emmett Bean Federal Center, Indianapolis	2011
ERMCO	1,800	Indianapolis	2010
Indiana Municipal Power Agency	1,000	Richmond	2014
Indiana Municipal Power Agency	1,000	Frankton	2014
Indiana Municipal Power Agency	1,000	Rensselaer	2014
JMS	1,000	Indianapolis	2013
Johnson-Melloh Solutions	750	Speedway	2013
Lake Village Solar LLC	650	Lake Village, Newton County	2013
Seating Technology, Inc.	627	Goshen	2013
Johnson-Melloh Solutions	524	Schaefer Technologies, Indianapolis	2013
Turtle Top Corp.	375	Elkhart County	2013
Indy Southside Sports Academy	200	Indianapolis	2014
Metal Pro Roofing	186	Franklin, Johnson County	2011
Harness Farms	144	Frankfort	2013
Indiana Veneers, Indianapolis	110	Indianapolis	2012
Johnson-Melloh Solutions	109	Indianapolis Department of Public Works	2013
A-Pallet, Indianapolis	108	Indianapolis	2013
Johnson Melloh Solutions Demonstration Lab	100	Indianapolis	2011

Table 6-2: PV systems in Indiana of 100kW and above capacity (Data source: NREL [19])

In addition Indiana utilities have several PV projects under development. Indiana Municipal Power Agency (IMPA) has six solar parks with a combined capacity of 10 MW under construction expected to be commissioned later this year. The six projects are a 0.7 MW project in Argos, a 0.3 MW project in Bainbridge, 3 MW project in Crawfordsville, 2 MW project in Pendleton, 3 MW in Peru and 1 MW in Tell City. IMPA's plan is to grow its PV portfolio to 120 MW in the next ten years [20]. Indiana Michigan Power (I&M) has proposed to build five PV projects with a combined total of 15.7 MW in its service territory. The proposed projects, which have been approved by the Indiana Utility Regulatory Commission (IURC) have an estimated total cost of $38 million [21]. Duke Energy has signed power purchase agreements totaling 20 MW with four PV projects currently under construction in Clay, Howard, Sullivan and Vigo Counties [22].

As explained previously, the factors being credited with the rapid growth in the PV market in the 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 feed-in tariffs by IPL and NIPSCO and the expansion of the Indiana net metering rule to include all customer classes and systems up to 1 MW. The IPL feed-in-tariff expired in 2013. While it was in place, it had $0.24/kWh for systems between 20 and 100 kW and $0.20/kWh for systems greater than 100kW up to 10 MW. Although the first phase of the NIPSCO feed-in-tariff has expired, a second phase with a 10 MW allocation for solar projects has been in place since March 2015. The first phase of the NIPSCO feed-in-tariff had offered $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 second phase of the NIPSCO feed-in-tariff offers $0.17/kWh for micro solar projects that make it into the queue in the first capacity allocation lottery and $0.1564/kWh for subsequent ones. Micro solar projects are defined as those with a nameplate capacity from 5 kW to no more than 10 kW. The rate for intermediate solar projects is $0.15/kW for projects that make it into the queue within the first capacity allocation lottery and $0.138 for subsequent ones [23]. More details of the NIPSCO feed-in tariff are provided in Section 1 of this report. Table 6-3 shows the renewable generation contracted Indiana utilities through their feed-in tariffs and Table 6-4 generation contracted to Indiana utilities through the net metering programs.

	Wind (kW)	Photovoltaic (kW)	Biomass (kW)	Total (kW)
IPL	0	96,978	0	96,978
NIPSCO	160	15,194	14,350	29,702
Total kW	160	112,172	14,350	126,680

Table 6-3: Renewable generation contracted under feed-in tariffs (Data source: IURC [24])

	Wind (kW)	Solar (kW)	Total (kW)
Duke	2,210	2,283	4,495
Indiana Michigan	254	360	614
IPL	50	253	303
NIPSCO	1,926	773	2,699
Vectren	4	677	681
Total	**2,657**	**4,431**	**8,792**

Table 6-4: Renewable generation contracted under net metering (Data source: IURC [24])

6.5 Incentives for PV systems

Federal Incentives

- U.S. DOE Loan Guarantee Program (Section 1703, Title IV of Energy Policy Act of 2005 provides loan guarantees for large scale innovative renewable energy projects that reduce the emission of pollutants, including renewable energy projects [16].
- Business Energy Investment Tax Credit (ITC) credits up to 30 percent of expenditures, with no maximum credit, on qualifying solar energy installations [16].
- 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 added by the Economic Stimulus Act of 2008 expired at the end of 2014 [16].
- USDA 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 [16].
- Clean Renewable Energy Bonds (CREBs) are tax credit bonds designed to offset the tax liability of not-for-profit entities such as public utilities, and local and state governments that because of their structure do not benefit from the traditional renewable energy production tax credit (PTC). In February 2015 the IRS announced the allocation of nearly $1.4 billion for new CREBS available from March 2015 [16].

- <u>Qualified Energy Conservation Bonds (QECBs)</u> 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 [16].
- <u>High Energy Cost Grant Program</u> 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, 25].
- <u>Residential Renewable Energy Tax Credit</u> 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 [16].
- <u>Green Power Purchasing Goal</u> requires 20 percent of energy used by federal agencies must be obtained from renewable resources by 2020 [16].
- <u>Energy Efficiency Mortgage</u> 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 the Federal Housing Authority or the Department of Veterans Affairs [16].

Indiana Incentives

- <u>Solar Access Laws</u> 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 [16].
- <u>Net Metering Rule</u> 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 [16].
- <u>Clean Energy Credit Program (Energy Efficiency and Renewable Energy Set-aside)</u> allocates nitrogen oxides (NOx) allowances for renewable energy and energy efficiency projects that displace utility electricity generation. These NOx credits can then be traded in the regional NOx market that covers 21 states in the eastern United States. One NOx allowance is allocated for each ton of NOx emissions displaced. Several projects may be combined in one application to meet the one ton minimum requirement [26].
- <u>Renewable Energy Property Tax Exemption</u> provides property tax exemptions for solar thermal, PV, wind, hydroelectric and geothermal systems [16].
- <u>Community Conservation Challenge Grant</u> 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. At the writing of this report winners for 2015 had been selected and the challenge closed for the year [16, 27].

- 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, which includes electricity, from state gross retail tax. However, only wind energy has clearly specified rules from the Department of Revenue [16].
- 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 [16].
- 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 solar systems from 5kW to under 10kW is $0.17/kWh for the first batch to be selected in the first capacity allocation lottery (allocation 1) and $0.1564/kW for subsequent ones (allocation 2). The payment for solar systems larger than 10kW up to 200kW is $0.15/kWh for projects in allocation 1 and $0.138 for those in allocation 2 [16, 23, 28].

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://energy.gov/eere/energybasics/articles/photovoltaic-system-basics.
4. National Renewable Energy Laboratory (NREL). Solar photovoltaic technology basics. http://www.nrel.gov/learning/re_photovoltaics.html.
5. SEIA, Major projects list. May 28, 2015. http://www.seia.org/research-resources/major-solar-projects-list
6. Solar Energy Industries Association (SEIA), Major projects list. August 19, 2014.
7. CPV consortium. http://cpvconsortium.org/projects?country=United%20States

8. Green Rhino Energy. Concentrating Photovoltaics (CPV). http://www.greenrhinoenergy.com/solar/technologies/pv_concentration.php
9. EERE. Organic Photovoltaics Research. http://energy.gov/eere/sunshot/organic-photovoltaics-research
10. Lawrence Berkeley National Laboratory. Tracking the sun VIII: The Installed Price of Residential and Non-Residential Photovoltaic Systems in the United States.
http://emp.lbl.gov/publications/tracking-sun-viii-install
http://emp.lbl.gov/sites/all/files/lbnl-188238_0.pdf
emp.lbl.gov/sites/all/files/lbnl-188238%20data%20file.xls
http://emp.lbl.gov/sites/all/files/lbnl-188238%20presentation_0.pdf
11. Utility-Scale Solar 2013: An Empirical Analysis of Project Cost, Performance, and Pricing Trends in the United States.
http://emp.lbl.gov/publications/utility-scale-solar-2013-empirical-analysis-project-cost-performance-and-pricing-trends
http://emp.lbl.gov/sites/all/files/lbnl-6912e.pdf
http://emp.lbl.gov/sites/all/files/lbnl-6912e%20presentation_0.pdf
12. SEIA. U.S. solar market insight report, Q1 2014, executive summary. http://www.seia.org/sites/default/files/resources/fxD2AN7d502014q1smies.pdf
13. SEIA. U.S. solar market insight report, 2014 year-in-review, executive summary. http://www.seia.org/research-resources/solar-market-insight-report-2014-q4
14. 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
15. SEIA. U.S. solar market insight report, 2015 Q1. http://www.seia.org/research-resources/solar-market-insight-report-2015-q1
16. Database of State Incentives for Renewables and Efficiency (DSIRE). http://www.dsireusa.org/
17. SEIA. http://www.seia.org/policy/finance-tax/1603-treasury-program
18. U.S. Department of Energy, Loan Programs Office Section 1705 Loan Program. http://energy.gov/lpo/services/section-1705-loan-program
19. NREL. The open PV Project. http://openpv.nrel.gov/
20. Megawatt Daily. August 19, 2015
21. Indiana Michigan Power. New release February 5, 2015. https://www.indianamichiganpower.com/info/news/viewRelease.aspx?releaseID=1695
22. Inside Indiana Business with Gerry Dick. August 2 2015. http://www.insideindianabusiness.com/newsitem.asp?ID=72192
23. NIPSCO. March 4, 2015. http://www.nipsco.com/docs/default-source/electric-tariffs-122711-docs/rate-665.
24. George Stevens. Indiana Utility Regulatory Commission.

25. U.S. Department of Agriculture, Rural Development, Electric Programs. http://www.rd.usda.gov/programs-services/high-energy-cost-grants.
26. Department of Environmental Management. Indiana clean energy credit program. http://www.in.gov/idem/airquality/2553.htm
www.in.gov/oed/files/Presentation_Letterman.ppt
27. Indiana Office of Energy Development. Community Conservation Challenge. https://secure.in.gov/oed/2645.htm
28. NIPSCO. February 2015. https://www.nipsco.com/docs/default-source/our-services-docs/feed-in-tariff-faqs.pdf

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. The harnessing of moving water to perform work has been in use for thousands of years with the Greeks being on record to have used it to grind wheat more than 2,000 years ago. The evolution of the hydropower turbine began in the mid-1700s in Europe with the published work of Bernard Forest de Bélidor, a French engineer. The first use of a water driven dynamo in the U.S. was in 1880 in Grand Rapids, Michigan followed closely by Niagara Falls, New York where they were used to provide street lighting. Unlike modern hydropower plants, these two projects used direct current technology. The first modern alternating current hydropower plant in the world was installed in Appleton, Wisconsin in 1882. It generated enough electricity to light the inventor's home, the power plant and one neighboring building [1, 2].

From these beginnings hydroelectricity quickly rose to become one of the principal sources of electricity in the U.S. At the beginning of the 20th century hydropower provided over 40 percent of the electricity generated in the U.S. With the rise of other fuels, such as coal, nuclear, natural gas and wind, the role of hydroelectricity has dropped steadily to the point that it supplied only 6 percent of the total electricity generated in 2014. Although the quantity of hydropower as a proportion of the total electricity generated has diminished, it remains the main source of renewable electricity accounting for almost half the renewable electricity generated in the U.S. in 2014 [3, 4].

There are several different types of hydropower facilities today. They include [5]:

- Impoundment hydropower: These facilities use 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: These facilities channel some of the water through a canal or penstock. They may require a dam but are less obtrusive than impoundment facilities.

- Run-of-river projects: These facilities utilize the flow of water of the river and require little to no impoundment. Run-of-river plants can be designed for large flow rates with low head[10] 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. They are typically used in remote locations to serve the power needs of a single nearby home or business.

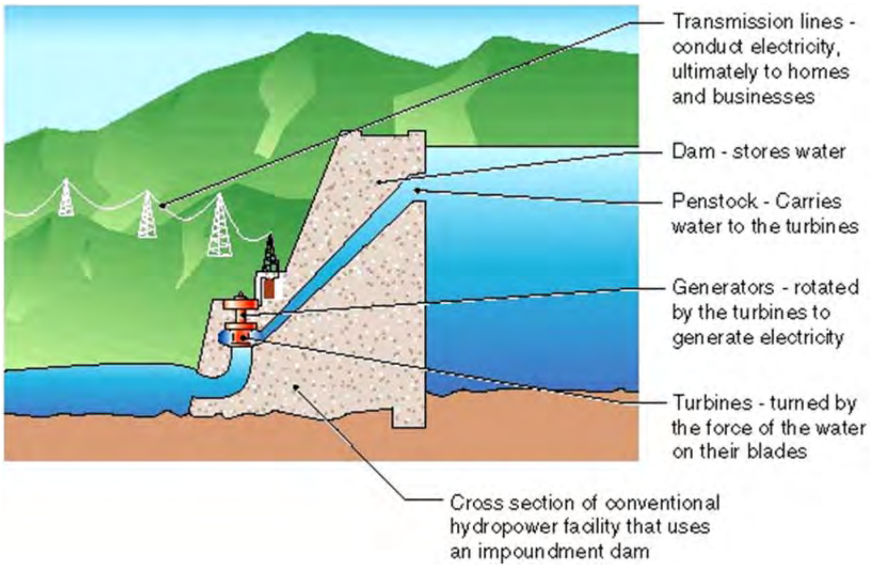


Figure 7-1: Schematic of impoundment hydropower facility (Source: DOE [6])

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 [7].

7.2 Economics of hydropower

Hydropower projects are very capital intensive and the cost is very site specific. Figure 7-2 shows the construction costs for U.S. hydropower projects from 1985 to 2015 normalized to 2014 dollars obtained from the 2014 DOE *Hydropower Market Report*. The projects are arranged in three groups: c*onduits, new stream-reach development and non-powered dams*.

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

Conduit hydropower projects are those constructed on water conveyance conduits put in place primarily for irrigation or water supply. *New stream-reach development* projects are small capacity hydropower projects that can be built on streams with minimum environmental impact, while *non-powered dams* are exactly that, hydropower projects added to dams already in place for other purposes, such us storage, irrigation or navigation [8].

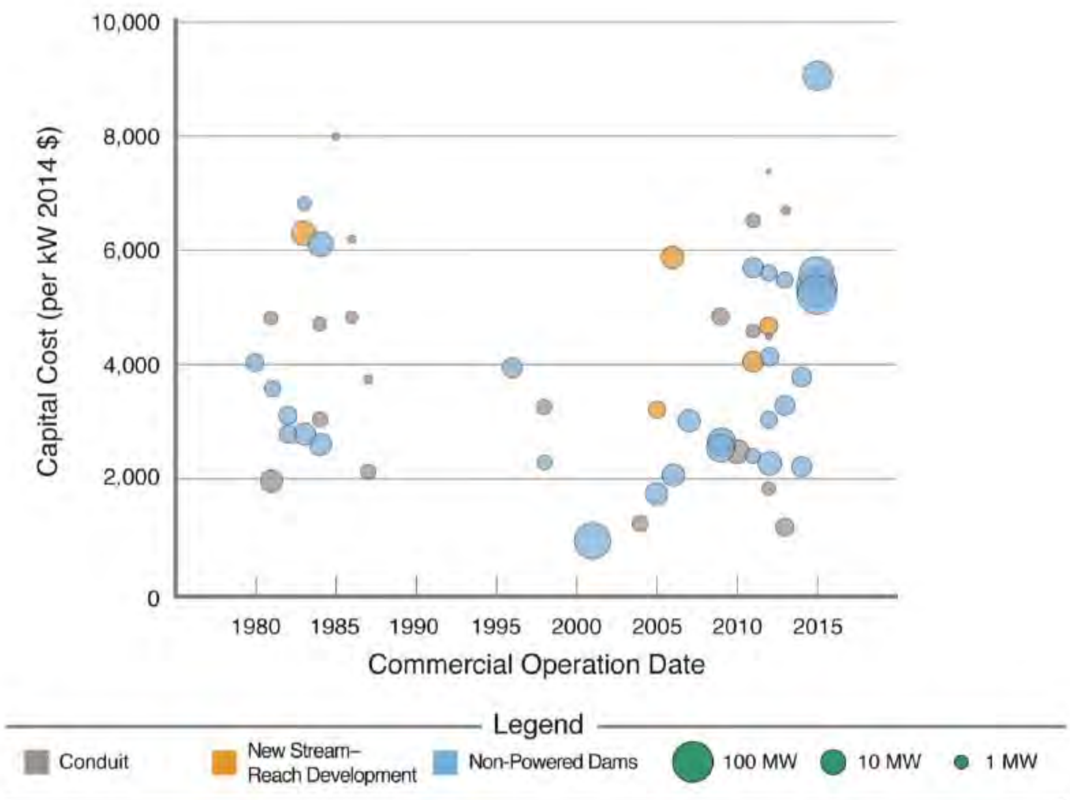


Figure 7-2: U.S. hydropower construction cost by project type and size (Source: DOE [8])

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 $9,417/kW cost in 2014 dollars estimate for the Susitna project in Alaska.

Project		Time*	Initial Capital Costs ($/kW)**
Idaho National Lab estimates		1996	1,700-2,300
EIA estimates	Hydroelectric	2013	2,936
	Pumped Storage	2013	5,288
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-Watana Project (Alaska)		2014	9,417
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	NA	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 and 2005 for the Hawaii pumped hydro project. The basis year for the AMP and the Alaska projects was not available. The document on which the AMP capital cost estimates were obtained was dated 2011, and 2014 for the document from which Alaska project was obtained.

Table 7-1: Initial capital costs of hydropower projects (Data sources: [9-14])

Once constructed, hydroelectric power plants have a major cost advantage since the fuel (water) is virtually free and also because they have very low O&M costs. According to the EIA updated electricity generating technologies cost estimates [10], hydroelectric plants have one of the lowest O&M costs among electricity generating technologies. Figure 7-3 shows the fixed and variable O&M costs of various generating technologies. As can be seen in the Figure 7-3, hydroelectricity's variable O&M costs are estimated at zero and the fixed O&M cost of $14/kW for a conventional hydroelectric plant is the second lowest after natural gas combustion turbines.

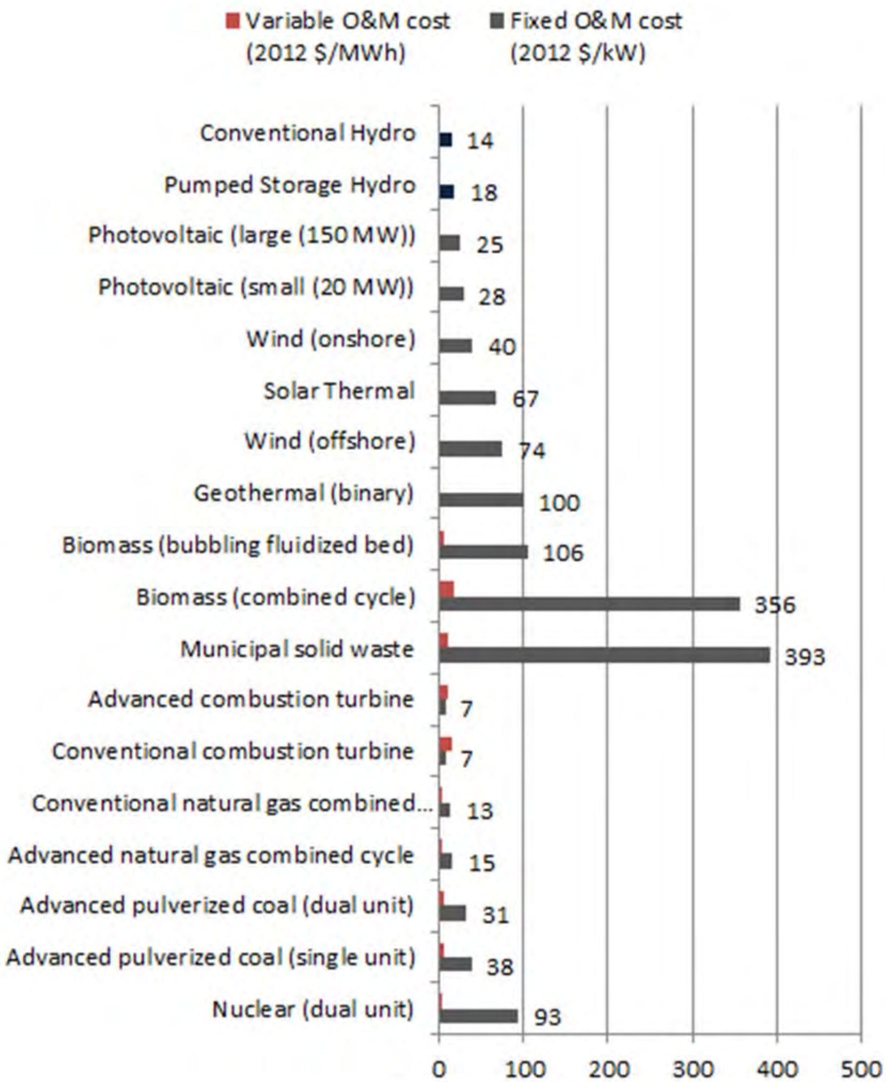


Figure 7-3: Variable and fixed O&M costs of generating technologies (Data source: EIA [10])

7.3 State of hydropower nationally

Hydropower has historically been the primary source of renewable energy in the U.S. Figure 7-4 shows the amount of electricity generated from renewable resources from 1949 to 2014. In the early parts of the 20th century hydroelectricity accounted for virtually all the renewable electricity consumed in the U.S. with all other renewable resources combined contributing less than one percent up to 1974. Although this dominance of hydroelectricity has steadily reduced over time, it still accounts for almost half of the renewable electricity generated and a third of the renewable energy consumed in the U.S. In 2014 hydroelectricity accounted for 48 percent of the renewable electricity generated and 26 percent of the total renewable energy consumed in the U.S.

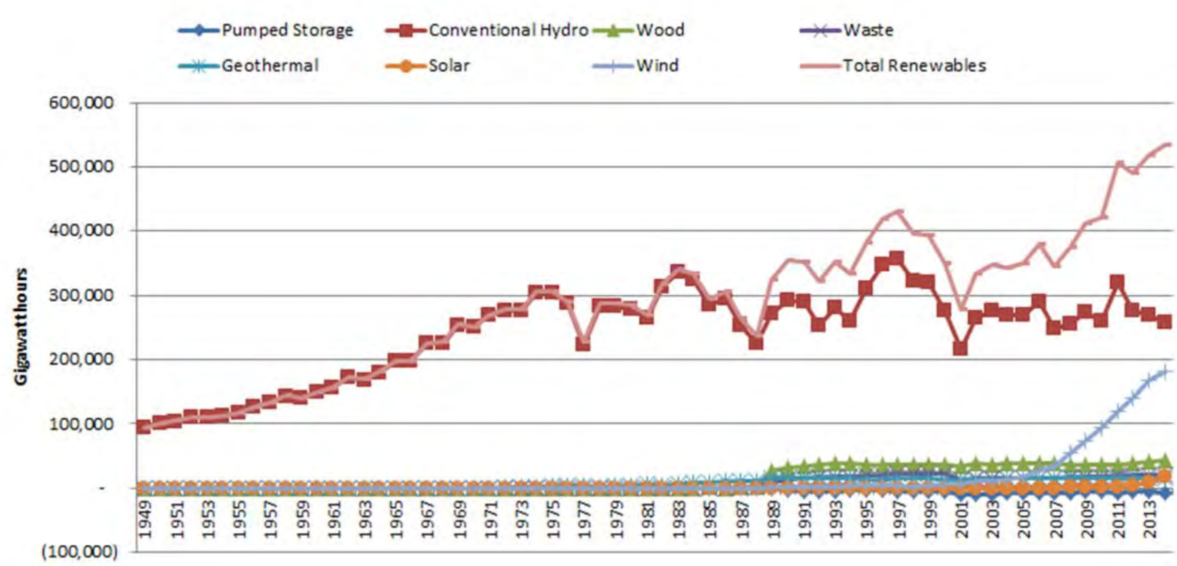


Figure 7-4: Net renewable electricity generation in the U.S. (1949-2014) (Data source: EIA [4])

The total installed hydropower capacity in the U.S. consists of 79.64 gigawatts (GW) of conventional hydro distributed over 2,198 projects and 21.6 GW of pumped hydro plants in 42 projects [8]. Table 7-2 is a list of the ten largest hydropower plants in the U.S.

Hydropower Plant	River	State	Capacity (MW)	Year of completion
Grand Coulee	Columbia	Washington	6,180	1942
Chief Joseph	Columbia	Washington	2,457	1958
John Day	Columbia	Oregon	2,160	1971
Bath County*	Little Back Creek	Virginia	2,100	1985
Robert Moses - Niagara	Niagara	New York	1,950	1961
The Dalles	Columbia	Oregon	1,805	1957
Ludington*	Lake Michigan	Michigan	1,872	1973
Raccoon Mountain	Tennessee River	Tennessee	1,530	1978
Hoover	Colorado	Nevada	1,434	1936
Pyramid/Castaic*	California Aqueduct	California	1,250	1973

*pumped hydropower stations

Table 7-2: Ten largest hydropower plants in the U.S. (Data source: EIA [15], USSD [16]),

Table 7-3 shows the top ten hydro states ranked by their hydroelectricity output in 2013 and Table 7-4 shows the top ten hydro states ranked by installed hydro capacity at the end of 2014. Nearly sixty percent of the hydroelectricity generation in 2013 was from the top four states of Washington, Oregon, New York, and California.

1. Washington	77,906,959		6. Tennessee	11,737,163
2. Oregon	33,457,372		7. Montana	9,953,300
3. New York	25,148,473		8. Idaho	9,100,528
4. California	24,541,380		9. North Carolina	6,433,282
5. Alabama	12,646,761		10. Arizona	5,950,654

Table 7-3: Top ten U.S. hydropower generating states in 2013 (MWh) (Data source: National Hydropower Association [17])

1. Washington	21,303		6. Montana	2,638
2. California	10,334		7. Idaho	2,568
3. Oregon	8,335		8. Tennessee	2,499
4. New York	4,673		9. Georgia	2,241
5. Alabama	3,109		10. Nevada	2,096

Table 7-4: Top ten U.S. hydropower capacity states at end of 2014 (MW) (Data source: DOE [8])

In 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 dams 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 7-5 shows the hydropower potential from non-powered dams for the states in the contiguous U.S.

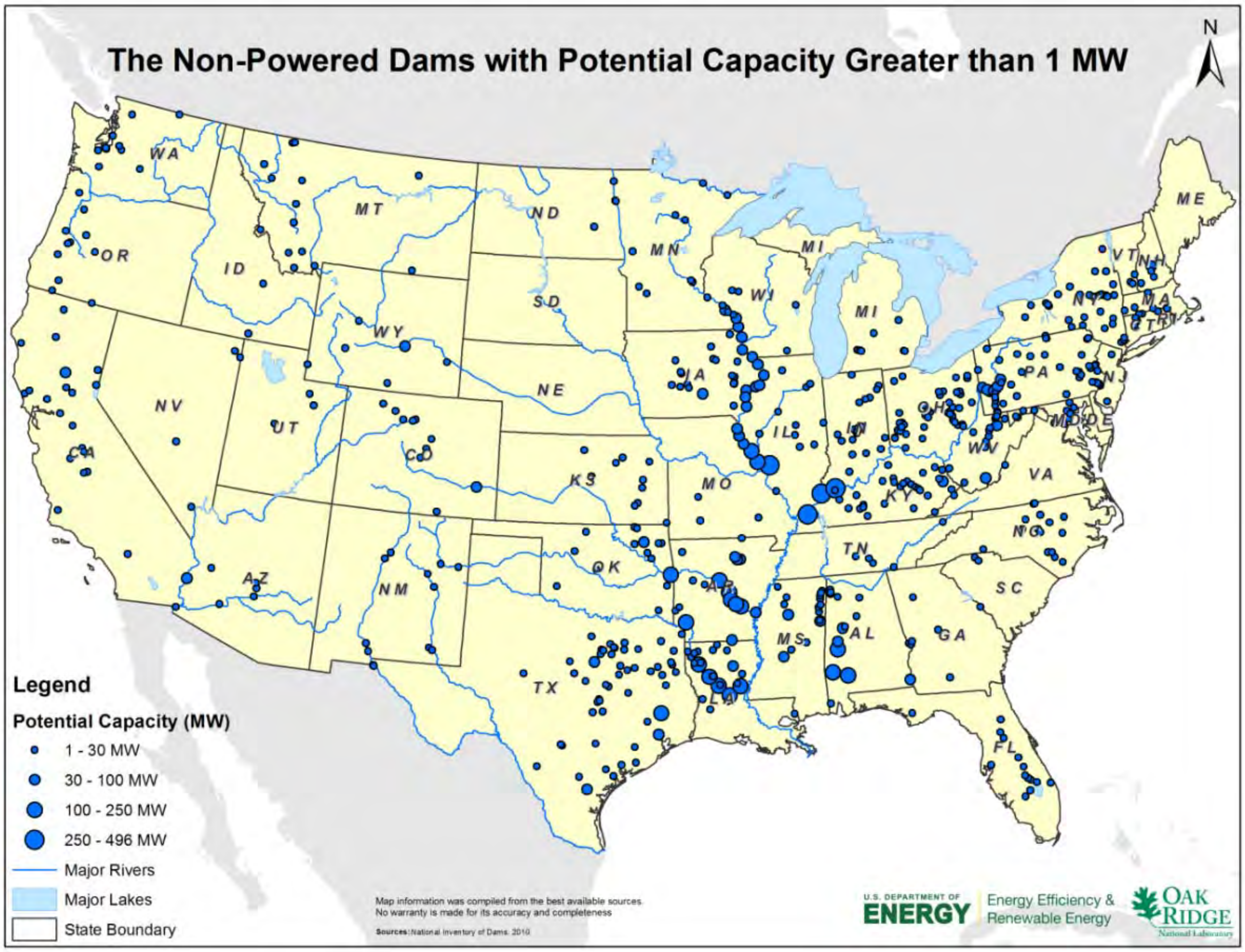


Figure 7-5: Non-powered dams with potential capacity over 1 MW (Source: DOE [18])

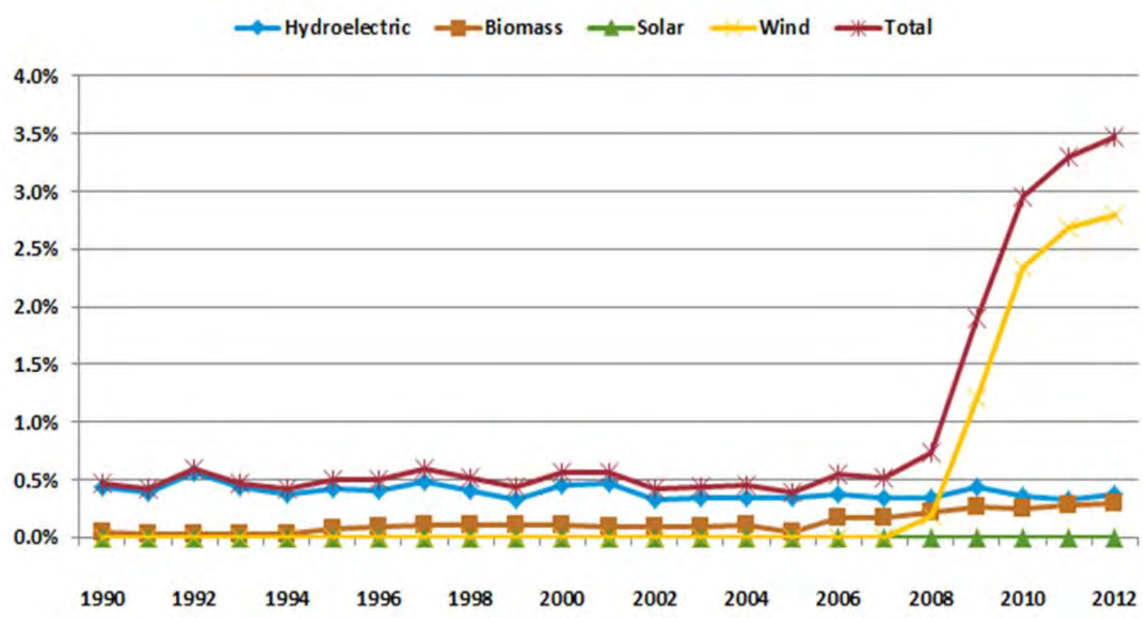
State	Potential Capacity (MW)		State	Potential Capacity (MW)
Illinois	1269		Kansas	92
Kentucky	1253		Montana	88
Arkansas	1136		Washington	85
Alabama	922		Arizona	80
Louisiana	857		Connecticut	68
Pennsylvania	679		Massachusetts	67
Texas	658		New Hampshire	63
Missouri	489		Virginia	50
Indiana	**454**		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 7-5: Hydropower potential from non-powered dams by state (Data source: DOE [18])

In April 2014 DOE released another assessment of hydropower potential this time focused on undeveloped stream-reaches: that is, rivers and streams that do not have existing dams of any kind (either hydropower plants or non-powered dams). The total hydropower potential in these rivers and streams is estimated at 84.7 GW capable of producing 460,000 GWh of electrical energy per year [19].

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 1,544 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. Furthermore the photovoltaic capacity has also been climbing rapidly to overtake hydropower with 120 MW installed at the writing of this report.



<u>Figure 7-6:</u> <u>Renewables share of Indiana net electricity generation (1990-2012)</u> (Data source: EIA [20])

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 7-6 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.

The April 2014 DOE assessment of hydropower potential in rivers and streams that do not have any dams today estimated that Indiana has the potential for 581 MW hydropower capacity capable of generating over 3,000 GWh of electricity per year. This is approximately 7 times the hydroelectricity generated in Indiana in 2012 and 3 percent of the total electricity generated in Indiana from all sources in 2012 [19].

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 7-6: Indiana non-powered dams with potential capacity over 1 MW (Data source: DOE [19])

American Municipal Power (AMP), a wholesale electricity supplier to municipal utilities in Ohio, Pennsylvania, Michigan, Virginia, Kentucky and West Virginia is in the process of developing five run-of-the-river hydroelectric projects along the Ohio River. Two of these projects, the 105 MW Meldahl and 84 MW Cannelton had started the commissioning process as of the writing of this report and were expected to start commercial production before the end 2015. Two others, the 72 MW Smithland project and the 35 MW Willow Island project are expected to be completed and commissioned in 2016. One project, the 48 MW Robert Byrd, was in the licensing process. One of these projects, the Cannelton project is located on the Indiana/Kentucky section of the river. The license application for a six project with a capacity of 49.5 MW at the Pike Island lock and dam in West Virginia has since been withdrawn [21-23]. 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 [24].

7.5 Incentives for hydropower

Federal Incentives

- Renewable Electricity Production Tax Credit (PTC) provides a 1.1 cents/kWh tax credit for small irrigation hydroelectric facilities for ten years of operation. The PTC expired in December 2014 but projects under construction in 2015 are eligible for the credit if they began construction before the end of 2014 [25].
- USDA 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 [25].
- Clean Renewable Energy Bonds (CREBs) are tax credit bonds designed to offset the tax liability of not-for-profit entities such as public utilities, and local and state governments that because of their structure do not benefit from the traditional renewable energy production tax credit (PTC). In February 2015 the IRS announced the allocation of nearly $1.4 billion for new CREBS available from March 2015 [25].
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- 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 [25, 26].
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Indiana Incentives

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- Renewable Energy Property Tax Exemption provides property tax exemptions for solar, wind, hydroelectric and geothermal systems [25].
- 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. At the writing of this report winners for 2015 had been selected and the challenge closed for the year [25, 28].
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7.6 References

1. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy (EERE). History of hydropower. http://energy.gov/eere/water/history-hydropower
2. The Library of Congress. http://www.americaslibrary.gov/jb/gilded/jb_gilded_hydro_1.html
3. U.S. Department of the Interior, Bureau of Reclamation. The history of hydropower development in the United States. http://www.usbr.gov/power/edu/history.html
4. EIA. May 2014 Monthly Energy Review. Table 7.2a. http://www.eia.gov/totalenergy/data/monthly/#electricity
5. Idaho National Laboratory (INL). Hydropower: Types of hydropower facilities. http://hydropower.inel.gov/hydrofacts/hydropower_facilities.shtml
6. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy (EERE). Types of hydropower plants. http://energy.gov/eere/water/types-hydropower-plants.
7. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy (EERE). Types of hydropower turbines. http://energy.gov/eere/water/types-hydropower-turbines
8. EERE. 2014 Hydropower Market Report. http://energy.gov/eere/water/downloads/2014-hydropower-market-report, http://energy.gov/sites/prod/files/2015/05/f22/2014%20Hydropower%20Market%20Report_20150512_rev6.pdf
9. INL. Hydropower: Plant costs and production expenses. http://hydropower.inel.gov/hydrofacts/plant_costs.shtml
10. 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
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. Susitna-Watana Hydro. http://www.susitna-watanahydro.org/?attachment_id=5018
13. Alaska Energy Authority. Susitna-Watana Hydro. Report to the Legislature, 2014. http://www.susitna-watanahydro.org/wp-content/uploads/2015/01/SWD110-Annual-Report-2014_FINAL3.pdf
14. AMP. Organization and generation project overview, June 2011.
15. EIA. Electricity Generating Capacity. Released January 2013. http://www.eia.gov/electricity/capacity/
16. United States Society on Dams. Largest hydro projects in the United States. http://ussdams.org/uscold_s.html

17. National Hydropower Association. U.S. hydro generating profile. http://hydro.org/why-hydro/available/hydro-in-the-states/
18. DOE. An Assessment of Energy Potential at Non-Powered Dams in the United States. http://nhaap.ornl.gov/content/non-powered-dam-potential http://www1.eere.energy.gov/water/pdfs/npd_report.pdf
19. New Stream-reach Development. A Comprehensive Assessment of Hydropower Energy Potential in the United States. http://nhaap.ornl.gov/nsd#NSDfindings, http://nhaap.ornl.gov/sites/default/files/ORNL_NSD_FY14_Final_Report.pdf
20. EIA. Indiana Electricity Profile Table 5, Release date: January 2012. http://www.eia.gov/electricity/state/indiana/
21. American Municipal Power (AMP). Hydroelectric power http://www.amppartners.org/generation/hydro
22. McGraw Hill Financial. Megawatt Daily, May 19, 2015
23. The State Journal, West Virginia, March 9, 2014. http://www.statejournal.com/story/24665101/pike-island-dam-hyrdoelectric-power-plant-permit-pulled
24. Mounds Lake Reservoir project website. http://moundslake.com/ http://moundslake.com/phase-2-reports/
25. Database of State Incentives for Renewables and Efficiency (DSIRE). http://www.dsireusa.org/
26. U.S. Department of Agriculture, High Energy Cost Grant Program overview. http://www.rd.usda.gov/programs-services/all-programs#Electric http://www.rd.usda.gov/programs-services/high-energy-cost-grants
27. Indiana Department of Environmental Management. Indiana clean energy credit program. http://www.in.gov/idem/airquality/2553.htm
28. Indiana Office of Energy Development. Community Conservation Challenge. https://secure.in.gov/oed/2645.htm