PURDUE UNIVERSITY
Discovery Park Energy Center

September 2011

2011
Indiana Renewable Energy Resources Study

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

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

2011 INDIANA RENEWABLE ENERGY RESOURCES STUDY

State Utility Forecasting Group

Energy Center

Purdue University

West Lafayette, Indiana

David Nderitu

Tianyun Ji

Benjamin Allen

Douglas Gotham

Paul Preckel

Darla Mize

Forrest Holland

Marco Velastegui

Tim Phillips

September 2011

Table of Contents

List of Figures

List of Tables

Acronyms and Abbreviations

AMP	American Municipal Power
AWEA	American Wind Energy Association
BIPV	Building Integrated Photovoltaic Panels
Btu	British Thermal Unit
CF	Capacity factor
CO_2	Carbon dioxide
CPV	Concentrating photovoltaic
CREB	Clean Renewable Energy Bonds
CSP	Concentrating Solar Power
CPS	Clean Energy Portfolio Standard
DOE	U.S. Department of Energy
DOI	U.S. U.S. Department of the Interior
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
FERC	Federal Energy Regulatory Commission
FHA	Federal Housing Authority
FY	Financial year
GW	Gigawatt
GWh	Gigawatthour
IEA	International Energy Agency
IMPA	Indiana Municipal Power Agency
INEL	Idaho National Engineering and Environmental Laboratory, U.S. Department of Energy

IPL	Indianapolis Power and Light Company
IREC	Interstate Renewable Energy Council
ITC	Business energy investment tax credit
IURC	Indiana Utility Regulatory Commission
kW	Kilowatt
kWh	Kilowatthour
LMOP	Landfill Methane Outreach Program, Energy Information Administration, U.S. Department of Energy
m/s	Meters per second
MACRS	Modified Accelerated Cost-Recovery System
MGY	Million gallons per year
mmBtu	million British Thermal Unit
mmscfd	million standard cubic feet per day
MMTCE	million metric tons of carbon equivalent
MOU	Memorandum of Understanding
mph	Miles per hour
MSW	Municipal solid waste
MACRS	Modified accelerated cost-recovery system
MTBE	Methyl tertiary butyl ether – a gasoline oxygenating additive
MW	Megawatt
MWh	Megawatthour
NIPSCO	Northern Indiana Public Service Company
NO_x	Nitrogen oxide
NRCS	Natural Resources Conservation Service, U.S. Department of Agriculture
NREL	National Renewable Energy Laboratory, U.S. Department of Energy
O&M	Operation and maintenance
OED	Indiana Office of Energy Development
ORNL	Oak Ridge National Laboratory, U.S. Department of Energy
POLYSYS	Policy Analysis System

PTC	Production tax credit
PV	Photovoltaic
REAP	Rural Energy for America Program, U.S. Department of Agriculture
REP	Renewable energy production – Indianapolis Power & Light feed-in tariff for renewable energy
REPI	Renewable Energy Production Incentive
QECB	Qualified Energy Conservation Bonds
RFA	Renewable Fuels Association
SEDS	State Energy Data System, Energy Information Administration, U.S. Department of Energy
SEGS	Solar Electric Generation System
SEIA	Solar Energy Industries Association
SOx	Sulphur oxides
SUFG	State Utility Forecasting Group
USDA	U.S. Department of Agriculture
VA	Veterans Affairs
VEETC	Volumetric ethanol tax credit
W/m^2	Watts Per Meter Squared
WVPA	Wabash Valley Power Association
WWT	Waste water treatment

Foreword

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

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

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

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

State Utility Forecasting Group
203 South Martin Jischke Drive
Mann Hall, Suite 154
West Lafayette, IN 47907-1971
Phone: 765-494-4223
e-mail: sufg@ecn.purdue.edu
https://www.purdue.edu/dp/energy/SUFG/

1. Overview

This first section of the 2011 Indiana Renewable Energy Resources Report presents an overview of the trends in renewable energy consumption in the U.S. and in Indiana.

1.1 Trends in renewable energy consumption in the United States

Figure 1-1 shows the amounts of renewable energy in quadrillion British thermal units (Btu) consumed in the U.S. from 1949 to 2010. Until the early 2000s hydroelectricity and woody biomass were the dominant sources of renewable energy consumed in the U.S. The last decade has seen a rapid increase in biofuels (mainly corn-based ethanol) and wind sources of renewable energy. The rapid increase in corn-ethanol has been driven by two factors: first as a replacement of the oxygenating additive MTBE which started being phased out in 2000, then due to the Federal Renewable Fuel Standard first authorized in the 2005 Energy Policy Act and then expanded in 2007. Similarly the rapid increase in wind energy started with the introduction of the Federal Production Tax Credit in 1992.

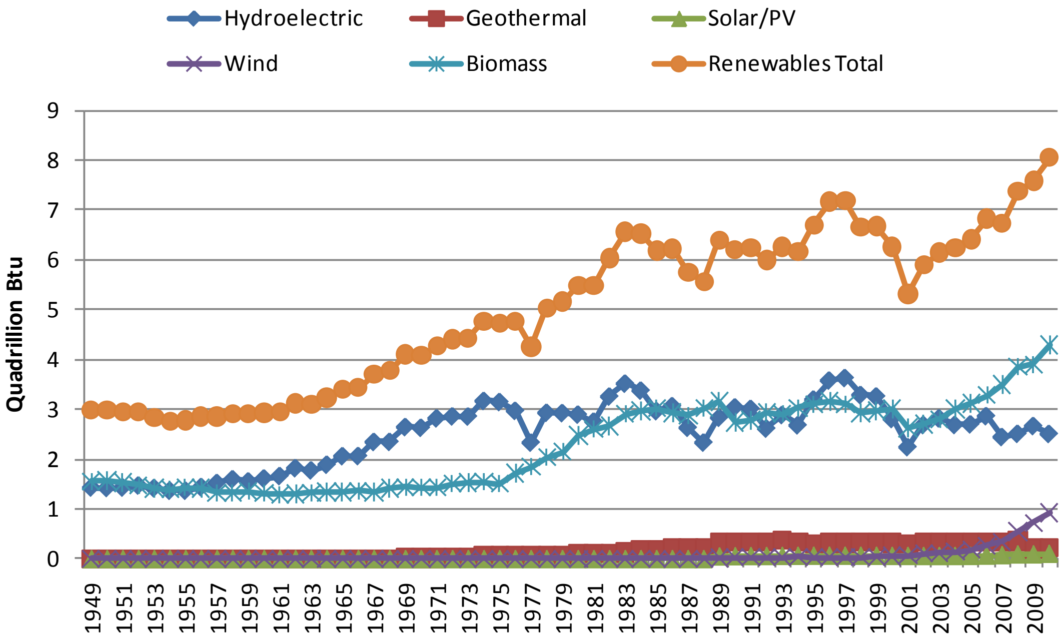


Figure 1-1: Renewable energy consumption in the U.S. (1949-2010) (Data source: EIA [1, 2])

Despite the growth shown in Figure 1-1, renewable energy's share of the total energy consumed in the U.S. remains modest at less than 10 percent. Figure 1-2 shows percentage contributions of renewable resources to the total energy consumed in the U.S. from 1949 to 2010. The share from renewable sources had been on steady decline from a high of 9 percent in 1983 to a low of 6 percent in 2001. With the expansion of corn-ethanol production capacity this share has risen to 8 percent in 2009 and 2010.

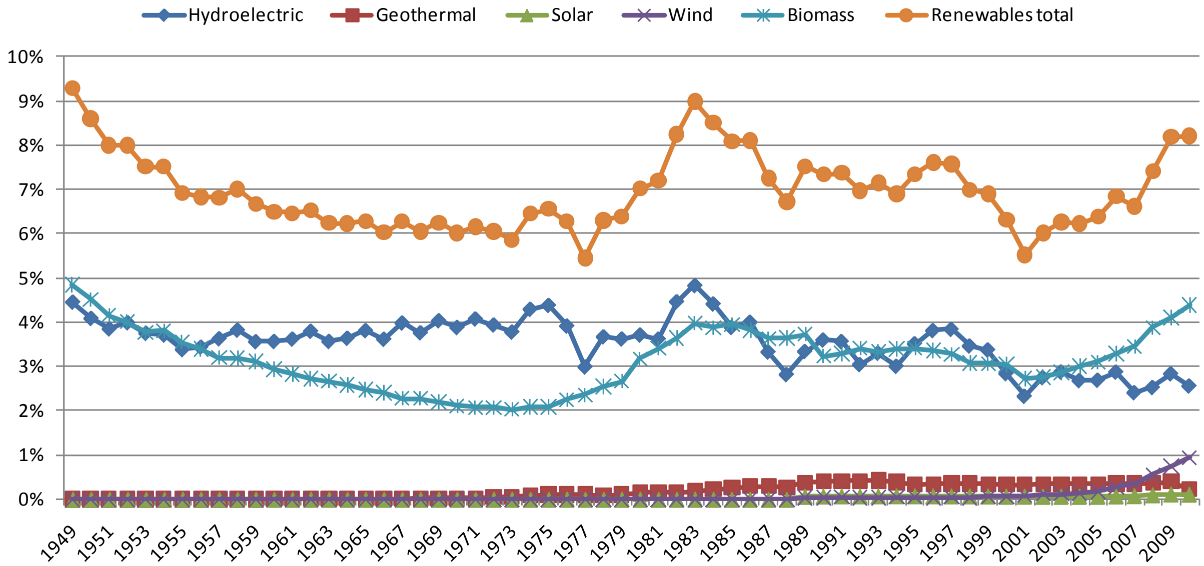


Figure 1-2: U.S. energy consumption by source (1949-2010) (Data source: EIA [1, 2])

Figure 1-3 shows the contribution of the various energy sources to total energy consumed in the U.S. in 2010. Petroleum continues to be the dominant energy source supplying 37 percent, followed by natural gas at 25 percent and coal at 21 percent. Among the renewable resources, biomass (including wood, biofuels, municipal solid waste, landfill gas and others) comprised over half of the renewable energy total, followed by hydroelectricity at 31 percent. Wind power's contribution increased to 11 percent from 9 percent in 2009, geothermal dropped from 5 percent in 2009 to 3 percent, and solar remained at 1 percent.

When one considers renewable resources in electricity generation (Figure 1-4), hydroelectricity plays a dominant role, exceeding all other renewable resources combined. Hydroelectricity makes up 60 percent of the renewable electricity generated. Wind energy takes second place at 22 percent of the renewable electricity and wood biomass takes third place at 9 percent. Waste biomass and geothermal each contributed 4 percent of the electricity generation in 2010 and solar contributes just 0.3 percent despite its rapid growth. As expected pumped hydroelectricity's net energy contribution was negative.[1]

---

[1] Pumped hydroelectric facilities use electricity from the grid during periods of low demand so as to be available to generate electricity during high demand periods. Due to evaporation and inefficiencies in the pumping and generating processes, less energy is generated than is used. The value of the lost energy is more than compensated because low cost, off-peak electricity is converted to high cost, on-peak electricity.

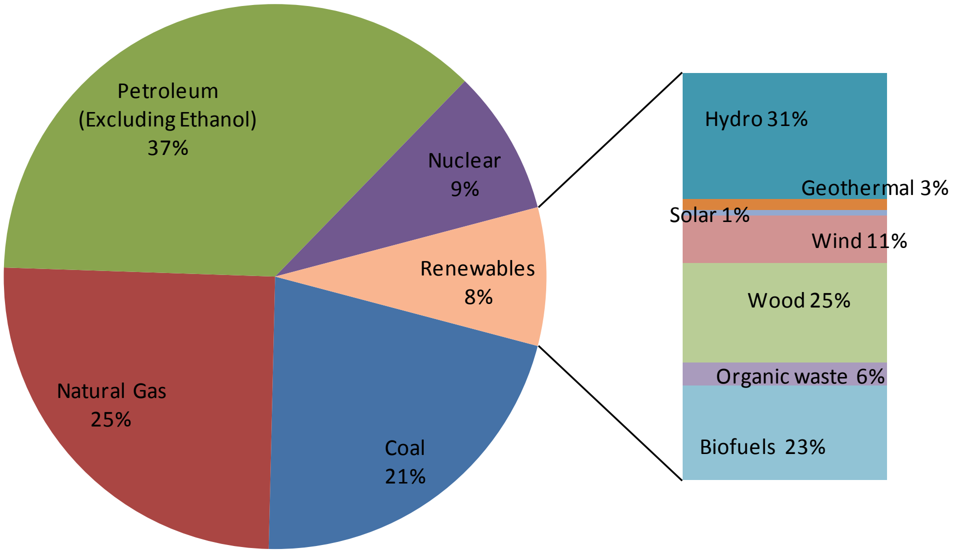


Figure 1-3: U.S. total energy consumption by energy source in 2010 (Data source: EIA [2])

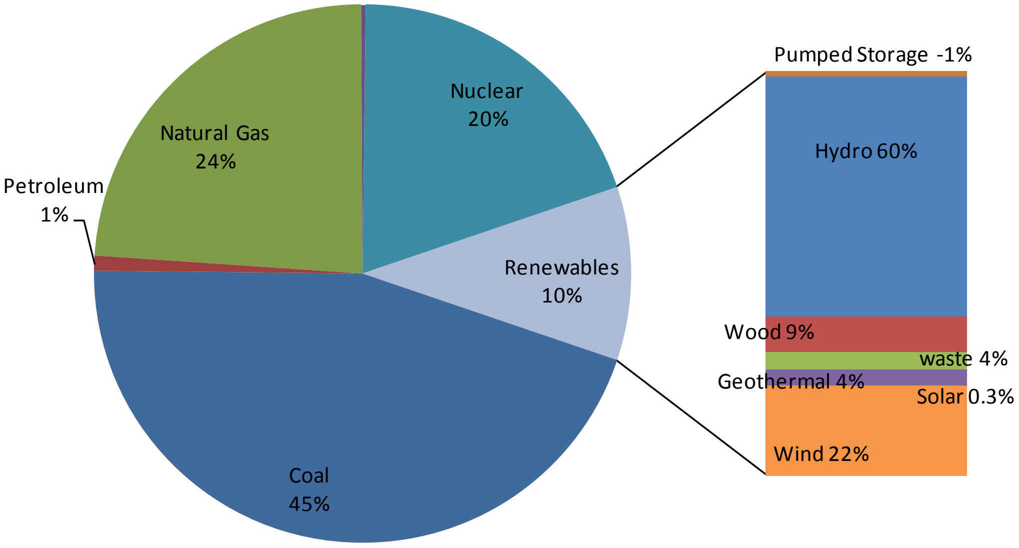


Figure 1-4: Net U.S. electricity generation by energy source in 2010 (Data source: EIA [3])

1.2 Trends in renewable energy consumption in Indiana

Figure 1-5 shows renewable energy consumption in Indiana from 1960 to 2009. In the 1980s, renewable resources contributed over 3 percent of total energy consumed in Indiana. In the 1990s the share fell to below 2 percent, before the recent increase in ethanol and wind increased it to over 4.6 percent. Woody biomass had been the main source of renewable energy in Indiana, contributing over 80 percent of the total renewable energy until the recent rise of corn-based ethanol.

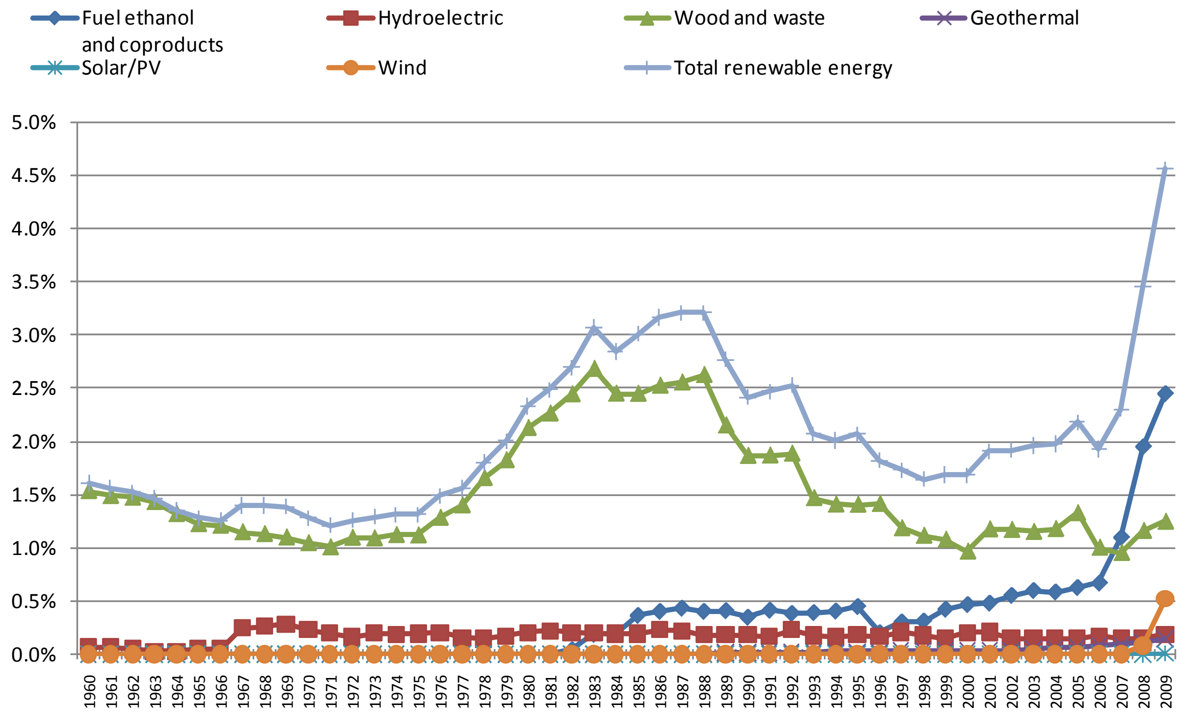


Figure 1-5: Renewables share of Indiana total energy consumption (1960-2009) (Data source: EIA [4])

Figure 1-6 shows the contribution of renewable energy to Indiana's electricity generation from 1990 to 2009. The arrival of utility scale wind energy projects in 2007 caused a rapid increase in renewable energy's share of Indiana's electricity generation. The share changed from a low of 0.5 percent in 2006 to 1.9 percent in 2009. Wind energy's share of the annual generation in 2009 was 1.5 percent and 2.4 percent in 2010 [5]. Hydroelectricity, which until 2007 was the dominant source of renewable electricity, has maintained its share at approximately 0.4 percent.

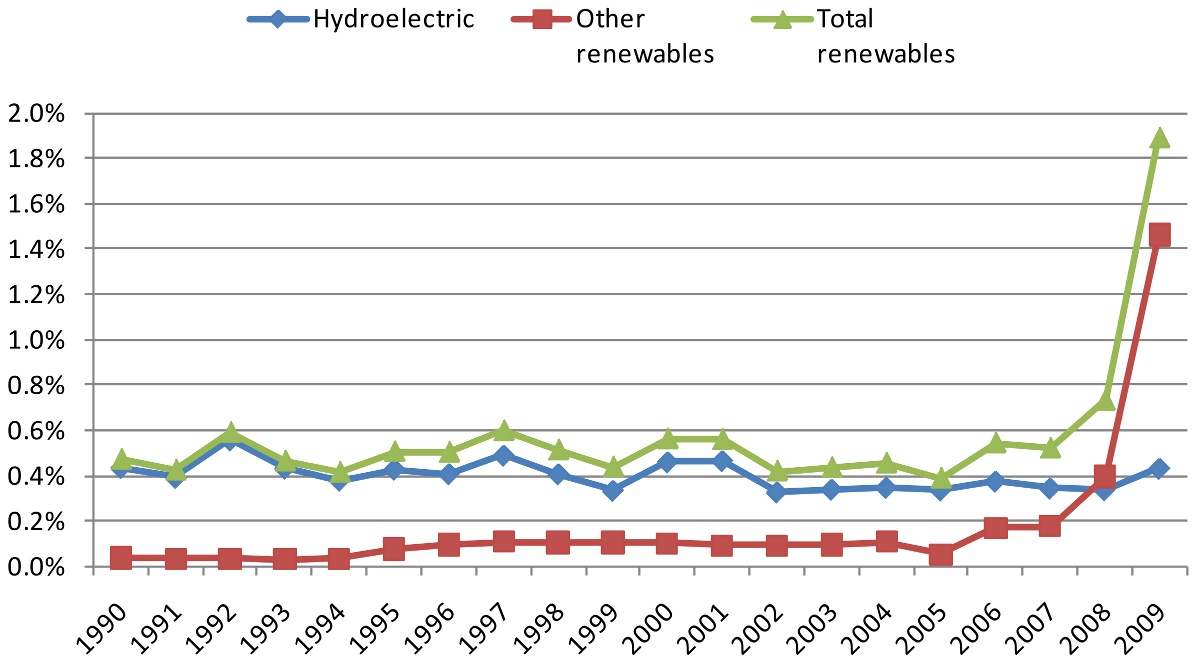


Figure 1-6: Renewables share of Indiana net electricity generation (1990-2009) (Data source: EIA [6])

The rapid growth in Indiana's wind generating capacity has slowed substantially, from a high of 907 MW wind capacity commissioned in 2009 to 301 MW commissioned in 2010. As of the writing of this section of the report, SUFG was not aware of any utility scale wind farm commissioned in 2011. This reduction in wind installation in Indiana is part of a national trend that has been attributed to factors such as

- the delayed impact of the 2008 global financial crisis affecting the availability of capital,
- the reduced demand for electricity and resulting low electricity wholesale prices, and
- the relatively low price of natural gas as a result of the development of shale gas [5].

Figure 1-7 shows the growth in Indiana wind capacity from 2008 to 2010. Three wind farms with a combined capacity of 352 MW had been approved for construction and one 200 MW wind farm was at an advanced stage of the application process at the writing of this report. Indiana utilities had signed agreements to purchase 871 MW of wind generation, 487 MW from wind farms located in Indiana and 384 MW from out of state.

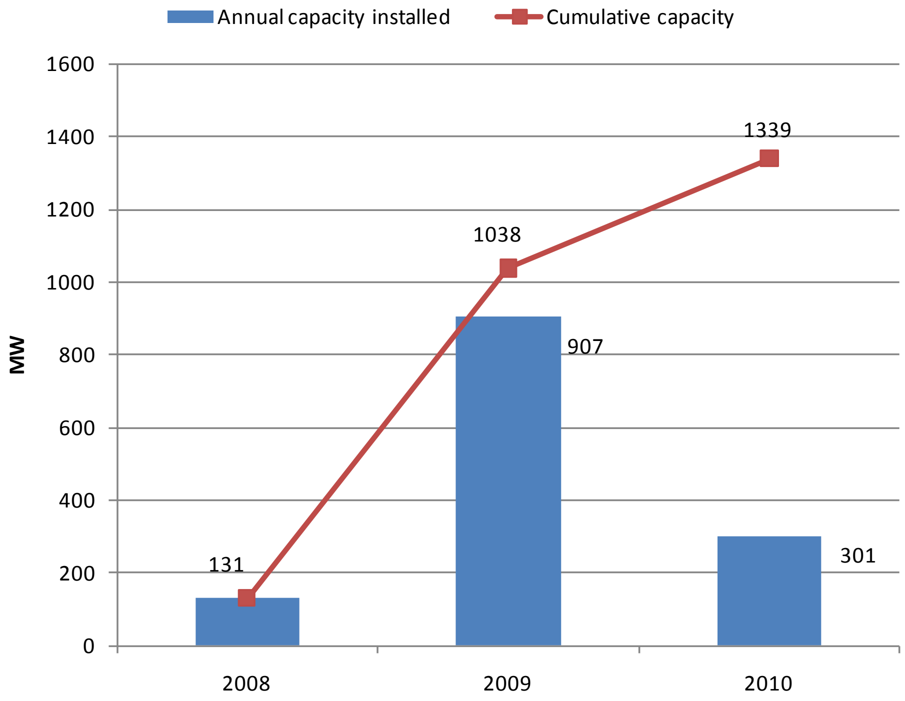


Figure 1-7: Wind energy installed capacity in Indiana (Data source: IURC [7]).

1.3 References

1. Energy Information Administration (EIA). 2009 Annual Energy Review Table 1.3. http://www.eia.doe.gov/emeu/aer/overview.html
2. EIA. April 2011. Monthly Energy Review Table 1.3. http://www.eia.doe.gov/totalenergy/data/monthly/#summary
3. EIA. Renewable. April 2011 Monthly Energy Review, Table 7.2a. http://www.eia.doe.gov/totalenergy/data/monthly/#electricity
4. EIA. State Energy Data System (SEDS) 2008. Released June 2010. http://www.eia.doe.gov/emeu/states/state.html?q_state_a=in&q_state=INDIANA and June 2011 update http://205.254.135.24/state/seds/seds-states.cfm?q_state_a=IN&q_state=Indiana

5. Department of Energy Office of Energy Efficiency and Renewable Energy (EERE). 2010 Wind technologies market report. http://www.windpoweringamerica.gov/pdfs/2010_annual_wind_market_report.pdf
6. EIA. Indiana Electricity Profile Table 5, Release date: April 201. http://www.eia.doe.gov/cneaf/electricity/st_profiles/indiana.html
7. Indiana Utility Regulatory Commission. Personal communication with staff.

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.

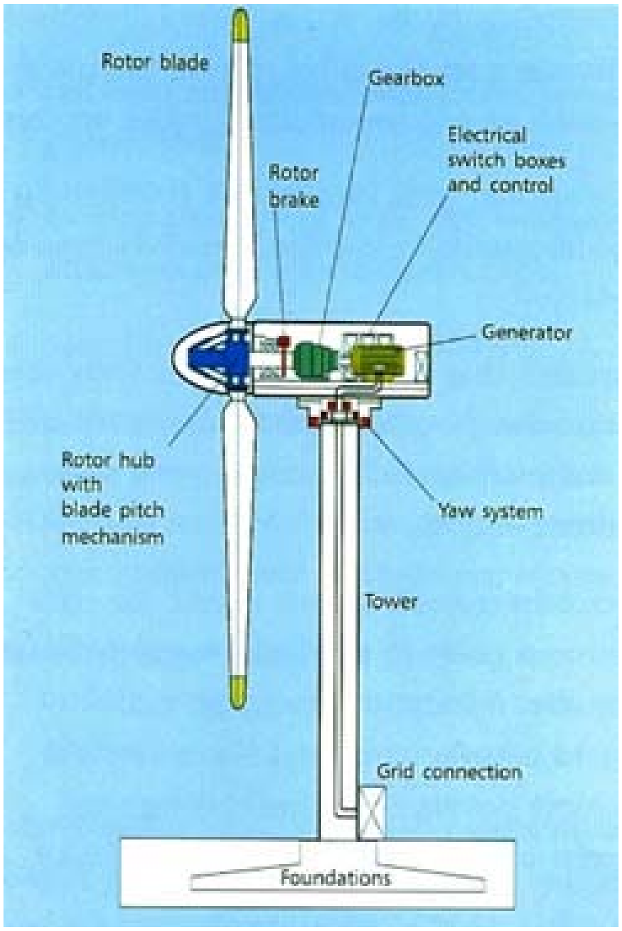


Figure 2-1: Horizontal wind turbine configuration (Source: South Ayrshire Council [1])

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. This has grown steadily to the point where the 1.5 megawatt (MW) wind turbine is common in modern day wind farms [2]. Despite this dramatic increase in size and capacity, a wind farm's generating capacity is still small compared to coal and nuclear power plants. The largest wind farm in the U.S. is the Horse

Hollow Wind Farm in Texas with a name plate capacity of 736 MW [3], while the largest coal power plant in Indiana is composed of five 600 MW units adding up to a plant capacity of 3,000 MW. Furthermore the capacity factor of a wind farm is typically far less than that of a baseload power plant.[2] A baseload coal or nuclear power plant in the U.S. will typically have an annual capacity factor of over 80 percent while the capacity factors of wind farms are estimated to range between 25 and 40 percent, depending on the average annual wind speeds at their location [4].

Wind speeds are important in determining a turbine's performance. Generally, annual average wind speeds of greater than 3 meters per second (m/s), or 7 miles per hour (mph), are required for small electric wind turbines not connected to the grid, whereas utility-scale wind plants require a minimum wind speed of 5 m/s (11 mph). 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 measured in watts per square meter (W/m^2), calculated from annual observed wind speeds and the density of air, is used to classify sites into "wind power classes" [5]. Table 2-1 lists the class distinctions 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	< 100	< 4.4 (9.8)	< 200	< 5.6 (12.5)
2	100 – 150	4.4 – 5.1 (9.8 – 11.5)	200 – 300	5.6 – 6.4 (12.5 – 14.3)
3	150 – 200	5.1 – 5.6 (11.5 – 12.5)	300 – 400	6.4 – 7.0 (14.3 – 15.7)
4	200 – 250	5.6 – 6.0 (12.5 – 13.4)	400 – 500	7.0 – 7.5 (15.7 – 16.8)
5	250 – 300	6.0 – 6.4 (13.4 – 14.3)	500 – 600	7.5 – 8.0 (16.8 – 17.9)
6	300 – 400	6.4 – 7.0 (14.3 – 15.7)	600 – 800	8.0 – 8.8 (17.9 – 19.7)
7	> 400	> 7.0 (15.7)	> 800	> 8.8 (19.7)

Table 2-1: Wind resource classification (Source: AWEA [5])

In addition to its 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

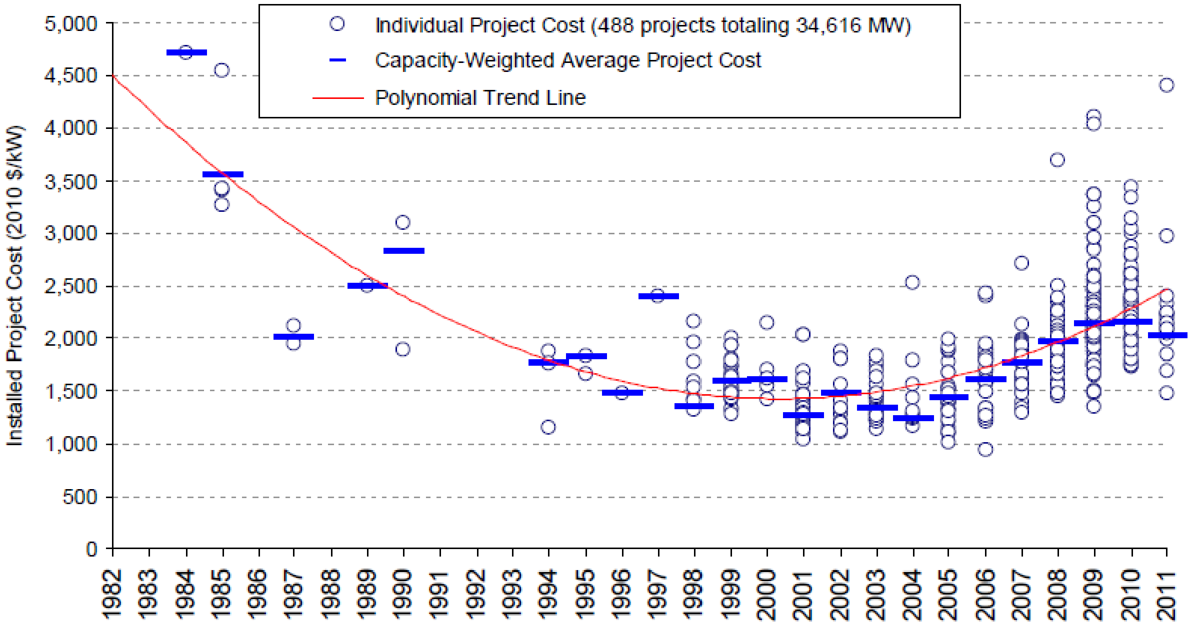
---

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

adjusting the number of turbines on the farm. Wind technology's main disadvantage when compared to traditional fossil fuel generation is that the amount of energy coming out of the turbine is solely dependent on the wind and the electric system operator cannot dispatch it to match the varying demand as is done with traditional generation. Another significant disadvantage 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 and the possibility of turbines causing radar interference.

2.2 Economics of wind energy

Through 2010, the installed cost of wind energy projects continued to follow an upward trend that started in the early 2000s. The $2,155/kW capacity-weighted average costs of projects installed in 2010 was 65 percent higher than the average cost of projects installed from 2001 through 2004. Figure 2-2 shows the trends in the installed projects costs from 1982 to 2010. Nevertheless, the $2,155/kW capacity-weighted average installed cost in 2010 was essentially unchanged from the $2,144/kW in 2009; it is also expected that average installed costs may decline in 2011 [6].

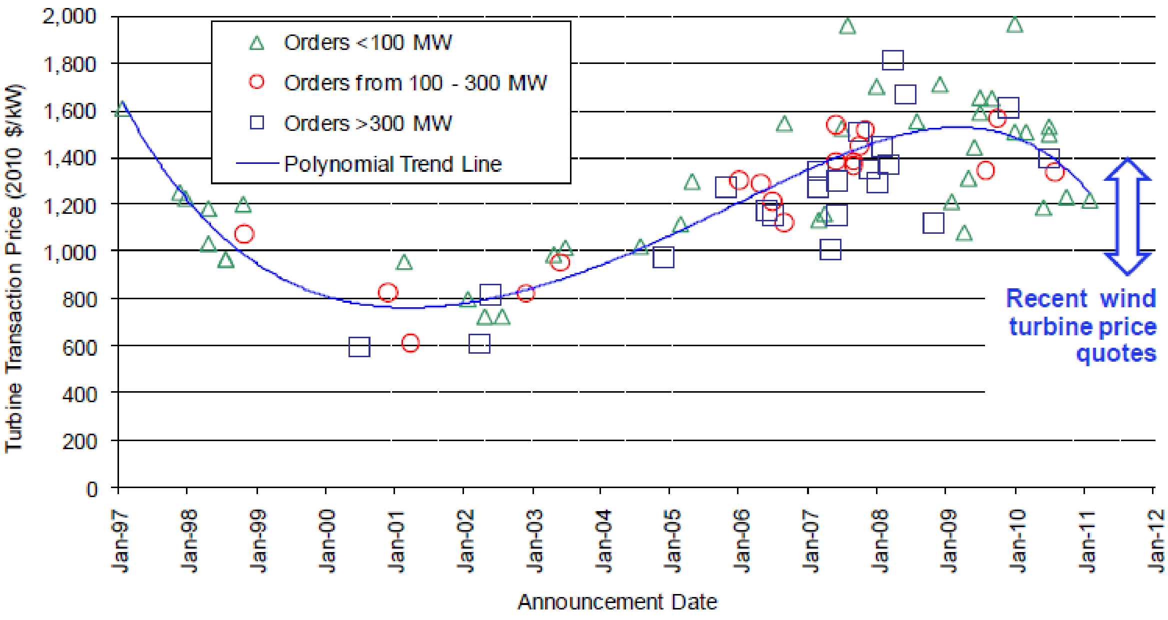


Note: 2011 data represent preliminary cost estimates for a sample of 17 projects totaling 1.1 GW that have either already been or will be built in 2011, and for which reliable cost estimates were available.

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

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

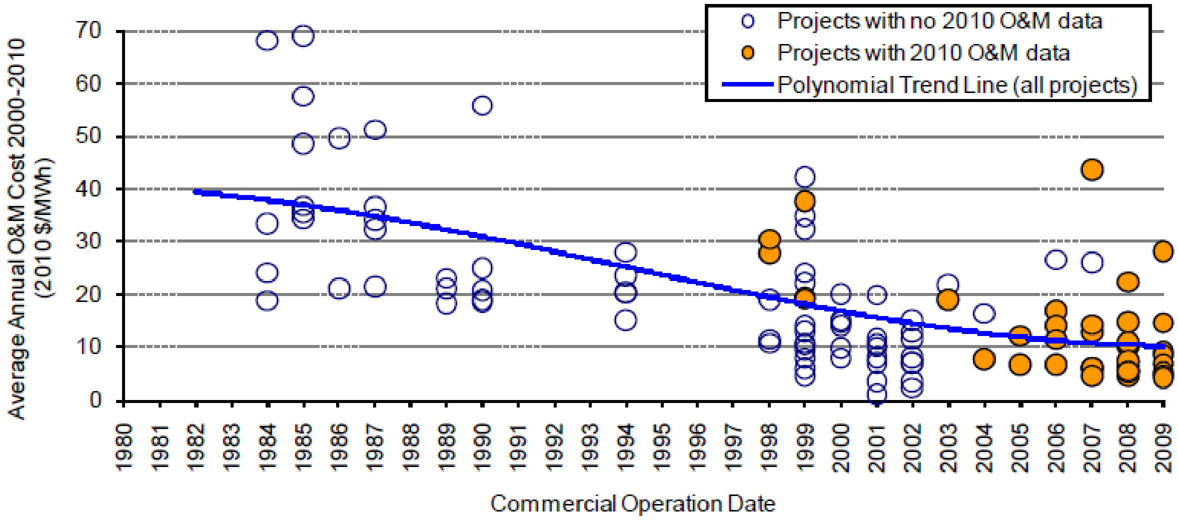
The expected decline in wind farm project costs is already being reflected by a reduction in prices of turbines in the beginning months of 2011. Figure 2-3 shows wind turbine costs over time as calculated for the projects included in the Lawrence Berkeley National Laboratory dataset used in the *2010 Wind Technologies Market Report* [6]. As illustrated in the diagram, turbine prices were in a steady decrease since 2008, when turbine prices achieved their peak. This decline reflected similar declines in energy and commodity prices, and a shift in the supply-demand balance for turbines towards a buyer's market. These price reductions are expected to drive down total project costs and wind power prices.



Source: Berkeley Lab

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

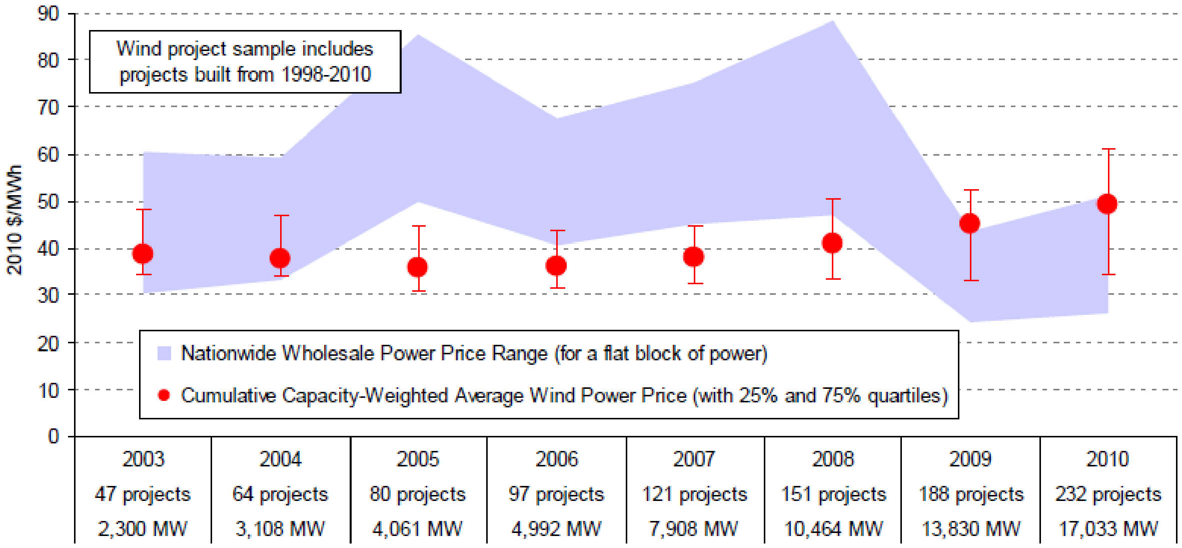
Operation and maintenance (O&M) costs are a significant component of the overall cost of wind energy, but can vary substantially among projects. Figure 2-4 shows O&M costs using data compiled by Berkeley Lab for 126 wind projects installed between 1982 and 2009 with a total capacity of 7,502 MW. It suggests that projects installed recently have incurred lower average O&M costs. Specifically, capacity-weighted average O&M costs for the 24 sampled projects constructed in the 1980s were $33/MWh, which dropped to $22/MWh for the 37 projects installed in the 1990s, and to $10/MWh for the 65 projects installed since 2000 [6].



Source: Berkeley Lab; seven data points suppressed to protect confidentiality

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

Figure 2-5 shows the range of average annual wholesale electricity prices for a flat block of power and the cumulative capacity-weighted average price received by wind power projects in each year from 2003 to 2010. On a cumulative basis, average wind power prices compared favorably to wholesale electricity prices from 2003 through 2008. However, increasing wind power prices combined with a sharp drop in wholesale electricity prices in 2009 (driven by lower natural gas prices and reduced electricity demand), decreased the competitiveness of wind power. Low wholesale electricity prices continued to challenge the relative economics of wind power in 2010 [6].



Source: Berkeley Lab, FERC, Ventyx, ICE

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

2.3 State of wind energy nationally

In 2010 the U.S. wind power industry experienced a significant reduction in new builds compared to both 2008 and 2009. As can be seen in Figure 2-6, the 5,113 MW of new capacity added in 2010 is much lower than the 9,994 MW added in 2009. In 2010 $11 billion were invested in wind power project installations. This level was similar in magnitude to investment in 2007, but just half the investment in 2009 and 40 percent lower than in 2008. Wind power comprised 25 percent of U.S. electric generating capacity additions in 2010; this is down from 42 percent in 2009, 43 percent in 2008, and 34 percent in 2007. The reduced growth in 2010 can be attributed to the following factors [6]:

1. The delayed impact of the global financial crisis affected the capital availability for 2010 projects that were being planned in 2009;
2. The prices of natural gas and wholesale electricity were relatively low, inhibiting the development of merchant projects that were more common in previous years;
3. Slumping overall demand for energy reduced utility demand for wind energy power purchase agreements; and
4. 2009 capacity additions being largely determined by decisions made prior to the global financial crisis, while decisions on 2010 capacity additions were often made at the height of the financial crisis.

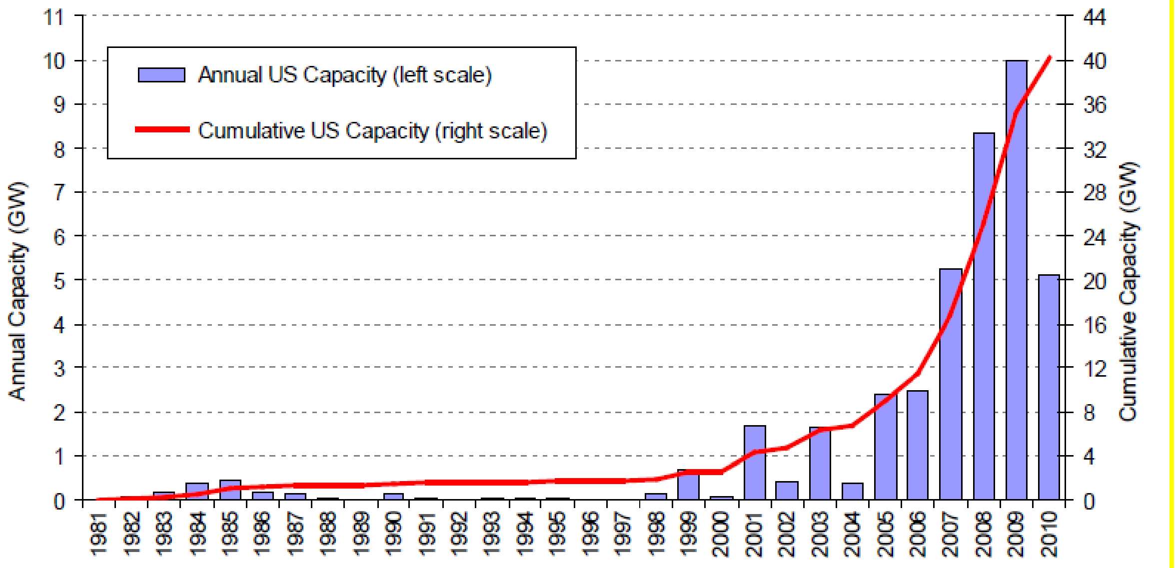


Figure 2-6: Annual capacity additions and cumulative capacity in the U.S. (Source: EERE [6])

Despite the low growth in 2010, cumulative wind power capacity still had a healthy growth of 15 percent in 2010, bringing the total to 40,267 MW. Expectations are for moderately higher capacity additions in 2011 than in 2010, but still below the 2009 level [6]. Continued and expanded federal and state incentives and renewable portfolio standards and goals at the state level played important roles in keeping the wind industry active. Figure 2-7 is a map showing the states that have enacted some form of renewable portfolio standard or set a non-binding goal.

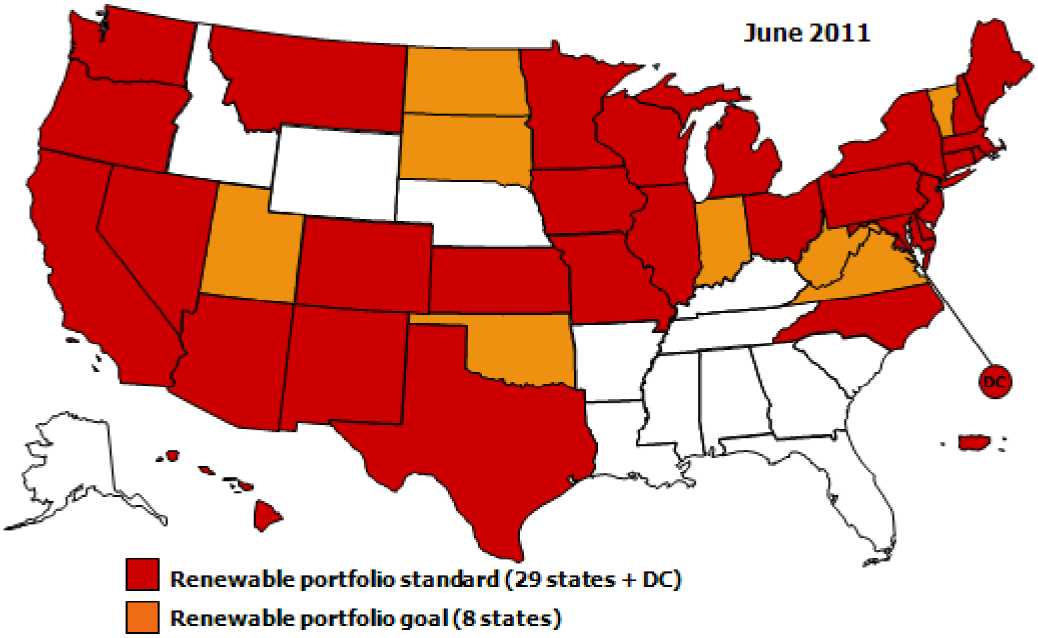
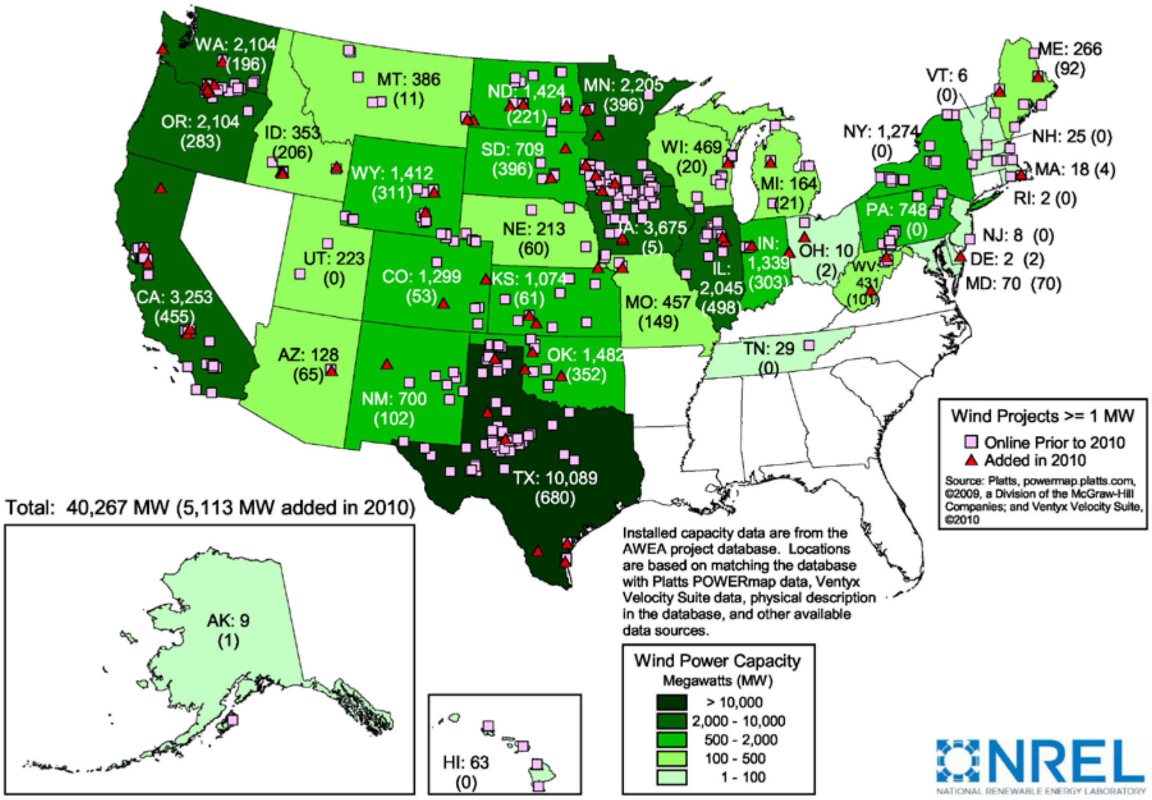


Figure 2-7: Renewable portfolio standards across the U.S. (Source: DSIRE[7])

Figure 2-8 shows the cumulative capacity of wind energy installed in states as of the end of 2010. Texas continued to lead with a total capacity of 10,089 MW installed, which is the first state to exceed the 10 GW milestone. Texas also led in terms of new wind power capacity, with 680 MW installed in 2010, but this figure is much lower than the 2,292 MW installed in 2009 and 2,671 MW installed in 2008. The other top five states in terms of cumulative capacity were Iowa – 3,675 MW; California – 3,253; Minnesota – 2,205; and Washington/Oregon – 2,104. Indiana's place as a wind energy state has changed dramatically, from having no utility-scale wind project in 2007 to being ranked 11th nationally with an installed capacity of 1,339 MW at the end of 2010.

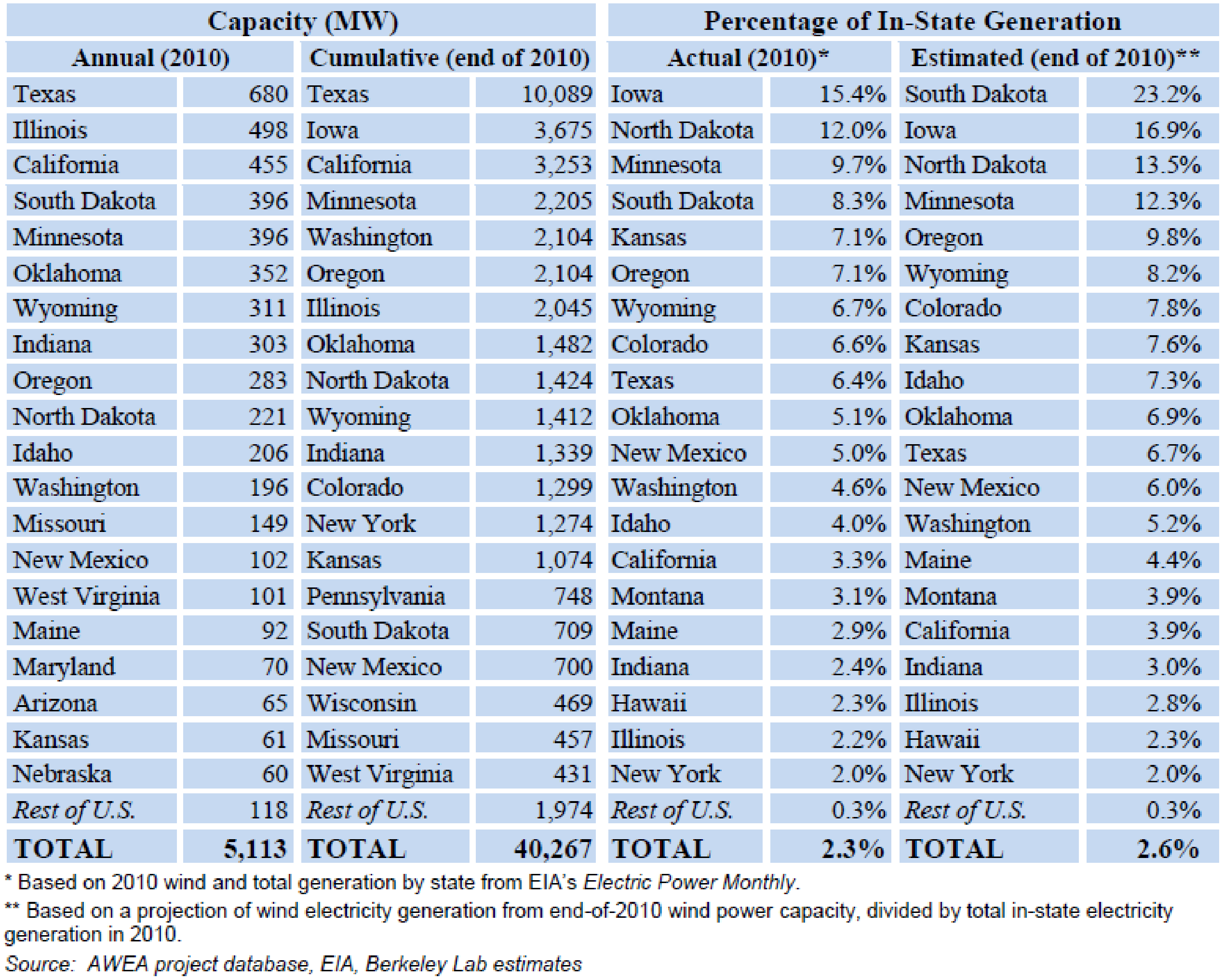


Source: Platts, powermap.platts.com, ©2009, a Division of the McGraw-Hill Companies; and Ventyx Velocity Suite, ©2010

Installed capacity data are from the AWEA project database. Locations are based on matching the database with Platts POWERmap data, Ventyx Velocity Suite data, physical description in the database, and other available data sources.

Figure 2-8: Wind power capacity by state at the end of 2010 (MW) (Source: EERE [6])

With regard to the penetration of wind energy as a percent of the total electricity generated in 2010, Texas dropped to ninth place with 6.4 percent. The leading five states in wind energy penetration in 2010 are Iowa –15.4 percent; North Dakota – 12 percent; Minnesota – 9.7 percent; South Dakota – 8.3 percent; and Kansas – 7.1 percent. Table 2-2 shows the top twenty states in capacity added in 2010, total cumulative capacity, actual and estimated penetration of wind energy in 2010. Indiana's wind penetration ranks 17th nationally at 2.4 percent of total in-state electricity generation, which is slightly above the U.S. average of 2.3 percent.



Capacity (MW)				Percentage of In-State Generation			
Annual (2010)		Cumulative (end of 2010)		Actual (2010)*		Estimated (end of 2010)**	
Texas	680	Texas	10,089	Iowa	15.4%	South Dakota	23.2%
Illinois	498	Iowa	3,675	North Dakota	12.0%	Iowa	16.9%
California	455	California	3,253	Minnesota	9.7%	North Dakota	13.5%
South Dakota	396	Minnesota	2,205	South Dakota	8.3%	Minnesota	12.3%
Minnesota	396	Washington	2,104	Kansas	7.1%	Oregon	9.8%
Oklahoma	352	Oregon	2,104	Oregon	7.1%	Wyoming	8.2%
Wyoming	311	Illinois	2,045	Wyoming	6.7%	Colorado	7.8%
Indiana	303	Oklahoma	1,482	Colorado	6.6%	Kansas	7.6%
Oregon	283	North Dakota	1,424	Texas	6.4%	Idaho	7.3%
North Dakota	221	Wyoming	1,412	Oklahoma	5.1%	Oklahoma	6.9%
Idaho	206	Indiana	1,339	New Mexico	5.0%	Texas	6.7%
Washington	196	Colorado	1,299	Washington	4.6%	New Mexico	6.0%
Missouri	149	New York	1,274	Idaho	4.0%	Washington	5.2%
New Mexico	102	Kansas	1,074	California	3.3%	Maine	4.4%
West Virginia	101	Pennsylvania	748	Montana	3.1%	Montana	3.9%
Maine	92	South Dakota	709	Maine	2.9%	California	3.9%
Maryland	70	New Mexico	700	Indiana	2.4%	Indiana	3.0%
Arizona	65	Wisconsin	469	Hawaii	2.3%	Illinois	2.8%
Kansas	61	Missouri	457	Illinois	2.2%	Hawaii	2.3%
Nebraska	60	West Virginia	431	New York	2.0%	New York	2.0%
Rest of U.S.	118	*Rest of U.S.*	1,974	*Rest of U.S.*	0.3%	*Rest of U.S.*	0.3%
TOTAL	**5,113**	**TOTAL**	**40,267**	**TOTAL**	**2.3%**	**TOTAL**	**2.6%**

* Based on 2010 wind and total generation by state from EIA's *Electric Power Monthly*.

** Based on a projection of wind electricity generation from end-of-2010 wind power capacity, divided by total in-state electricity generation in 2010.

Source: AWEA project database, EIA, Berkeley Lab estimates

Table 2-2: U.S. wind power rankings: Top 20 states (Data source: EERE [6])

Access to transmission continued to be a major issue in wind energy development since the most abundant on shore wind energy resource is in the Great Plains (Figure 2-9) and distant from the major population centers along the coasts. Although Figure 2-9 does not show it, the wind resources off the coasts are typically better than onshore winds, with higher wind speeds that are steadier and with less ground level interference. To date, no offshore projects have been installed in the United States, but interest in developing offshore wind energy exists in several parts of the country. The U.S. Department of the Interior (DOI) signed a Memorandum of Understanding (MOU) with the governors of 10 coastal states in June 2010 forming the Atlantic Offshore Wind Energy Consortium, to facilitate the coordination of offshore development off the East Coast. Also, DOI's Bureau of Ocean Energy Management, Regulation, and Enforcement formed renewable energy task forces in several coastal states to facilitate offshore wind project development. There are nine proposed offshore wind projects with capacity of 2,322 MW that have made significant advances in the permitting and development process in the U.S. [6]

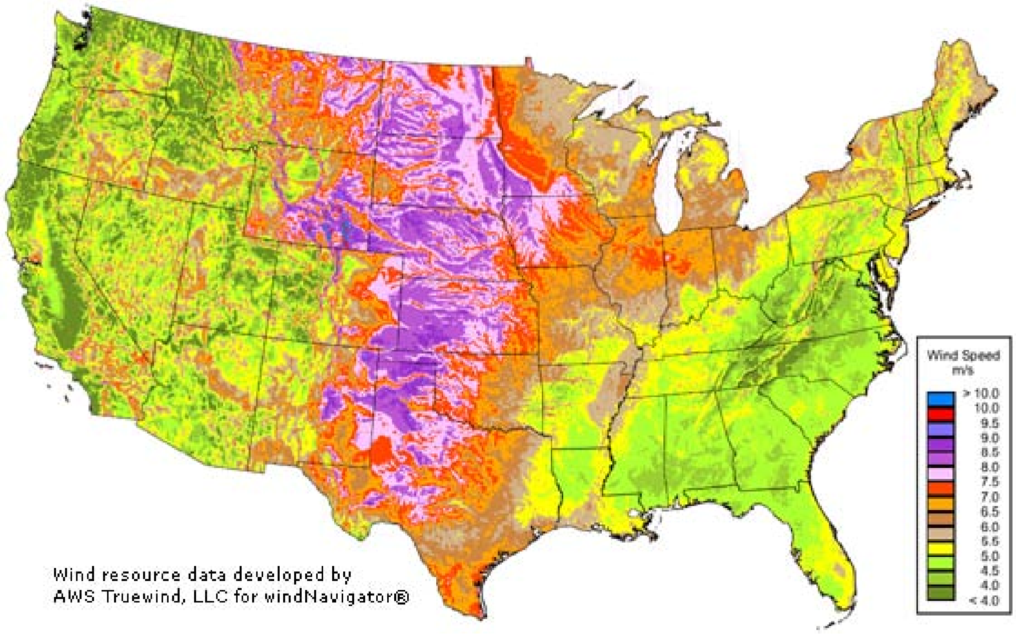
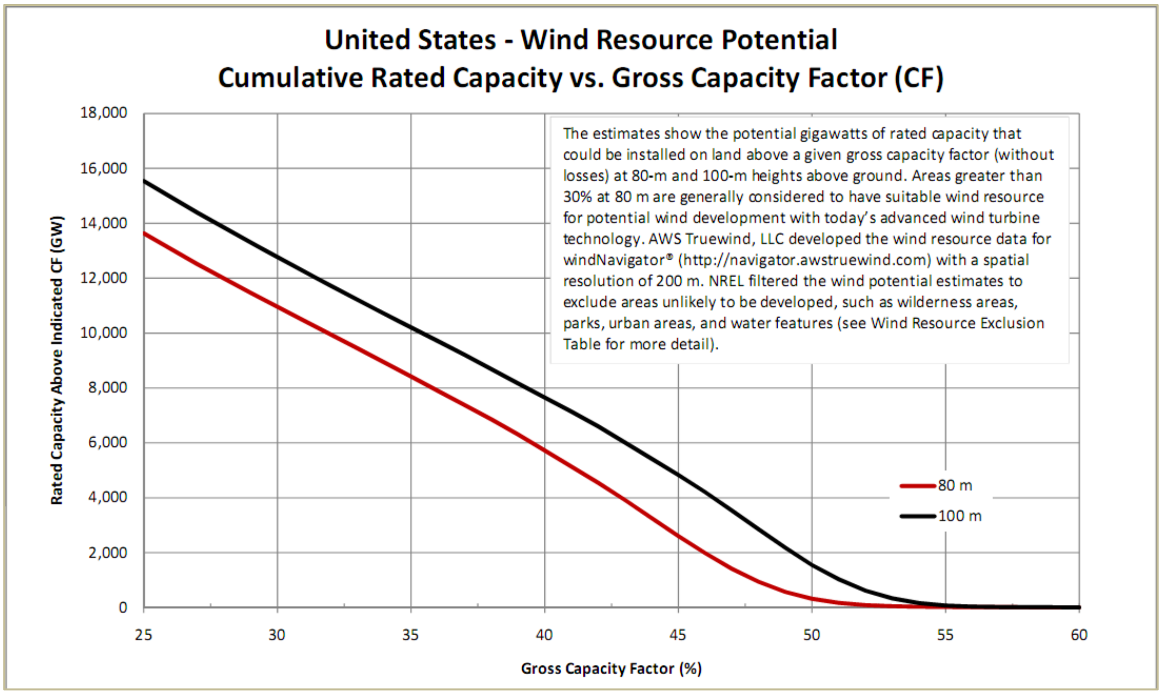


Figure 2-9: 80-meter onshore wind resource map (Source: EERE [8]

The U.S. has significant wind energy potential. Areas with gross capacity factor (without loss) greater than 30 percent at 80-meter height are generally considered as windy land areas, which have suitable wind resource for potential wind development with today's advanced wind turbine technology. National Renewable Energy Laboratory (NREL) estimated that the potential rated capacity that could be installed on available windy land areas across U.S. is 10,956,912 MW, and the annual wind energy that could be generated from these potential installed capacities is 38,552,706 GWh. Current installed capacity of the entire U.S. is only 40,267 MW [6], indicating potential for additional wind energy. Figure 2-10 shows the potential gigawatts of rated capacity above a given gross capacity factor (without losses) at 80-meter and 100-meter heights above ground [8].

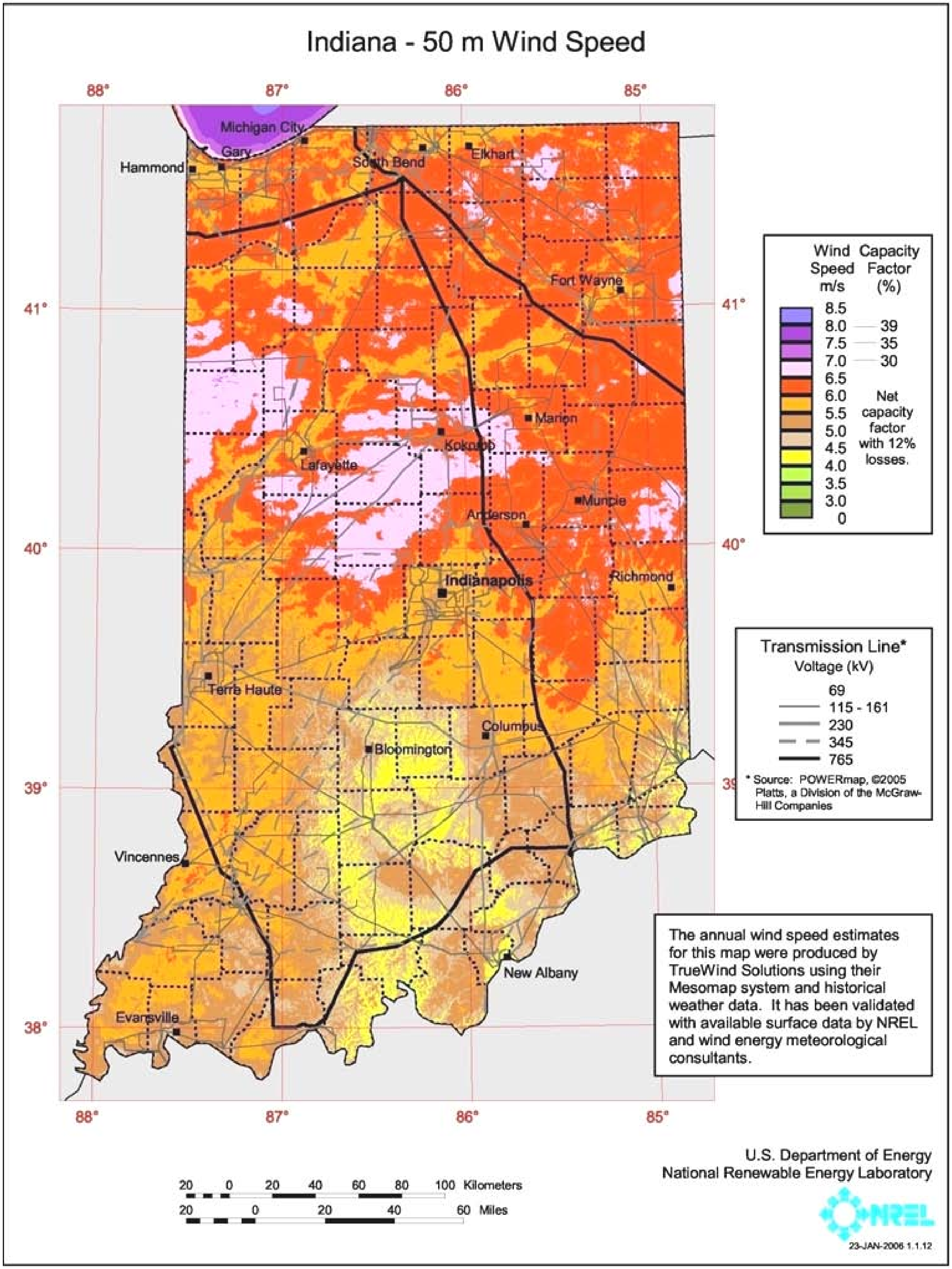


The estimates show the potential gigawatts of rated capacity that could be installed on land above a given gross capacity factor (without losses) at 80-m and 100-m heights above ground. Areas greater than 30% at 80 m are generally considered to have suitable wind resource for potential wind development with today's advanced wind turbine technology. AWS Truewind, LLC developed the wind resource data for windNavigator® (http://navigator.awstruewind.com) with a spatial resolution of 200 m. NREL filtered the wind potential estimates to exclude areas unlikely to be developed, such as wilderness areas, parks, urban areas, and water features (see Wind Resource Exclusion Table for more detail).

Figure 2-10: U.S. wind resource potential chart (Source: NREL [8])

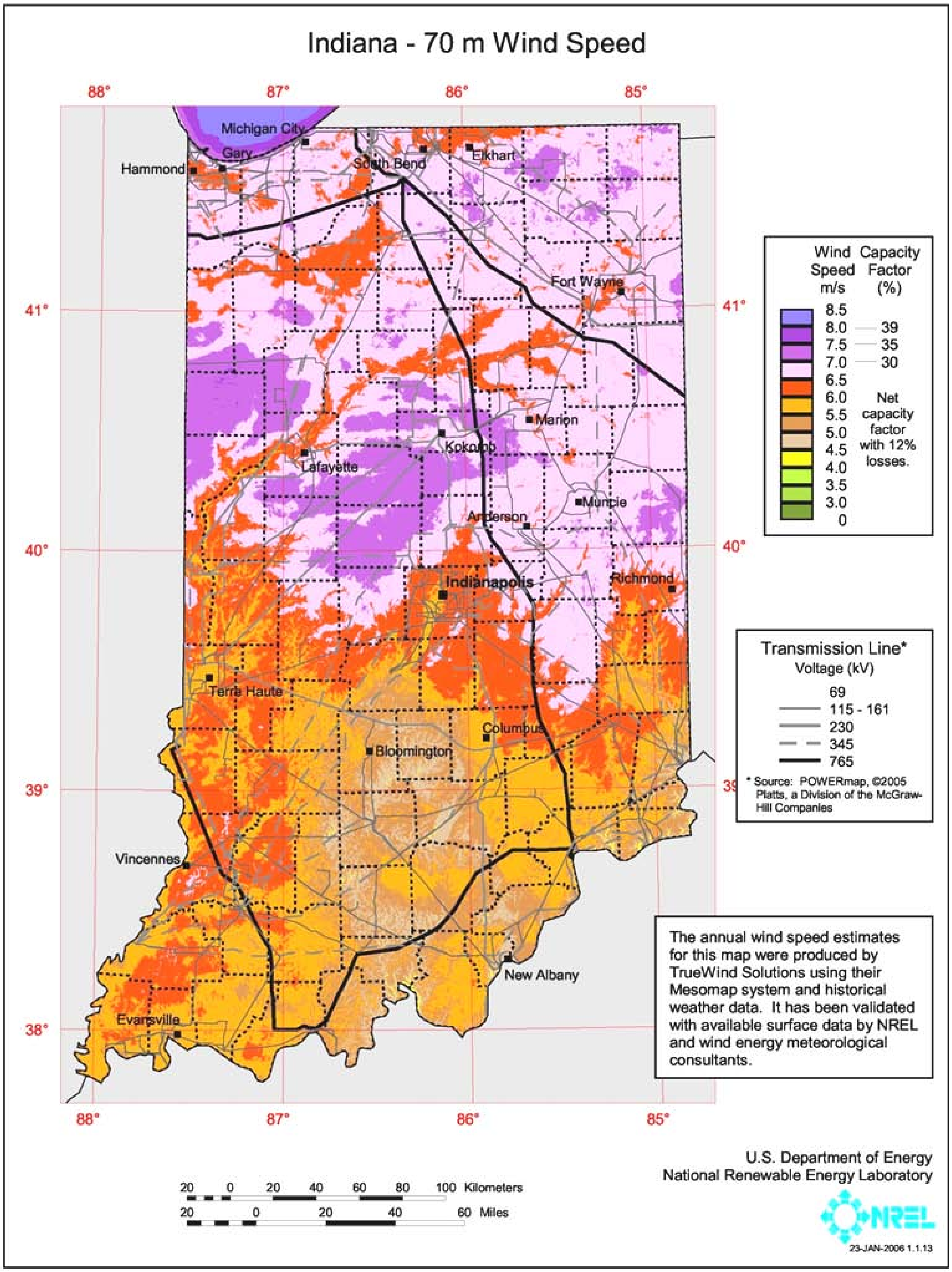
2.4 Wind energy in Indiana

Indiana has roughly two wind regions, with the northern half having class 2 winds (12.5 – 14.3 mph at a height of 50 meters) and the southern half having class 1 winds (0 – 12.5 mph). Figures 2-11through 2-13 show the wind energy distribution in Indiana at 50, 70 and 100 meters, respectively [9]. The higher altitude wind maps indicate that wind speeds are significantly faster farther up. For instance, much of northern Indiana experiences class 4 or better winds at 100 meters. The total wind resource in the entire state is 148,288 MW at 80 meters [10].



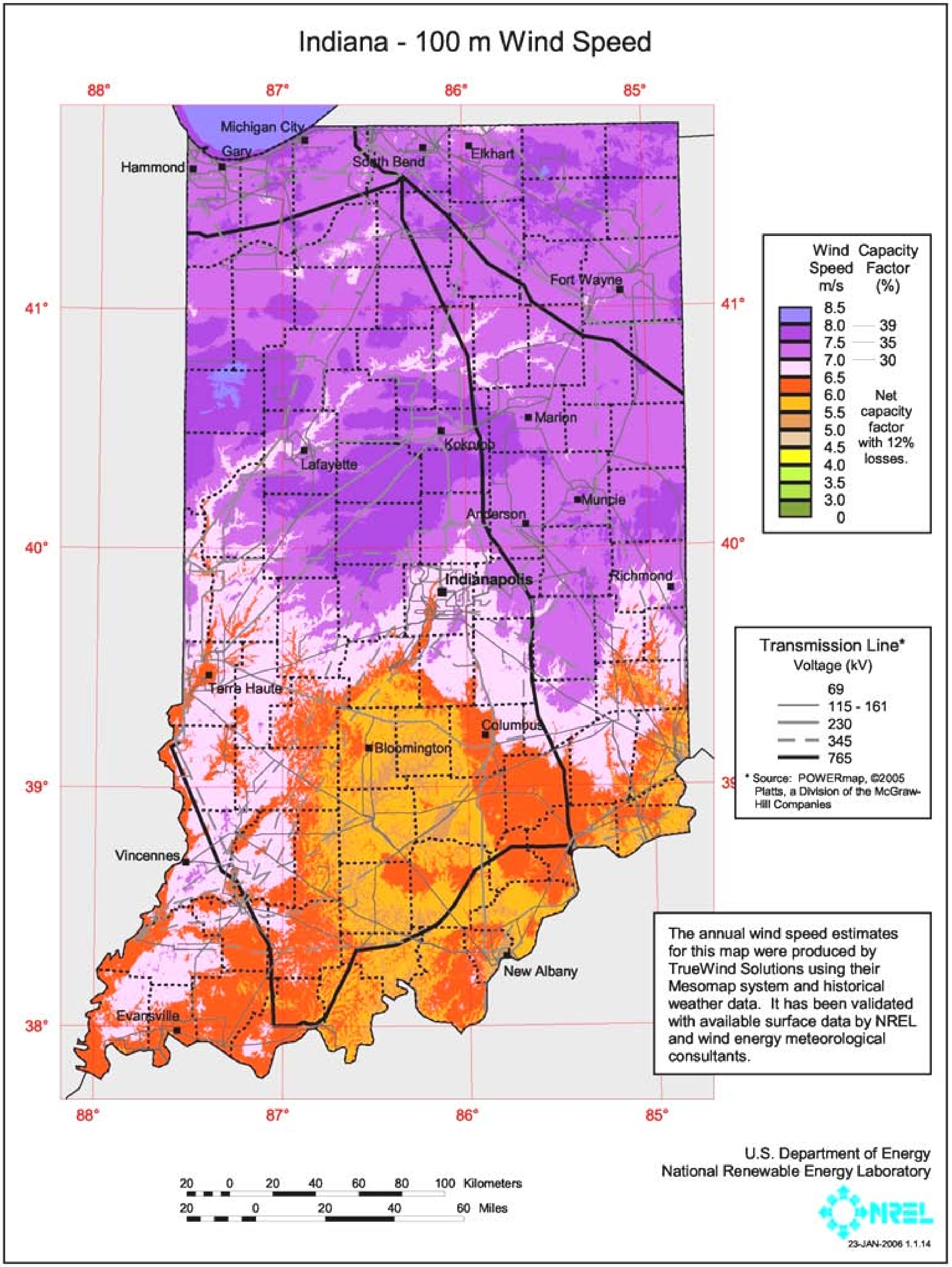
The annual wind speed estimates for this map were produced by TrueWind Solutions using their Mesomap system and historical weather data. It has been validated with available surface data by NREL and wind energy meteorological consultants.

Figure 2-11: Indiana wind speed at 50 meters height (Source: OED/NREL [9])



The annual wind speed estimates for this map were produced by TrueWind Solutions using their Mesomap system and historical weather data. It has been validated with available surface data by NREL and wind energy meteorological consultants.

Figure 2-12: Indiana wind speed at 70 meters height (Source: OED/NREL [9])



The annual wind speed estimates for this map were produced by TrueWind Solutions using their Mesomap system and historical weather data. It has been validated with available surface data by NREL and wind energy meteorological consultants.

Figure 2-13: Indiana wind speed at 100 meters height (Source: OED/NREL [9])

Indiana wind energy generation capacity has grown rapidly from only 20 kW grid connected capacity before 2007 to the 1,339 MW by the end of 2010. The first utility wind project in Indiana was the Benton County Wind Farm completed in 2008. The most rapid growth was in 2009 with 908 MW of capacity commissioned. This consisted of 600 MW for the first phases of the Fowler Ridge Wind Farm in Benton County, 200 MW of the first phase of Meadow Lake Wind Farm in White County, 106 MW of Hoosier Wind Farm in Benton County and a 2 MW project at the Randolph Eastern School Corporation. The pace of construction dropped to 301 MW in 2010, and as of July no utility scale wind farm had been commissioned in 2011. Four wind farm projects with a total capacity of 552 MW had successfully completed the approval process for construction. They include continuing phases of the Fowler Ridge and Meadow Lake projects, a 101 MW project in Newton County and a 200 MW project in Tipton and Madison Counties. Table 2-3 shows the status of the various Indiana wind farm projects.

Project Name	County	Capacity (MW)	Developer	Date Completed	Power Purchaser
Benton County Wind Farm	Benton	131	Orion	May 2008	Duke (101 MW) Vectren (30 MW)
Fowler Ridge Wind Farm 1	Benton	301	BP / Dominion	March 2009	I&M (100 MW), Dominion (201 MW)
Fowler Ridge Wind Farm IIA	Benton	200	BP / Sempra	December 2009	AEP (50x3 MW), Vectren (50 MW)
Fowler Ridge Wind Farm III	Benton	99	BP / Sempra	February 2009	AEP Appalachian (99 MW)
Hoosier Wind Project	Benton	106	enXco	November 2009	IPL (106 MW)
Union City/Randolph Eastern School Corporation	Randolph	2	Operated by Performance Services Corporation	2009	
Meadow Lake Phase I	White	200	Horizon (EDP)	October 2009	Wholesale market COMED (50 MW)
Meadow Lake Phase IIA	White	99	Horizon (EDP)	September 2010	Wholesale market COMED (25 MW) Ameren (25 MW)
Meadow Lake Phase III	White	104	Horizon (EDP)	September 2010	Wholesale market Ameren (25 MW)

Approved or under construction

Spartan Wind Farm 1	Newton	101	Duke Generation Services		Wholesale market
Wildcat Wind Farm 1	Tipton & Madison	200	E.ON Climate & Renewables		Wholesale market
Meadow Lake Phase V	White	101	Horizon (EDP)		Wholesale market
Fowler Ridge IIB	Benton	150	Dominion / BP		Wholesale market

Table 2-3: Status of wind generation projects in Indiana (Data source: IURC [11])

Indiana utilities have signed power purchase agreements to purchase electricity from these wind farms and from wind farms outside Indiana as shown in Table 2-4.

Utility	Project	State	Power Purchase Agreement (MW)
Duke Energy	Benton County Wind Farm	Indiana	100
Vectren	Benton County Wind Farm	Indiana	30
Vectren	Fowler Ridge Wind Farm 2	Indiana	50
Indiana Michigan	Fowler Ridge Wind Farm 1	Indiana	100
Indiana Michigan	Meadow Lake Wind Farm	Indiana	50
NIPSCO	Buffalo Ridge	South Dakota	50
NIPSCO	Barton Windpower	Iowa	50
IPL	Hoosier Wind	Indiana	106
IPL	Lakefield Wind	Minnesota	201
WVPA	AgriWind	Illinois	8
IMPA	Crystal Lake Wind	Iowa	50

Table 2-4: Wind energy purchase agreements by Indiana utilities (Data source: IURC [11])

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 2.2 cents/kWh during the first ten years of operation. The PTC was modified in the February 2009 American Recovery and Reinvestment Act to allow producers who would qualify for the PTC to opt to take the federal business energy investment tax credit (ITC) or equivalent cash grant from the U.S. Department of Treasury (Renewable Energy Grants: 30 percent of property that is part of a qualified small wind property) [7].

- Business Energy Investment Tax Credit (ITC) credits up to 30 percent of expenditures with no maximum credit on qualifying wind energy installations (small wind turbines placed in service after December 31, 2008). Eligible small wind property includes wind turbines up to 100 kW in capacity [7].
- Renewable Energy Production Incentive (REPI) provides financial incentives similar to the Production Tax Credit to wind generators owned by not-for-profit groups, public-owned utilities and other such organizations. REPI payments are subject to availability of annual appropriations by Congress [7].
- Residential Renewable Energy Tax Credit allows taxpayers to claim 30 percent of their qualifying expenditures on installation of small wind-energy systems for the dwelling in which they reside. The maximum credit is $500 per 0.5 kW, not to exceed $4,000, for systems placed in service in 2008; there is no maximum credit for systems placed in service after 2008 [7].
- Modified Accelerated Cost-Recovery System (MACRS): This program allows businesses to recover investments in qualified solar, wind and geothermal property through depreciation deductions. For property acquired and placed in service after September 8, 2010 and before January 1, 2012, the allowable first year deduction is 100 percent of the adjusted basis. For property placed in service from 2008 to 2012, for which the placed in service date does not fall within this window, the allowable first-year deduction is 50 percent of the adjusted basis [7].
- Qualified Energy Conservation Bonds (QECBs) are tax credit bonds to qualified energy conservation projects, which are not subject to the U.S. Department of Treasury application process and instead are allocated to each state based upon its percentage of the U.S. population. The states are then required to allocate a certain percentage to “large local governments (i.e., municipalities and counties with populations of 100,000 or more)”. Qualified energy conservation projects include energy efficiency capital expenditures in public buildings; green community programs; renewable energy production; various research and development applications; mass commuting facilities that reduce energy consumption; several types of energy related demonstration projects; and public energy efficiency education campaigns [7].
- Energy Efficiency Mortgage can be used by homeowners to finance a variety of energy efficiency measures, including renewable energy technologies, in a new or existing home. The federal government supports these loans by insuring them through FHA or VA programs. This allows borrowers who might otherwise be denied loans to pursue energy efficient improvements [7].
- Rural Energy for America Program (REAP) promotes energy efficiency and renewable energy for agricultural producers and rural small businesses through the use of (1) grants and loan guarantees for energy efficiency improvements and renewable energy systems, and (2) grants for energy audits and renewable energy development assistance. The program

covers up to 25 percent of costs. Congress has allocated funding for the new program in the following amounts: $60 million for FY 2010, $70 million for FY 2011, and $70 million for FY 2012 [7].

- High Energy Cost Grant Program administered by the U.S. Department of Agriculture (USDA) is aimed at improving the electricity supply infrastructure in rural areas having home energy costs exceeding 275 percent of the national average. Eligible infrastructure includes renewable resources generation. The USDA has allocated a total of $15.5 million for the 2010 funding cycle. The individual grants range from $75,000 to $5 million [12].

Indiana Incentives

- Net metering rule: Renewable resource facilities with a maximum capacity of 1 MW are qualified for net metering. The net excess generation is credited to the customer in the next billing cycle [7].
- Renewable Energy Property Tax Exemption: provides property tax exemptions for solar thermal, wind, hydroelectric and geothermal systems [7].
- Emissions Credits: Electricity generators that do not emit nitrogen oxides (NO_x) and that displace utility generation are eligible to receive NO_x emissions credits under the Indiana Clean Energy Credit Program [13].
- Clean Energy Portfolio Standard (CPS) passed in May 2011 sets a voluntary goal of 4 percent between 2013 and 2018, 7 percent between 2019 and 2024, and 10 percent clean energy by 2025, based on 2010 retail sales. Participation in CPS makes utilities eligible for incentives in order to pay for the compliance projects [7].
- Indianapolis Power & Light Co. – Rate REP Renewable Energy Production: IPL is offering a "feed-in tariff" to facilities that produce renewable energy. IPL can purchase renewable energy and contract the production for up to 10 years. Compensation for small wind facilities is $0.14/kWh and for large wind facilities is $0.075/kWh [7].
- Northern Indiana Public Service Company: The NIPSCO feed-in tariff offers incentive rates for electricity generated from renewable resources. The payments for electricity from wind generating facilities are $0.17/kWh for facilities with a capacity less than 100 kW and $0.10/kW for facilities with capacities between 100 and 2,000 kW. The renewable tariff is an experimental tariff running until December 31, 2013. The generating unit size allowed under the tariff is between 5 and 5,000 kW while the total allowed system-wide capacity is 30 MW. Five hundred kilowatts of the system-wide cap is reserved for wind projects of capacity less than 10 kW [14].

2.6 References

1. South Ayrshire Council, United Kingdom. http://www.south-ayrshire.gov.uk/images/wind_turbine_drawing.jpg
2. Wind Powering America. NREL. Wind energy update, April 2011. http://www.windpoweringamerica.gov/pdfs/wpa/wpa_update.pdf
3. American Wind Energy Association (AWEA). http://archive.awea.org/newsroom/releases/Annual_US_Wind_Power_Rankings_041107.html
4. AWEA. Wind energy basics. http://archive.awea.org/faq/wwt_basics.html
5. AWEA. Basic principles of wind resource evaluation. http://archive.awea.org/faq/basicwr.html
6. Department of Energy Office of Energy Efficiency and Renewable Energy (EERE). 2010 Wind technologies market report. http://www.windpoweringamerica.gov/pdfs/2010_annual_wind_market_report.pdf
7. Database of State Incentives for Renewables & Efficiency (DSIRE). http://www.dsireusa.org/
8. EERE. Wind resource potential. http://www.windpoweringamerica.gov/wind_maps.asp
9. Indiana Office of Energy Development. Indiana Wind Maps & Reports., http://www.in.gov/oed/2425.htm
10. AWEA. Wind energy facts: Indiana. http://www.awea.org/learnabout/publications/upload/1Q-11-Indiana.pdf
11. George Stevens. Indiana Utility Regulatory Commission.
12. U.S. Department of Agriculture, Rural Development, Electric Programs. http://www.usda.gov/rus/electric/hecgp/overview.htm
13. Indiana Department of Environmental Management. Clean Energy Credit. http://www.in.gov/idem/4134.htm
14. Northern Indiana Public Service Company. http://www.nipsco.com/About-us/Rates Tariffs/Electric-Service-Tariff.aspx

3. Dedicated Energy Crops

3.1 Introduction

Dedicated energy crops represent one of three types of biomass or organic matter that can be converted into energy. The other two types are dual-use food crops, such as corn and soybeans, and organic waste such as forest residues, agricultural residues, livestock manure and municipal solid waste. The use of organic waste biomass as a source of energy is the subject of the next section (Section 4) of this report.

Unlike dual-use food crops and organic waste biomass, the dedicated energy crop industry is still in its infancy. Among renewable resources, biomass has the added feature of being readily converted to liquid fuels for the transportation industry. This ability to be used for transportation fuels, electric energy and chemicals is the drive behind the substantial research effort by the Federal Government to develop a sustainable biomass industry [1, 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 which can then be used to drive a turbine to generate electricity. Combustion can be done either in a dedicated biomass-only boiler or cofired with other fuels such as coal. Cofiring of biomass in coal boilers has the advantage of lowering the emission of sulfur oxides (SOx), nitrogen oxides (NOx) and net lifecycle carbon. However, the widespread application of cofiring with coal has been hindered by the occurrence of alkali deposits that cause slag and corrosion in boiler heat transfer surfaces in the coal boilers [3].

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

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

To take full advantage of the strengths of the different biomass-to-energy conversion processes, the DOE Biomass Program is developing an integrated biorefinery that combines all three processes in one plant that produces multiple products. By producing multiple products, the biorefineries will be able to take advantage of the differences in biomass feedstocks and intermediate products to maximize the value obtained from the feedstock. Figure 3-1 shows the schematic diagram of the biorefinery concept.

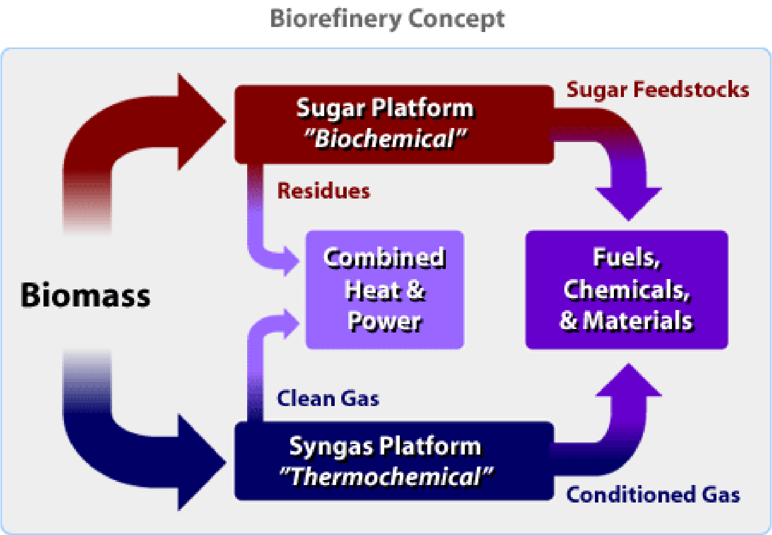


Figure 3-1: Biorefinery platforms (Source: NREL [6])

The Bioenergy Feedstock Development Program at Oak Ridge National Laboratory (ORNL) has identified hybrid poplars, hybrid willows, and switchgrass as having the greatest potential as dedicated energy crops over a wide geographic range [7]. Canola, a specialized oilseed, is also a potential energy crop that is being grown in the Northern Plains region [8]. As a relatively new crop, adoption of canola is limited by farmer confidence and the large amount of land required for profitable initial production.

Switchgrass falls under the category of herbaceous energy crops. These energy crops are perennials that are harvested annually after taking an initial two to three years to reach full productivity. A 2005 study by McLaughlin and Kszos reported a current average annual yield of switchgrass clones of 4.2 - 10.2 dry tons/acre in the U.S. [9]. Hybrid poplar and hybrid willow are short rotation, fast growing hardwood trees. They are harvested within five to eight years after planting. The comparative chemical characteristics of relevant energy crops and conventional fossil fuels are shown in Table 3-1 [10].

Fuel Source	Heating Value (gigajoule/ton)	Ash (%)	Sulfur (%)
Switchgrass	18.3	4.5-5.8	0.12
Hybrid Poplar/Willow	19	0.5-1.5	0.03
Coal (Low Rank)	15-19	5-20	1-3
Coal (High Rank)	27-30	1-10	0.5-1.5
Oil	42-45	0.5-1.5	0.2-1.2

Table 3-1: Comparative chemical characteristics of energy crops and fossil fuels (Source: ORNL [10])

3.2 Economics of energy crops

Commercial scale production of dedicated energy crops is not happening currently in the U.S. For large scale production to occur, the price paid to farmers will have to be high enough to compete with current uses of cropland such as food crops. On the consumption end, the price of the energy crops is constrained by prices of current fuels such as coal in electricity generation and petroleum in transportation. Figure 3-2 shows the supply curves of energy crops and other biomass resources from a 2002 report from the Energy Information Administration [11].

The supply curves were developed using the POLYSYS (Policy Analysis) model maintained by the ORNL. The fundamental assumption underlying the POLYSYS model is that farmers will only switch crops if growing the new crop will produce as much profit as their current crop. Figure 3-2 indicates that energy crops will be supplied to the market when the average price (in 2000 dollars) paid for biomass exceeds $2.10 per million Btu (mmBtu). This price threshold translates to approximately $2.66/mmBtu in 2010 dollars. Comparing this to the $2.30/mmBtu [12] average price of coal delivered to electric utilities in 2010 shows that energy crops are not yet competitive against coal as fuel for electricity generation.

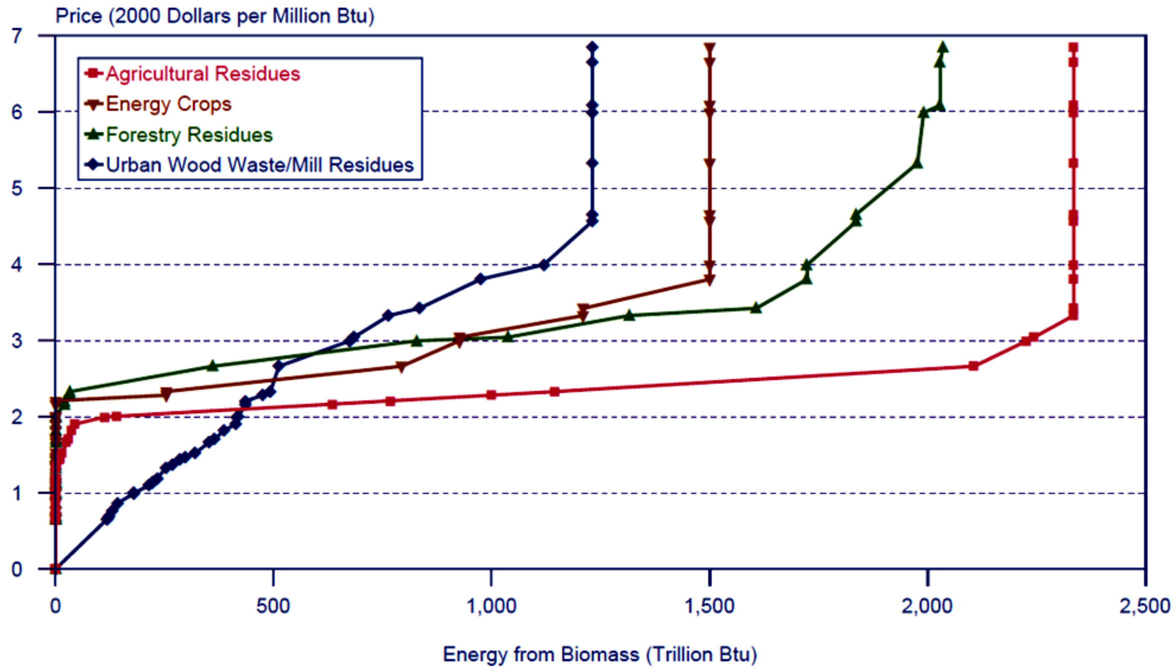


Figure 3-2: POLYSYS estimated biomass supply curve for year 2020 (Source: EIA [11])

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 rapid growth of corn and soybean biofuels plants in Indiana since 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 1,088 MGY have been constructed, bringing the total corn-ethanol capacity to 1,188 MGY. The first two soybean biodiesel plants in Indiana, with a combined capacity of 10 MGY, were commissioned in 2006. Since then two more soybean biodiesel and one waste oils (primarily discarded cooking oils from the food industry) based biodiesel plants have been constructed in Indiana bringing the total biodiesel capacity to 118 MGY. Tables 3-2 and 3-3 show the location and capacities of the ethanol and biodiesel plants.

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

- The use of corn-ethanol as an oxygenating additive in gasoline in place of the chemical MTBE. The shift from MTBE was due to its being associated with ground water pollution. The replacement of MTBE was mandated both by states and the 2005 Energy Policy Act [13].

- The enactment of the renewable fuel standard under the 2005 Energy Policy Act that required that 7.5 billion gallons of renewable fuel must be blended into gasoline by 2012. This has since been expanded to a requirement of 36 billion gallons of renewable fuel by 2022 [14].
- 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 allows for a 45 cents/gallon tax credit to be given to individuals who produce the mixture of gasoline and ethanol. This tax credit is due to expire December 31, 2011 [15].

Company	**Year**	**Town/County**	**Current Capacity (MGY*)**
New Energy Corp	1985	South Bend/St. Joseph	100
Central Indiana Ethanol	2007	Marion/Grant	40
Iroquois Bio-Energy Co.	2007	Rensselaer/Jasper	40
POET Biorefining	2007	Portland/Jay	65
The Andersons	2007	Clymers/Cass	110
Valero Energy	2007	Linden/Montgomery	100
(formerly Alta) POET Biorefining	2008 reopened 2011	Cloverdale/Putman	90
Cardinal Ethanol	2008	Harrisville/Randolph	100
Indiana Bio-Energy	2008	Bluffton/Wells	110
POET Energy	2008	Alexandria/Madison	60
POET Energy	2008	North Manchester/Wabash	65
Abengoa Bioenergy Indiana	2009	Mt. Vernon/Posey	88
Aventine	2011	Mt. Vernon/Posey	220

*MGY denotes million gallons per year.

Table 3-2: Ethanol plants in Indiana (Source: ISDA [16])

Biodiesel plant Name	**Year**	**Town/County**	**Estimated Capacity (MGY)**
Evergreen Renewables (not producing)	2006	Hammond/Lake	5
Integrity Biofuels	2006	Morristown/Shelby	5
E-biofuels	2007	Middletowm/Henry	10
Louis Dreyfus	2007	Claypool/Kosciusko	88
Xenerga* (not producing)	2008	Kingsbury/LaPorte	10

* Xenerga plant uses waste oils and animal fats as feedstock, the others use soybeans.

Table 3-3: Biodiesel plants in Indiana (Source: ISDA [16])

3.3 State of energy crops nationally

Dedicated energy crops (trees and grasses) are not yet being produced for the most part on large scale for the purposes of bioenergy production. Herbaceous crops (grasses) are currently grown as livestock feed and for soil conservation purposes. The short rotation woody biomass crops (trees) being grown commercially today are mainly for production of fiber and in a few locations for bioenergy demonstration projects [17]

In a combined effort with the USDA, DOE's Biomass Program has a major research and development effort aimed at increasing the biomass production in the U.S. to a level where it will be able to replace 30 percent of the nation's petroleum consumption by the year 2030 distributed as follows: 5 percent of the nation's electric power, 20 percent of the nation's transportation fuel and 25 percent of its chemicals. Figures 3-3 show the locations of the bioenergy crops test sites.

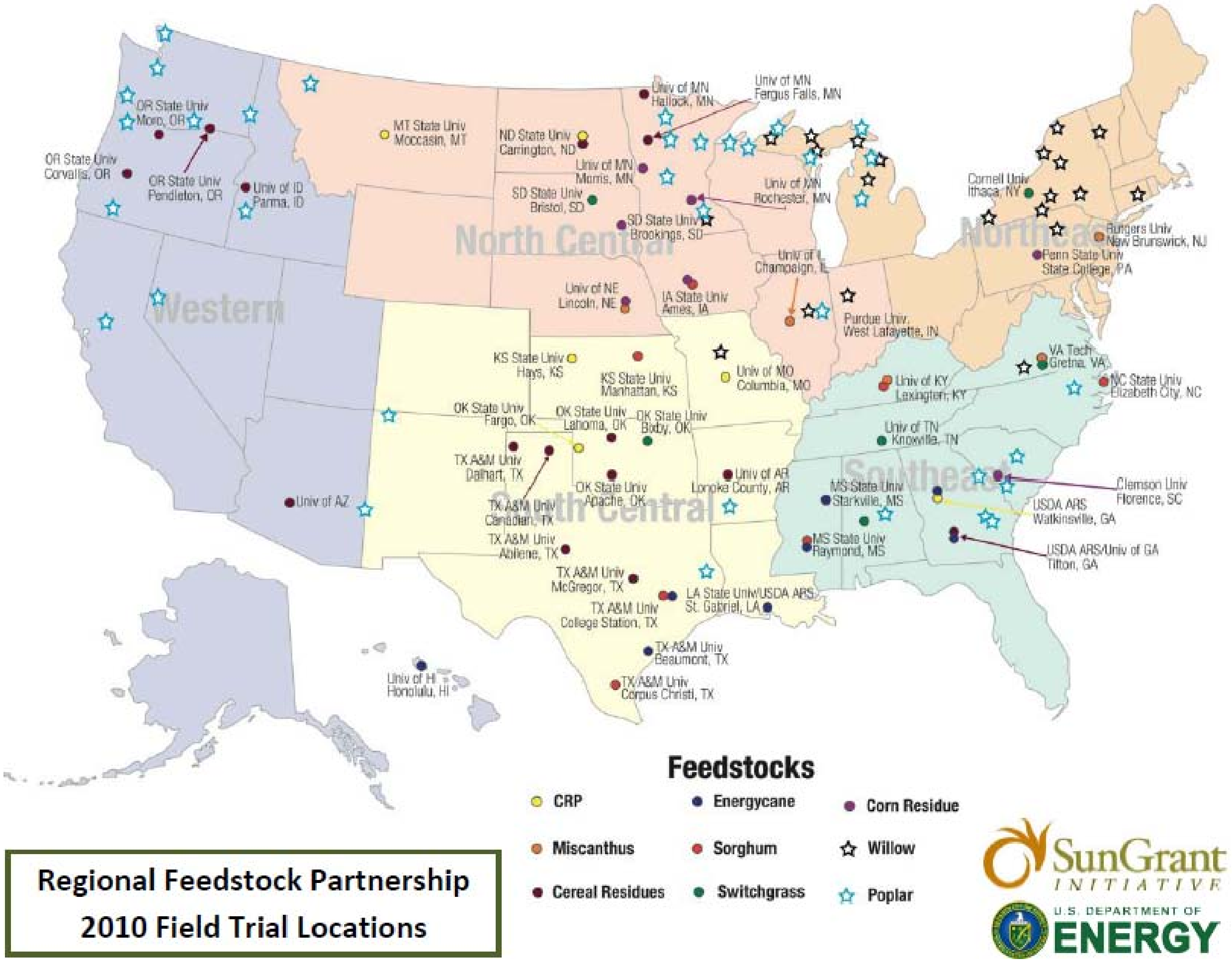


Figure 3-3 2010 energy crop test stations (Source EERE [17])

3.4 Energy crops in Indiana

Figure 3-4 shows the levels of energy crops that would be produced in Indiana at three different biomass price levels used in a 1998/1999 USDA/DOE study using the POLYSYS model. As the figure shows, energy crops do not begin to be competitive with traditional food crops until the biomass price approaches $40 per dry ton. At $50 per ton, biomass production jumps to 5 million tons per year [18, 19]. The biomass price levels needed to achieve the production levels shown in Figure 3-4 will be even higher today given that food crop price levels are much higher than they were in 1999.

The estimates of switchgrass and poplar production potential in a 2006 ORNL [20] study are shown in Figure 3-5. The study used the same agricultural sector model (POYSYS) referred to previously. As can be seen in Figure 3-5, central Indiana has the highest potential for switchgrass production while the northeast and southeast regions of Indiana have the highest potential for hybrid poplar production.

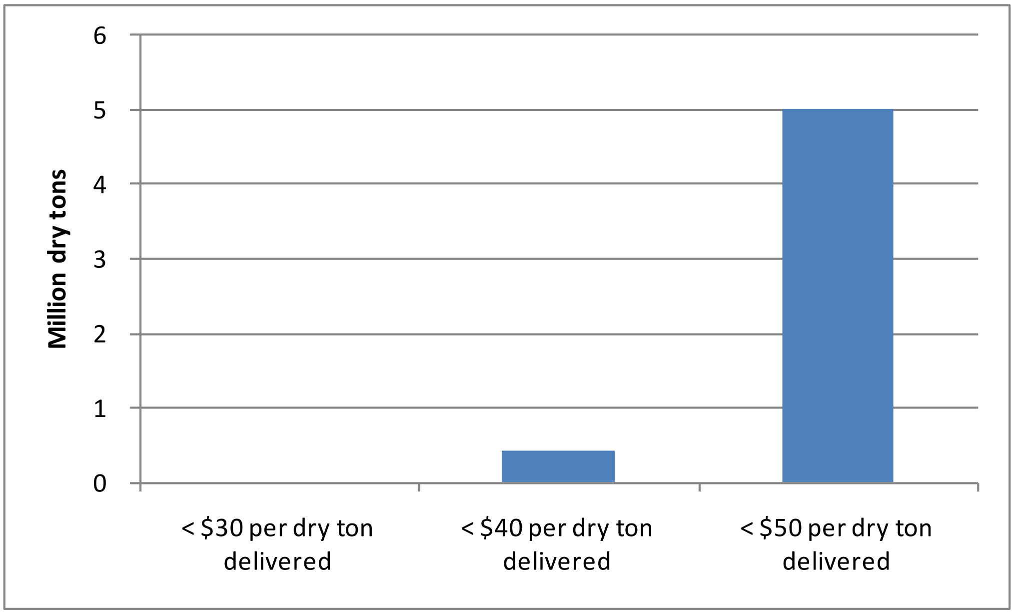


Figure 3-4: Estimated annual cumulative energy crop quantities by delivered price (1997 dollars) for Indiana (Data source: ORNL [18])

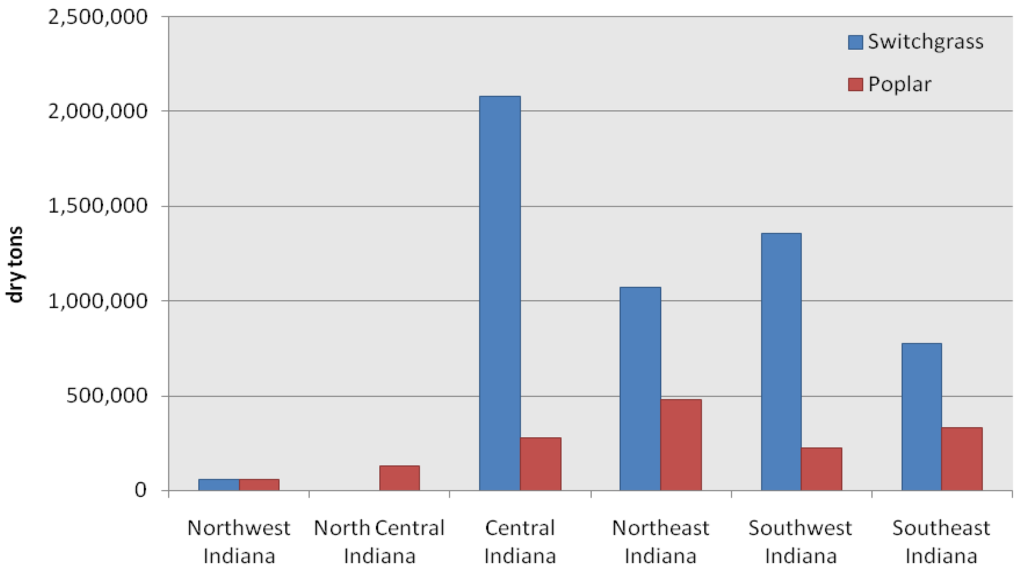


Figure 3-5: Estimated annual potential production of switchgrass and hybrid poplar for Indiana, USDA baseline 2001 (Source: ORNL [20])

A 2002 study at Ball State University estimated that there was potential to produce 90 million tons per year of switchgrass in Indiana if all the crop land was converted to the production of this energy crop. These 90 million tons of switchgrass would produce 450,000 GWh of energy, which is approximately four times Indiana's annual electrical energy consumption.

In an April 2008 working paper, Brechbill and Tyner of Purdue's Agricultural Economics Department did an extensive study of the cost of producing switchgrass and harvesting corn stover for the energy industry. Table 3-4 shows the average cost of producing switchgrass given in this study [21]. The table includes the farmer's choice to either: purchase and own the harvesting equipment or hire the services of a specialized custom operator.

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

Table 3-4: Average cost ($/ton) for producing switchgrass in Indiana (Data source: Brechbill & Tyner [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 2.2 cents/kWh tax credit for wind, geothermal and closed-loop biomass and 1.1 cents/kWh for open-loop biomass, landfill gas municipal solid waste, small hydroelectric and marine energy technologies. As part of the February 2009 American Recovery and Reinvestment Act the PTC was modified to provide the option for qualified producers to take the federal business energy investment tax credit (ITC) or an equivalent cash grant from the U.S. Department of Treasury. Dedicated energy crops fall under the closed loop biomass category [22].
- Business Energy Investment Tax Credit (ITC) credits up to 30 percent of expenditures on qualified renewable energy systems [22].
- Renewable Energy Production Incentive (REPI) provides financial incentive payments for electricity produced and sold by new qualifying renewable energy generation facilities. Qualifying facilities are eligible for annual incentive payments of 1.5 cents/kWh for the first ten years of production, subject to the availability of annual appropriations in each federal fiscal year of operation. The Energy Policy Act of 2005 expanded the list of eligible technologies and facilities owners, and reauthorized the payment for fiscal years 2006 through 2026 [22].
- Rural Energy for America Program promotes energy efficiency and renewable energy for agricultural producers and rural small businesses through the use of (1) grants and loan guarantees for energy efficiency improvements and renewable energy systems, and (2) grants for energy audits and renewable energy development assistance. The program covers up to 25 percent of costs [22].
- Qualified Energy Conservation Bonds (QECBs) are qualified tax credit bonds that are allocated to each state based upon their state's percentage of the U.S. population. The states are then required to allocate a certain percentage to "large local governments." In February 2009, these funds were expanded to $3.2 billion [22].
- Value-Added Producer Grant Program: Grants are available to independent producers, agricultural producer groups, farmer or rancher cooperatives, and majority-controlled producer-based business ventures seeking funding. Previously awarded grants supported energy generated on-farm through the use of agricultural commodities, wind power, water power, or solar power. The maximum award per grant was $300,000 [23].
- High Energy Cost Grant Program administered by the U.S. Department of Agriculture (USDA) is aimed at improving the electricity supply infrastructure in rural areas having home energy costs exceeding 275 percent of the national average. Eligible infrastructure includes renewable resources generation. The USDA has allocated a total of $15.5 million for the 2010 funding cycle. The individual grants range from $75,000 to $5 million [24].

Indiana Incentives

- Net metering rule: Renewable resource facilities with a maximum capacity of 1 MW qualify for net metering. The net excess generation is credited to the customer in the next billing cycle [22].
- Emissions Credits: Electricity generators that do not emit NO_x and that displace utility generation are eligible to receive NO_x emissions credits under the Indiana Clean Energy Credit Program [IDEM]. These credits can be sold on the national market.
- Clean Energy Portfolio Standard (CPS) passed in May 2011 sets a voluntary goal of 4 percent between 2013 and 2018, 7 percent between 2019 and 2024, and 10 percent clean energy by 2025, based on 2010 retail sales. Participation in CPS makes utilities eligible for incentives in order to pay for the compliance projects [22].
- Indianapolis Power & Light Co. – Rate REP Renewable Energy Production: IPL is offering a "feed-in tariff" to facilities that produce renewable energy. IPL can purchase renewable energy and contract the production for up to 10 years. Biomass compensation is $6.18/kW per month plus $0.085/kWh [22, 26].
- Northern Indiana Public Service Company – The NIPSCO feed-in tariff offers incentive rates for electricity generated from renewable resources on 10 year contracts. Payment for biomass facilities is $106/kW. The tariff is an experimental on running until December 31, 2013. The generating unit size allowed under the tariff is between 5 and 5,000 kW while the total allowed system-wide cap is 30 MW [27].

3.6 References

1. U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE). Biomass Program http://www1.eere.energy.gov/biomass/about.html
2. 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
3. Ileleji, Klein., Purdue Agricultural and Biological Engineering Department. Technologies for generating power from biomass. Presentation at the Indiana Biomass Working Group, March 2010.
4. EERE. Biomass Program. Processing and conversion http://www1.eere.energy.gov/biomass/processing_conversion.html
5. NREL. Thermochemical technology overview http://extension.psu.edu/energy/news/spotlight/presentations/ne-renewable-energy-conference-2008
6. National Renewable Energy Laboratory (NREL). What is a biorefinery? April 2007. http://www.nrel.gov/biomass/biorefinery.html

7. Walsh, Marie E., ORNL. BIOCOST: a Tool to estimate energy crop costs. http://faculty.ksu.edu.sa/62311/Research%20Library/Biocost%20Estimating%20Production%20Costs%20of%20Bioenergy%20Crops.htm
8. Raymer, P.L. 2002. Canola: An emerging oilseed crop. p. 122–126. In: J. Janick and A. Whipkey (eds.), Trends in new crops and new uses. ASHS Press, Alexandria, VA. http://www.hort.purdue.edu/newcrop/ncnu02/v5-122.html
9. McLaughlin, S.B. and Kszos, L.A. Development of switchgrass (Panicum virgatum) as a bioenergy feedstock in the United States. http://www.sciencedirect.com/science/article/pii/S0961953404001904
10. Scurlock, Jonathan, ORNL. Bioenergy feedstock characteristics. http://cta.ornl.gov/bedb/appendix_b/Bioenergy_Feedstock_Characteristics.xls
11. Haq, Zia. EIA. Biomass for Electricity Generation. July 2002. http://www.eia.doe.gov/oiaf/analysispaper/biomass/pdf/biomass.pdf
12. EIA. Electric Power Monthly, July 2011. http://www.eia.gov/cneaf/electricity/epm/epm_sum.html
13. Texas State Energy Conservation Office. 2010. http://www.seco.cpa.state.tx.us/re_ethanol_mtbe.htm
14. EPA.Renewable Fuel Standard. May 2010. http://www.epa.gov/otaq/fuels/renewablefuels/index.htm
15. RFA. VEETC. 2005. http://www.ethanolrfa.org/pages/federal-tax-incentives-veetc
16. Indiana State Department of Agriculture. Fact Sheet: Biofuels plants in Indiana. http://www.in.gov/isda/biofuels/factsheet.pdf
17. EERE. Roadmap for agricultural biomass feedstock supply in the United States. http://www1.eere.energy.gov/biomass/about.html
18. Walsh, Marie E., et al. Oak Ridge National Laboratory (ORNL). Biomass feedstock availability in the United States: 1999 State Level Analysis. http://pbadupws.nrc.gov/docs/ML0719/ML071930137.pdf
19. Walsh, Marie; Graham, Robin; Urgate, Daniel; Slinsky, Stephen; Ray, Daryll; and Shapouri, Hosein. Economic analysis of energy crop production in the U.S. location, quantities, price and impacts on traditional agricultural crops, 1998. http://www.energy.wsu.edu/EnergyLibrary/AgricultureMatters/CatalogItemDetail.aspx?id=72
20. Oak Ridge National Laboratory, Indiana’s counties energy crops estimates. Data provided by Dr. Wallace Tyner.
21. 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
22. Database of State Incentives for Renewables & Efficiency (DSIRE). http://www.dsireusa.org/

23. U.S. Department of Agriculture. Value-added producer grants, 2008. http://www.rurdev.usda.gov/rbs/coops/vadg.htm
24. U.S. Department of Agriculture, Rural Development, Electric Programs. http://www.usda.gov/rus/electric/hecgp/overview.htm
25. Indiana Department of Environmental Management. Indiana Clean Energy Credit Program. http://www.in.gov/idem/4134.htm
26. Indianapolis Power and Light Company. Renewable Energy Production. http://www.iplpower.com/ipl/index?page=IPLGeneral&Menu=01000000&DocID=020391af33d6012801538fc10057cb
27. Northern Indiana Public Service Company. http://www.nipsco.com/About-us/Rates-Tariffs/Electric-Service-Tariff.aspx

4. Organic Waste Biomass

4.1 Introduction

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

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

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

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

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 4-1, wood and wood-derived fuels have been second only to hydroelectricity as a source of renewable energy in the U.S. Up 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.

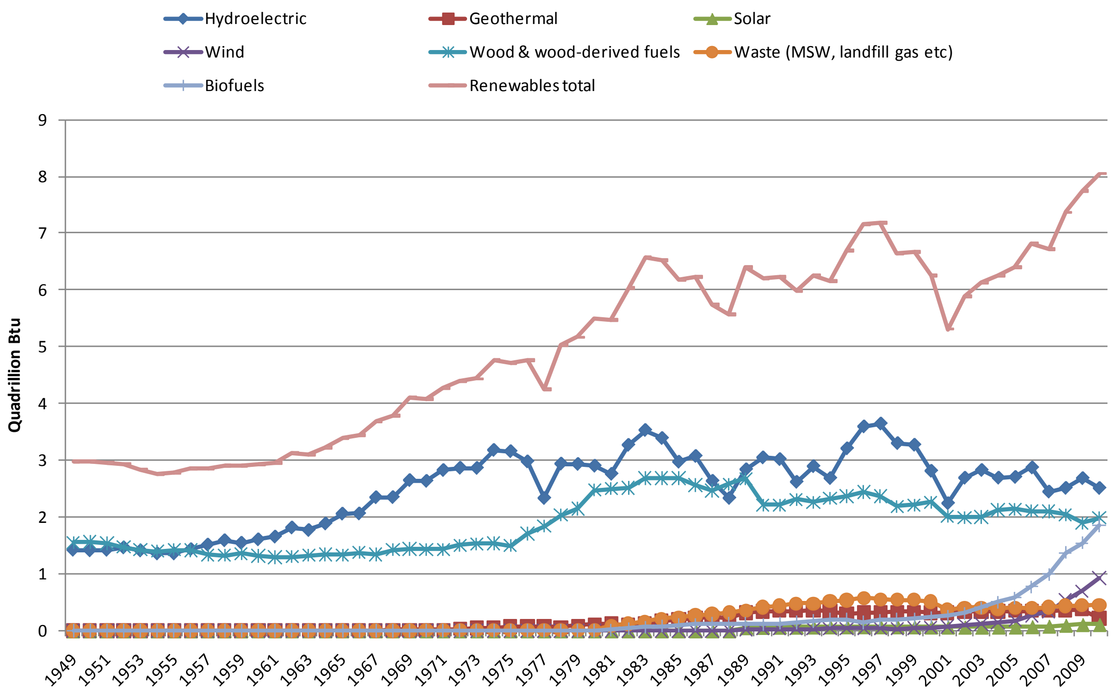


Figure 4-1: U.S. renewable energy consumption 1949-2009 (Source: EIA [1])

Although not as large a source as wood and wood-derived fuels, municipal solid waste has also been a significant contributor to the nation's renewable energy mix. According to the U.S. Environmental Protection Agency (EPA), there are 86 municipal solid waste burning power plants operating in 24 states with a combined electricity generating capacity of 2,720 MW. One such plant is the Covanta Energy facility in Indianapolis that is used to generate steam for heating in downtown Indianapolis [2]. The Covanta facility in Indianapolis does not generate electricity.

Another significant source of organic waste based energy is landfill gas. Landfill gas contains about 50 percent methane. One of the main motivations for capturing and burning landfill gas is because landfills are one the main sources of human-related methane emissions in the U.S. Methane gas is 21 times more effective than carbon dioxide as a heat trapping greenhouse gas. Thus, converting landfill gas to energy provides a financial benefit to the environmental task [3].

Livestock manure is in use currently as an energy source with 160 anaerobic digester biogas recovery systems in operation in livestock farms in the U.S. at the end of 2010. Anaerobic digestion of biomass waste consists of a controlled breakdown of organic wastes by microorganisms in an oxygen deficient environment. EPA estimates that 8,200 swine and dairy farms in the U.S. have the capability to support biogas recovery systems producing enough biogas to supply 1,600 MW of electricity generating capacity [4].

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 EPA out of the approximately 1,000 wastewater treatment facilities nationwide that had enough effluent inflow to support anaerobic digesters at the end of 2006, only about 500 of them had digesters installed. And out of these 500 that had installed anaerobic digesters only 106 capture the biogas for energy conversion resulting in a combined 220 MW electricity generating capacity. EPA estimated that if all the 500 wastewater treatment plants that had anaerobic digesters in place captured the biogas for energy conversion, they could support a further 340 MW of electricity generating capacity [5].

Biomass, including agricultural crop residues, is expected to play a significant role in the energy supply portfolio in the U.S. in the future. One of the characteristics that makes biomass a very attractive source of renewable energy is its ability to be converted both to electricity and to liquid fuels for the transportation industry. In 2005 the U.S. Department of Agriculture (USDA) and the U.S. Department of Energy (DOE) issued a joint report from a study done to investigate the viability of using energy from biomass to replace 30 percent of U.S. petroleum consumption by the year 2030. According to this report, titled *Biomass Feedstock for a Bioenergy and Bioproducts Industry: the Technical Feasibility of a Billion-Ton Annual Supply* [6], corn stover is the most abundant untapped source of biomass currently available from croplands. Corn stover is the material left in the field after the grain is harvested. It consists of the stalk, the leaves, the husks and the cobs. The USDA/DOE report estimates that 75 million dry tons per year of corn stover can be sustainably removed from U.S. croplands under current farming conditions. All other crops can together contribute 38 million tons a year under current farming practices [6].

Large scale farming of algae is another area being considered as a potential source of bioenergy. Algae are simple organisms, ranging from microscopic-sized algae to seaweeds that grow to over 100 feet. Like other plants, they utilize energy from the sun through photosynthesis to convert carbon dioxide from the air into biomass usable for energy production. Algae have several advantages over other biomass as a source of energy and especially in the production of biodiesel. These advantages include [7, 8]:

- 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 elegant application for the use of algae is the coupling of an algae bioreactor with a coal power plant to allow the power plant to provide the carbon dioxide needed for algae growth. In this way a combined benefit of producing bioenergy while reducing carbon dioxide emission is achieved. Such an experiment was conducted at the Arizona Public Service Red Hawk power plant in 2006 and 2007 [9].

The production of algae for energy is still in the development stage. According to the DOE algae research program there are major technical hurdles to be overcome before commercial scale energy production from algae is a reality and energy from algae is more of a long term goal [7, 8].

4.2 Economics of organic waste biomass

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

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

In the case of municipal solid waste, 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 most expensive plants to build and operate [2]. In the November 2010 Energy Information Administration (EIA) plant cost estimates, the MSW power plant was listed as having the highest capital cost at over $8,000/kW among the technologies considered and the highest fixed O&M cost at over $370/kW [10].

Similarly, other organic waste streams such as animal waste, wastewater treatment and landfills that generate methane have greenhouse gas emissions reduction as a major objective and energy conversion as an added benefit. Further, the energy conversion efficiency, and therefore economics, is improved by the onsite 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.

Currently agricultural crop residues are not being collected for use as bioenergy feedstock because it is not yet profitable for farmers. In 2002 EIA published a report authored by Dr. Zia Haq containing the EIA's estimation of the amount biomass, including crop residues, used as input into the National Energy Modeling System. Dr. Haq utilized an agricultural sector model called POLYSYS (Policy Analysis System), which was developed by the Oak Ridge National Laboratory, to estimate possible future supplies of agricultural crop residues. The estimated national supply curve for biomass and energy crops produced by POLYSYS for the year 2020 is shown in Figure 4-2. According to these supply curves agricultural crop residues supply to the energy industry will start occurring when the price paid at the plant gate passes the 2.00 $/mmBtu level (2000 dollars). This price threshold translates to approximately 2.53 $/mmBtu in 2010 dollars. Comparing this to the 2.30 $/mmBtu [11] average price of coal delivered to electric utilities in 2010 shows that agricultural crop residue is not yet competitive against coal as fuel for electricity generation.

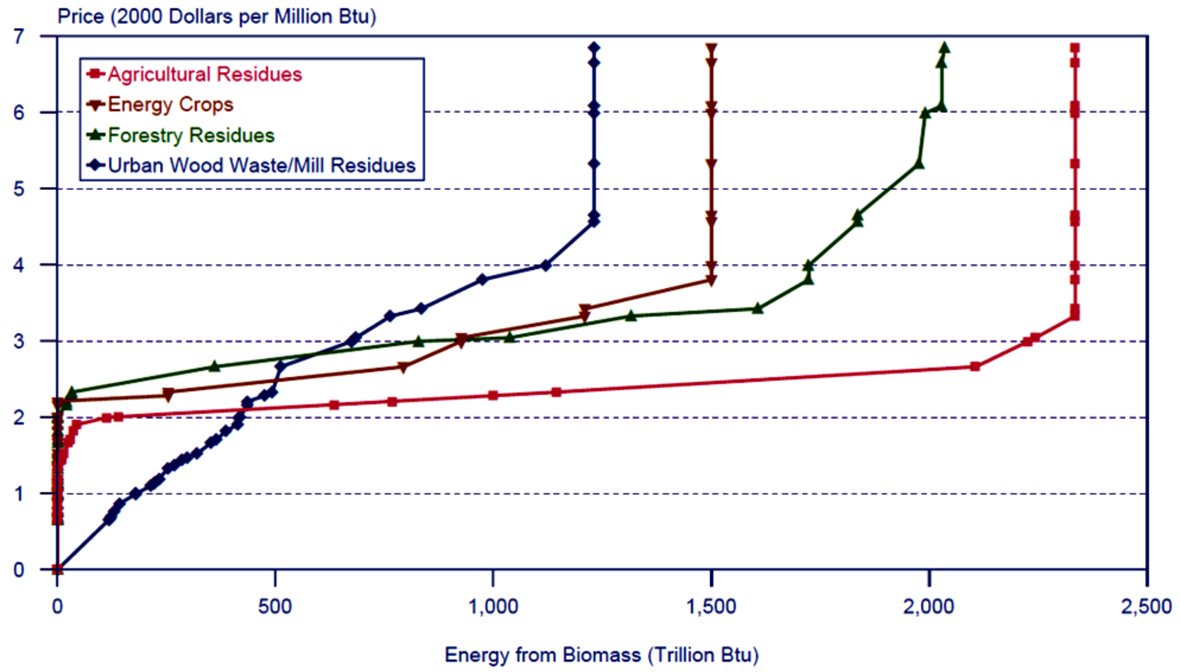


Figure 4-2: POLYSYS estimated biomass supply curve for year 2020 (Source: EIA [12])

Although the concept of using algae for energy production has been proven at the laboratory level, no commercial scale sustainable production facility has been established. According to the 2010 DOE National Algal Biofuels Technology Roadmap document there was not yet a credible estimate of the cost of algal biofuel [8].

4.3 State of organic waste biomass nationally

As has already been stated in previous sections and illustrated in Figure 4-1, organic biomass has historically been one of the main sources of renewable energy in the U.S., second only to hydroelectricity. Thirty percent of the 8 quadrillion Btu of renewable energy consumed in the U.S. in 2010 was from organic waste biomass. Wood contributed 25 percent and other organic wastes together contributed 6 percent. Figure 4-3 shows the contribution of renewable resources to the total energy consumed in the U.S. in 2010.

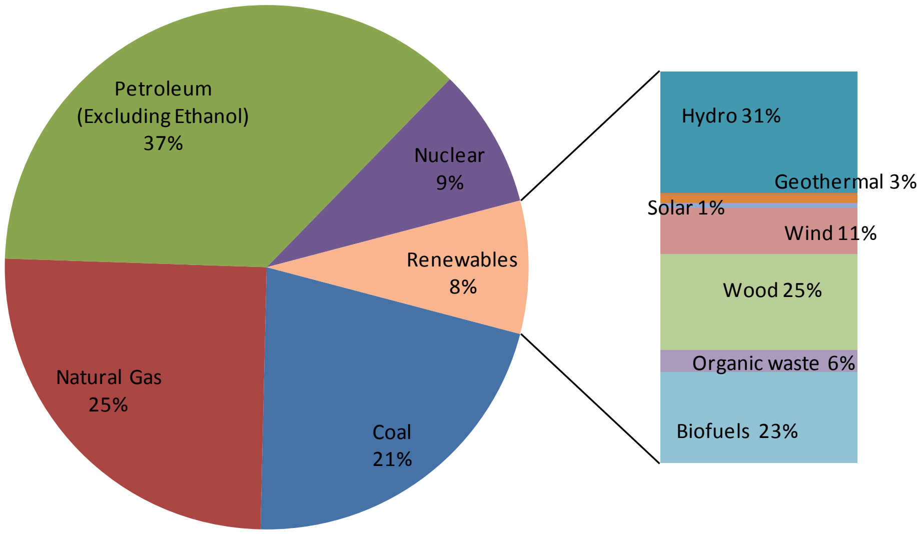


Figure 4-3: Summary of U.S. energy consumption in 2010 (Data source: EIA [1])

Organic waste biomass is also a significant source of electricity generation, ranking third after hydroelectricity and wind for renewable electricity generation in the U.S. in 2010. Figure 4-4 shows net electricity generation in the U.S. in 2010 by fuel type. Among the biomass resources, wood is the dominant source of renewable electricity contributing 4 percent of total renewable energy, followed by municipal solid waste and landfill gas, which together contributed 4 percent of the renewable energy. Municipal solid waste and landfill gas are grouped together in the 'other wastes' category.

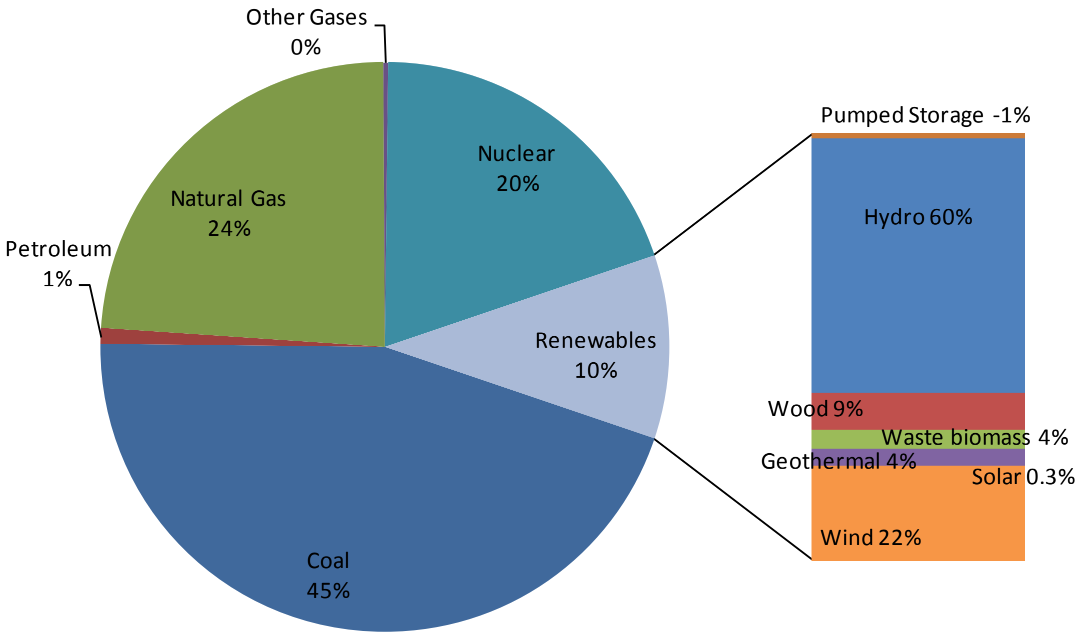


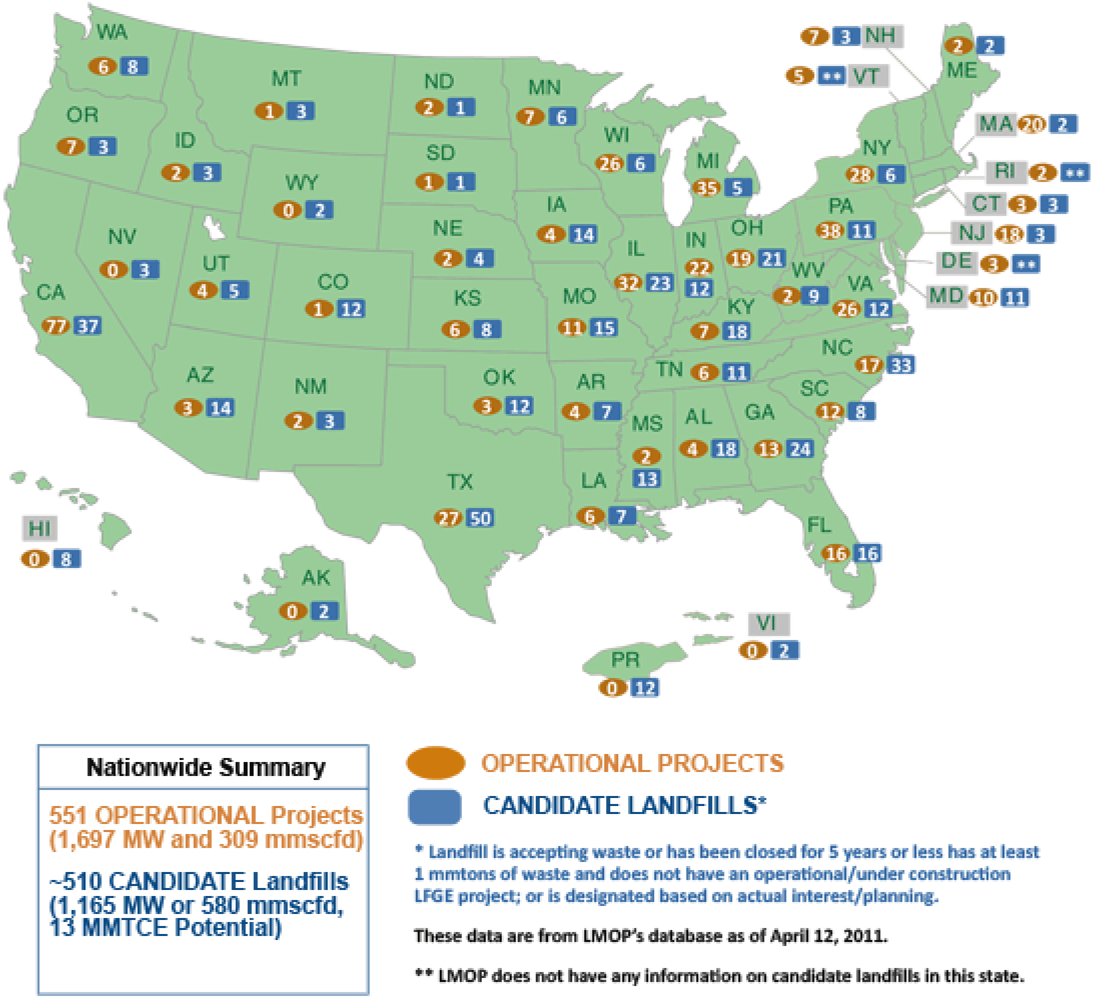
Figure 4-4: Summary of U.S net electricity generation in 2010 (Data source: EIA [13])

At the end of 2010 there were 86 MSW-to-energy power plants operating in 24 states in the U.S. distributed as shown in Table 4-1. The combined electric generating capacity of the plants was 2,572 MW plus the equivalent of 218 MW in steam output [14].

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

Table 4-1: Operating municipal solid waste energy plants (Data source: Energy Recovery Council [14])

Figure 4-5 shows the location of operational and ‘candidate’ landfill gas energy projects in the U.S. The candidate designation is for landfills that have the potential for installation of an energy recovery system. There are currently 561 landfills with energy conversion projects in operation. Approximately two thirds of these operational projects convert the landfill gas to electricity and one third provide biogas gas for direct use as a source of thermal energy. The operational projects have a combined capacity for 1,697 MW of electricity generation and 309 million standard cubic feet per day (mmscfd) of gas for thermal energy production. There are a 510 ‘candidate’ landfills that have the size and other characteristics necessary to support energy projects with a combined capacity of 1,165 MW of electricity generation and 580 mmscfd of gas for direct use [3].



Nationwide Summary

551 OPERATIONAL Projects (1,697 MW and 309 mmscfd)

~510 CANDIDATE Landfills (1,165 MW or 580 mmscfd, 13 MMTCE Potential)

* Landfill is accepting waste or has been closed for 5 years or less has at least 1 mmtons of waste and does not have an operational/under construction LFGE project; or is designated based on actual interest/planning.

These data are from LMOP's database as of April 12, 2011.

** LMOP does not have any information on candidate landfills in this state.

Legend

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

Figure 4-5: Landfill gas projects (Source: EPA [3])

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. Indiana is ranked among the top ten with potential for producing 3.5 billion cubic feet per year from 296 farms [4].

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

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

Table 4-3 shows the location of the 220 MW of electricity generating capacity installed in wastewater treatment plants in the U.S. According to the EPA Combined Heat and Power Partnership Program, this capacity could be increased by a further 340 MW if all the wastewater treatment plants that used anaerobic digestion technology to process their waste would capture the biogas and use it to generate electricity and heat. Out of the approximately 500 wastewater treatment facilities that utilized anaerobic digestion technology only 106 of them convert the biogas to energy.

State	Number of Sites	Capacity (MW)
Arkansas	1	1.7
Arizona	1	4.2
California	23	38.1
Colorado	2	7.9
Connecticut	1	0.2
Florida	1	6.0
Iowa	2	3.4
Idaho	2	0.5
Illinois	2	4.3
Massachusetts	1	76.0
Minnesota	2	5.1
Montana	3	1.1
Nebraska	3	5.4
New Hampshire	1	0.4
New Jersey	3	4.6
New York	5	13.3
Ohio	1	0.1
Oregon	10	5.9
Pennsylvania	3	22.4
Utah	2	2.6
Virginia	1	3.0
Washington	3	13.6
Wisconsin	2	0.5
Wyoming	1	0.03
Total	**76**	**220.1**

Table 4-3: Wastewater treatment combined heat and power systems in the U.S.
(Source: EPA [5])

Although crop residues are not in use today as a source of energy, it is the most readily available biomass feedstock. Figure 4-6 shows the amount of biomass available annually from agricultural residues and waste streams under current farming practices according to the USDA/DOE billion-ton of biomass by 2030 vision report [6].

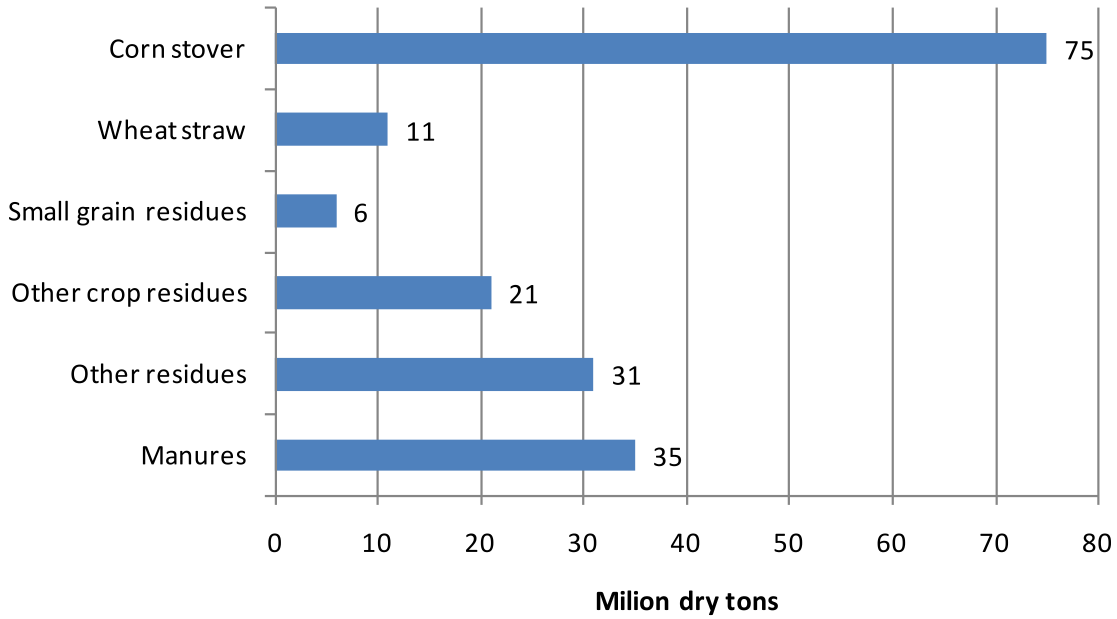


Figure 4-6: Current available organic waste biomass from agricultural lands (Data source: USDA/DOE [6])

The "small grain residues" bar in Figure 4-6 includes residues from sorghum, barley, oats and rice. The "other residues" bar in Figure 4-6 includes residues from cotton, oil seeds, tobacco, sugar crops, potatoes, beans, miscellaneous secondary agricultural processing residues, MSW and fats and greases.

4.4 Organic waste biomass in Indiana

Organic waste biomass, in particular wood residue and byproducts, has historically been the main source of renewable energy in Indiana. Figure 4-7 shows the contribution of the various renewable resources to the total annual energy consumed in Indiana since 1960. It was not until the rapid growth in corn ethanol production starting in 2007 that woody biomass energy's contribution was overtaken by ethanol as the primary source of renewable energy consumed in Indiana. The types of industries using wood residue and byproducts include the paper and pulp industry that has traditionally used the paper-making byproducts for cogeneration of electricity and process heat. Municipal solid waste is the other major source of energy from woody biomass, for example the Covanta Energy Corporation's Indianapolis facility uses municipal solid waste to generate steam used for district heating in downtown Indianapolis. The plant has capacity to process 2,175 tons of solid waste per day to produce at least 4,500 tons of steam per ton of solid waste [15].

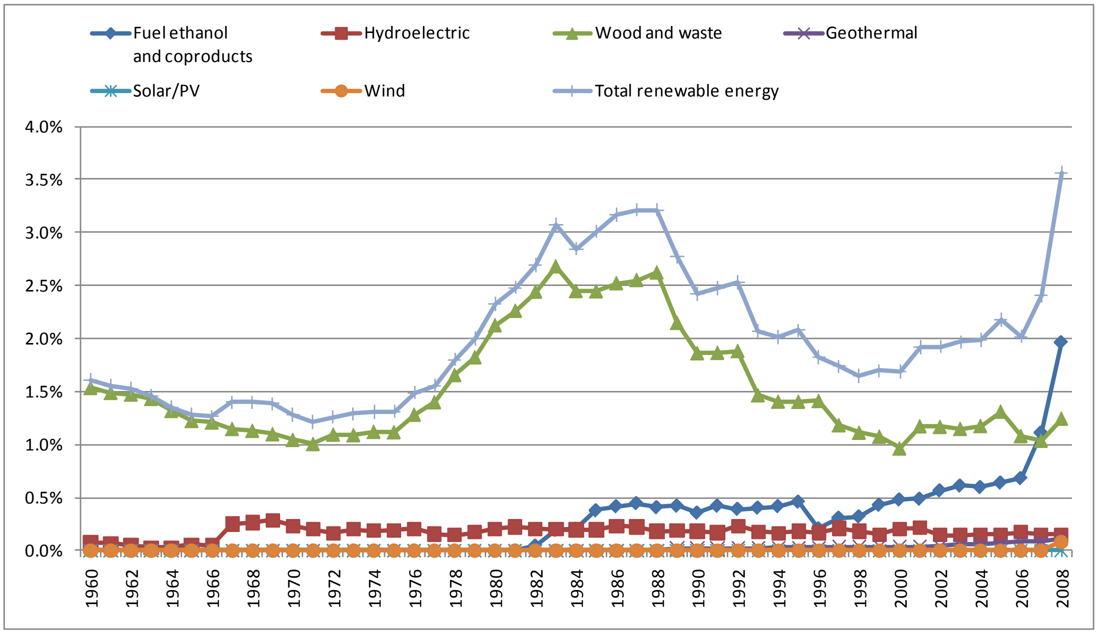


Figure 4-7: Renewables share of Indiana total energy consumption (Source EIA [16])

The other organic waste biomass that is a significant source of energy in Indiana is landfill gas. The most active user of landfill gas is Wabash Valley Power Association which has a total of 39.2 MW of electricity generating capacity from thirteen power plants on 7 landfills. Other major users of landfill energy include Hoosier Energy with 3.5 MW electricity generating capacity in a Clark County landfill and Granger Energy that has several energy conversion projects in the Southside landfill in Indianapolis. The Granger Energy project in the Southside Indianapolis landfill includes 4 MW of electricity generating capacity and supplies landfill gas to various area businesses for heating and steam generation. The total electricity generating capacity installed in Indiana landfills is 50.1 MW. Other operators of landfill electricity generating projects include Energy Systems LLC and the town of Munster [17].

Another source of biomass fuel use for electricity generation in Indiana is the anaerobic digestion of animal manure at three dairy farms in Northwest Indiana. The three dairies are the Boss Dairy No. 4, the Fair Oaks Dairy, and the Herrema Dairy. Each of these dairies has over 600 kW of generating capacity [18]. The Fair Oaks Farm is in the process of expanding its biogas production to include purification and compression of the biogas to pipeline quality methane to fuel 42 milk delivery trucks and a 1 MW electricity generator to power the methane cleaning and compression equipment [19].

In addition, SUFG is aware of a total of 195 kW of electricity generating capacity in wastewater treatment facilities 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 [20].

Figure 4-8 shows the amount of crop and woody biomass residue potentially available for energy production in Indiana. As can be seen in the figure, the most abundant residue available is corn stover. It is estimated that 6 million tons of corn stover per year could be sustainably collected from Indiana corn farms under current tillage practices and an additional 10 million tons if no-till practices are applied on all farms in the state. Figure 4-9 shows the corn stover production potential in Indiana regions under current tillage practices and with no-till farming.

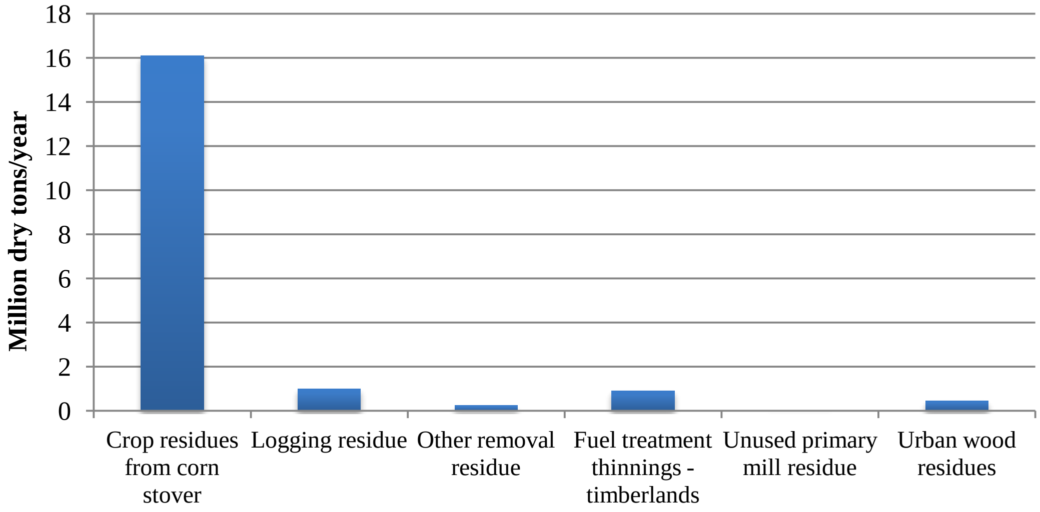


Figure 4-8: Estimated biomass production potential in Indiana (Source: ORNL [21])

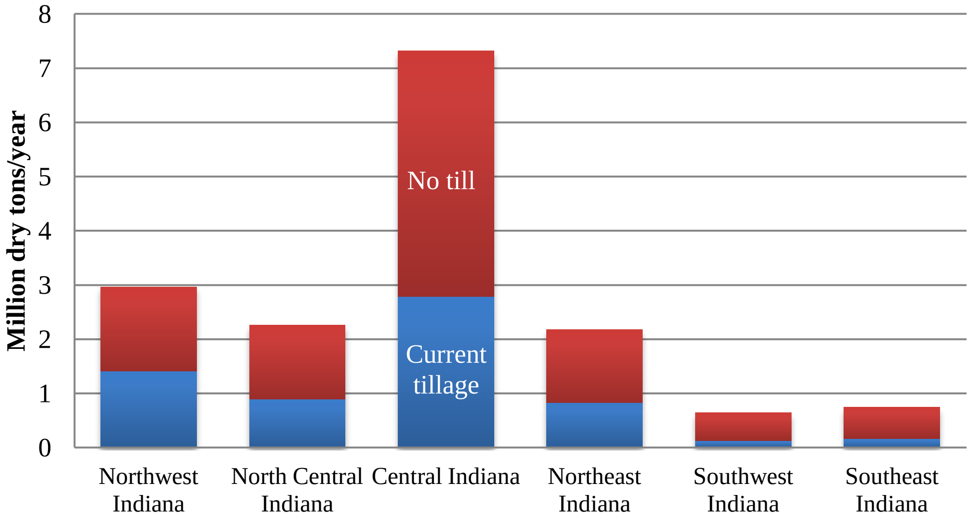


Figure 4-9: Estimated production potential of crop residues from corn stover in Indiana (Source: ORNL [21])

Assuming an energy density 7,500 Btu/lb for corn stover, the total energy available in the 16 million tons of corn stover is 240 trillion Btu. This is enough to supply approximately 9 percent of the 2,800 trillion Btu of Indiana's annual total energy consumption. If this corn stover was used to generate electricity at a power plant operating at 21 percent efficiency, it would result in 15,000 GWh of electricity – enough to supply approximately 13 percent of the 117,000 GWh of electricity generated annually. The cost to the farmer of collecting and handling this stover was estimated by Brechbill and Tyner [22] to be between $32 and $38 per ton depending on such characteristics as the size of the farm and method used to harvest the stover. If one assumes a transportation cost of $0.2 per ton and an average distance of 30 miles to the power plant, the plant gate cost of the stover will be 38-44 $/ton which is equivalent to $2.5 to $3 per mmBtu.

Table 4-4 shows the amount of woody biomass residue available annually in Indiana that is not already being utilized for other purposes.

	Amount available (tons)
Logging residues	500,696
Fuel treatment thinnings	457,259
Construction and demolition debris	268,996
MSW wood and yard trimmings	200,783
Other removal residues	123,131
Unused primary mill residue	28,020
Total	**1,578,885**

Table 4-4 Woody biomass available in Indiana for energy conversion (Data source: ORNL [21])

Assuming a 9,000 Btu/lb energy density for wood, the energy available in the 1.6 million tons of wood residue annually is 28 trillion Btu. This is enough to supply approximately 1 percent of the 2,800 trillion Btu Indiana annual energy demand. If this woody biomass was burned in a 21 percent efficiency electricity power plant it would generate 1,700 GWh of electricity, which is approximately 1.5 percent of the 117,000 GWh Indiana annual electricity demand.

Two Indiana companies (Algaewheel and Stellarwind Bio Energy) are involved in algal biofuels development. In 2010 Algaewheel installed an algae based wastewater treatment system at the city of Reynolds as part of the Biotown USA initiative intended to make Reynolds energy self-sufficient by supplying all its needs from local renewable resources. Algaewheel Corporation has also carried out Indiana pilot projects in Seymour, Whitestown and at Purdue University's swine research facility [23, 24]. In 2009 Stellarwind Bio Energy LLC established a corporate headquarters and a small scale production facility to manufacture algal oil that can be refined to produce liquid transportation fuels [25].

4.5 Incentives for organic waste biomass

Federal Incentives

- Renewable Electricity Production Tax Credit (PTC) provides a 2.2 cents/kWh tax credit for wind, geothermal and closed-loop biomass and 1.1 cents/kWh for open-loop biomass, landfill gas municipal solid waste, small hydroelectric and marine energy technologies. Organic waste biomass falls under the open-loop category. As part of the February 2009 American Recovery and Reinvestment Act the PTC was modified to provide the option for qualified producers to take the federal business energy investment credit (ITC) or an equivalent cash grant from the U.S. Department of Treasury [26].
- Business Energy Investment Tax Credit (ITC) credits up to 30 percent of expenditures on qualifying renewable energy systems [26].
- Renewable Energy Production Incentive (REPI) provides financial incentive payments for electricity produced and sold by new qualifying renewable energy generation facilities. Qualifying facilities are eligible for annual incentive payments of 1.5 cents/kWh for the first ten years of production, subject to the availability of annual appropriations in each federal fiscal year of operation. The Energy Policy Act of 2005 expanded the list of eligible technologies and facilities owners, and reauthorized the payment for fiscal years 2006 through 2026 [26].
- Rural Energy for America Program (REAP) covers up to 25 percent of costs for eligible projects at certain types of institutions. Eligible renewable energy projects include wind, solar, biomass and geothermal; and hydrogen derived from biomass or water using wind, solar or geothermal energy sources. REAP incentives are generally available to state government entities, local governments, tribal governments, land-grant colleges and universities, rural electric cooperatives and public power entities, and other entities, as determined by USDA [26].
- 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 a state's percentage of the U.S. population [26].
- High Energy Cost Grant Program administered by the U.S. Department of Agriculture (USDA) is aimed at improving the electricity supply infrastructure in

rural areas having home energy costs exceeding 275 percent of the national average. Eligible infrastructure includes renewable resources generation. The USDA has allocated a total of $15.5 million for the 2010 funding cycle. The individual grants range from $75,000 to $5 million [27]

Indiana Incentives

- Clean Energy Portfolio Standard (CPS) passed in May 2011 sets a voluntary goal of 4 percent between 2013 and 2018, 7 percent between 2019 and 2024, and 10 percent clean energy by 2025, based on 2010 retail sales. Participation in CPS makes utilities eligible for incentives in order to pay for the compliance projects [26].
- Indianapolis Power & Light Co. – Rate REP Renewable Energy Production offers a "feed-in tariff" to facilities that produce renewable energy. IPL can purchase renewable energy and contract the production for up to 10 years. Biomass compensation is $6.18/kW per month plus $0.085/kWh [26].
- Northern Indiana Public Service Company – The NIPSCO feed-in tariff offers incentive rates for electricity generated from renewable resources for up to 10 years. The payment for biomass facilities is $106/kW. The tariff is an experimental one running until December 31, 2013. The total system-wide renewable capacity allowed under the tariff is 30 MW with 500 kW of the cap reserved for solar projects of capacity less than 10 kW and 500 kW reserved for wind projects of capacity less than 10 kW [28].
- Emissions Credits are received by electricity generators that do not emit NO_x and that displace utility generation are eligible to receive NO_x emissions credits under the Indiana Clean Energy Credit Program [29]. These credits can be sold on the national market.

4.6 References

1. Energy Information Administration (EIA). 2010 Annual Energy Review. http://www.eia.gov/totalenergy/data/annual/#renewable
2. U.S. Environmental Protection Agency. http://www.epa.gov/wastes/nonhaz/municipal/wte/index.htm
3. EPA. Landfill Methane Outreach Program. http://www.epa.gov/lmop/basic-info/index.html
4. AgSTar, Market opportunities for biogas recovery systems at U.S. livestock facilities. http://www.epa.gov/agstar/documents/biogas_recovery_systems_screenres.pdf
5. EPA Combined Heat and Power Partnership, Opportunities for and benefits of combined heat and power at wastewater treatment facilities. http://www.epa.gov/agstar/documents/biogas_recovery_systems_screenres.pdf

6. 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
7. 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
8. EERE. National algal biofuels technology roadmap. May 2010. http://www1.eere.energy.gov/biomass/pdfs/algal_biofuels_roadmap.pdf
9. Arizona Public Service news release, Technology development project fact sheet, FF010: emissions to fuel project, http://www.aps.com/_files/renewable/FF010EmissionstoFuelProject.pdf
10. EIA. Updated capital cost estimates for electricity generation plants. November 2010. http://www.eia.gov/oiaf/beck_plantcosts/pdf/updatedplantcosts.pdf
11. EIA. Electric Power Monthly June 2011 Edition. http://www.eia.gov/cneaf/electricity/epm/epm_sum.html
12. Haq, Zia. EIA. Biomass for electricity generation. July 2002. http://www.eia.doe.gov/oiaf/analysispaper/biomass/pdf/biomass.pdf
13. Energy Information Administration (EIA). Monthly Energy Review, April 2011. http://www.eia.doe.gov/totalenergy/data/monthly/
14. Energy Recovery Council. http://www.wte.org/userfiles/file/ERC_2010_Directory.pdf
15. Covanta Energy Corporation. http://www.covantaholding.com/site/locations/covanta-indianapolis.html
16. EIA. State Energy Data System (SEDS) 2008. Released June 2010. http://www.eia.doe.gov/emeu/states/state.html?q_state_a=in&q_state=INDIANA and June 2011 update http://205.254.135.24/state/seds/seds states.cfm/qstatea=IN&qstate=Indiana
17. U.S. Environmental Protection Agency, Landfill Methane Outreach Program (LMOP). http://www.epa.gov/lmop/projects-candidates/index.html
18. Kramer, Joseph M. Agricultural Biogas Casebook - 2004 update. http://www.renewwisconsin.org/biogas/.../Agricultural%20Biogas%20Casebook%202004%20Update.pdf
19. Fair Oaks Farm press release. June 14, 2011. http://www.fofarms.com/en/home#Scene_1
20. West Lafayette wastewater treatment plant. http://www.westlafayette.in.gov/department/division.php?fDD=11-185
21. ORNL. Indiana’s counties energy crops estimates. Data provided by Dr. Wallace Tyner, 2010.

22. 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/
23. http://ecolocalizer.com/2008/06/19/biotown-usa-is-total-energy-self-sufficency-possible/
24. http://www.algaewheel.com/2009/04/30/chris-limcaco-named-lugar-energy-patriot/
25. Stellarwind Bio Energy LLC. http://stellarwindbioenergy.com/?q=About%20Us
26. Database of State Incentives for Renewables and Efficiency (DSIRE). http://www.dsireusa.org/
27. U.S. Department of Agriculture, Rural Development, Electric Programs. http://www.usda.gov/rus/electric/hecgp/overview.htm
28. Northern Indiana Public Service Company. http://www.nipsco.com/About-us/Rates-Tariffs/Electric-Service-Tariff.aspx
29. Indiana Department of Environmental Management. Indiana clean energy credit program. http://www.in.gov/idem/4134.htm

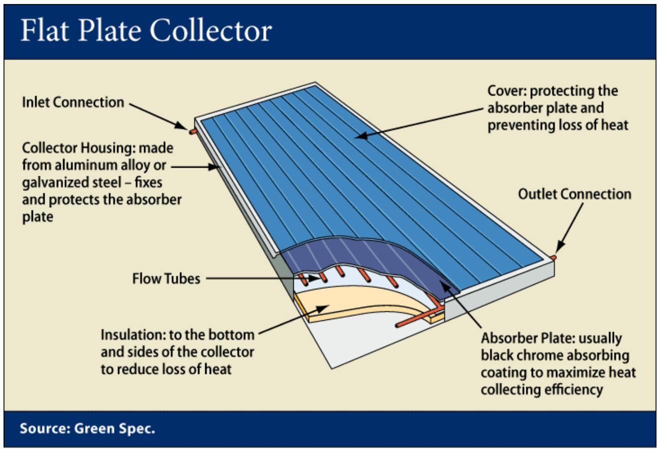
5. Solar Energy

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.

The capture of solar thermal energy is done using solar energy 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 large scale electricity generating projects while non-concentrating collectors are typically used for small scale projects that require relatively low temperatures, such as solar water heating for pools and homes.

The most commonly used non-concentrating collectors are flat-plate designs. Of the various flat-plate design types, all consist of (1) a flat-plate absorber, which intercepts and absorbs the solar energy, (2) a transparent cover (glazing) that allows solar energy to pass through but reduces heat loss from the absorber, (3) a heat-transport fluid (air or water) flowing through tubes to remove heat from the absorber, and (4) 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:** General layout of a flat-plate collector</u> (Source: Texas Energy Report [2])

The three main types of thermal concentrating solar power (CSP) systems are parabolic trough, solar power tower, and solar dish/engine system. Figure 5-2 shows the general layout of the three systems.

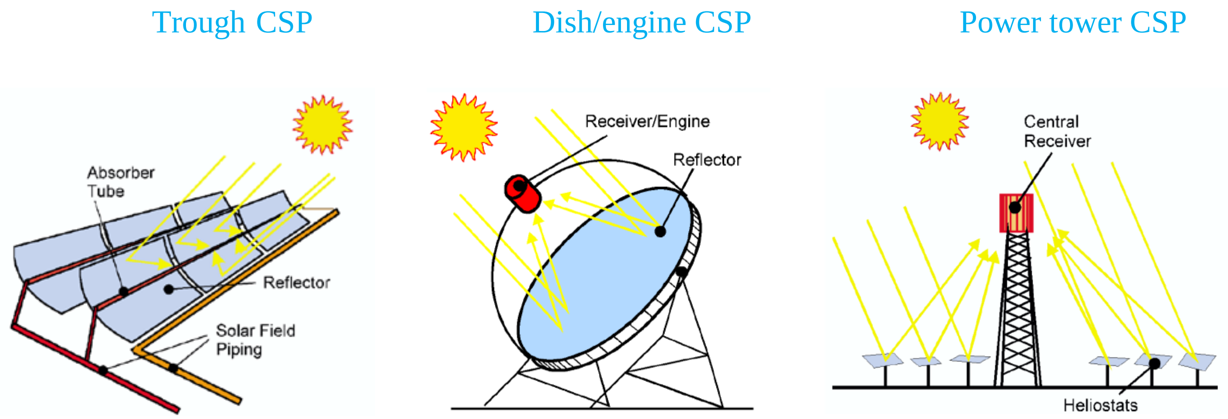


Figure 5-2: Types of concentrating solar power (CSP) collectors (Source: NREL [3])

The trough CSP system has trough shaped collectors with a parabolic cross section and a receiver tube located at the focal line of the trough. 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. Current trough systems range from small-scale (1 MW) to the large-scale 354 MW *Solar Electric Generating System* (SEGS) in California [4]. The trough system does not achieve as high temperatures as the power tower system and therefore has lower energy conversion efficiency. It is however the most developed and widely used CSP technology currently. Both the trough and the power tower systems have substantial cooling water requirements, a potentially limiting factor in the Southwestern desert terrain where the solar resource is most abundant [3].

A recently developed variation of the parabolic trough system is the linear Fresnel reflector. In this system the parabolic trough is approximated by a series of flat or slightly curved mirrors that focus the radiation onto a stationary conductor as shown in Figure 5-3.

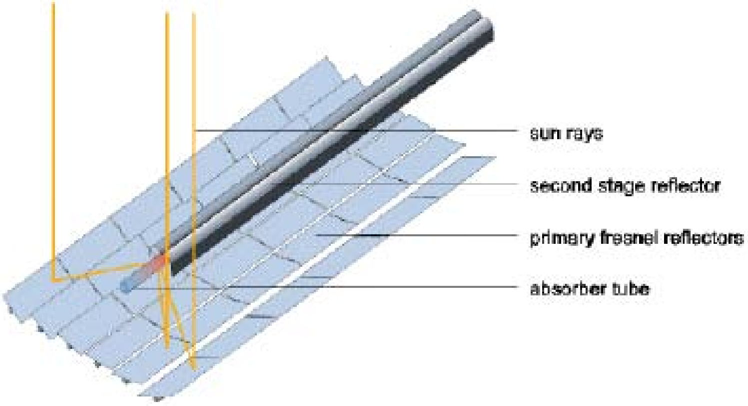


Figure 5-3: A linear Fresnel CSP collector (Source: IEA [6])

The power tower CSP system utilizes thousands of flat sun-tracking mirrors that concentrate the solar energy on a tower-mounted heat exchanger. This system avoids the heat lost during transportation of the working fluid to the central heat exchanger. 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 [4]. This system provides higher efficiency than the trough system because all sunlight is concentrated on a single point, which can then reach a very high temperature [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. 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 [5]. Many of these dish systems would have to be combined to make a utility-scale power plant. The dish/engine design results in the highest efficiency of the thermal designs; an array of dishes can produce 60 percent more electricity per acre than a trough system [3]. The dish/engine system does not use any cooling water which puts it at an advantage over the other two systems. However, it is the least developed of the three CSP technologies with several challenges to be overcome in the design of the reflectors and the solar collectors. Table 5-1 displays the main characteristics of the three CSP technologies [7].

		Parabolic Trough	**Power Tower**	**Dish/Engine**
Size		30 – 320$^{\#}$ MW	10 – 200$^{\#}$ MW	5 – 25$^{\#}$ kW
Operating Temperature (°C/°F)		390 / 734	565 / 1,049	750 / 1,382
Annual Capacity Factor$^{\#}$		23 – 50 percent	20 – 77 percent	25 percent
Net Annual Efficiency$^{\#}$		11 – 16 percent	7 – 20 percent	12 – 25 percent
Commercial Status		Available	Scale-up Demonstration	Prototype Demonstration
Technology Development Risk		Low	Medium	High
Storage Available		Limited	Yes	Battery
Hybrid Designs		Yes	Yes	Yes
Cost (1997$)	$\$/\text{m}^2$	630 - 275$^{\#}$	475 – 200$^{\#}$	3,100 – 320$^{\#}$
	$\$/\text{kW}$	4,000 – 2,700$^{\#}$	4,400 – 2,500$^{\#}$	12,600 – 1,300$^{\#}$
	$\$/\text{kW}_p^{+}$	4,000 – 1,300$^{\#}$	2,400 - 900$^{\#}$	12,600 – 1,100$^{\#}$

$^{\#}$ Values indicate changes over the 1997 – 2030 time frame.
$^{+}$ $\$/\text{kW}_p$ removes the effect of thermal storage (or hybridization for dish/engine).

Table 5-1: Characteristics of solar thermal electric power systems (Data source: EERE [7])

5.2 Economics of solar technologies

Figures 5-4 and 5-5 show the cost estimates of utility scale electricity generating technologies given in the November 2010 EIA update of generating plant costs [8]. Figure 5-4 shows the EIA estimate of the overnight[3] capital costs, and Figure 5-5 shows the estimate of the fixed and variable operating and maintenance (O&M) costs. The solar thermal technology's capital cost of approximately $4,700 /kW is in the mid-range among the renewable technologies between the low end of wind generation at $2,400/kW and the high end $8,200/kW for municipal solid waste based generation technology.

---

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

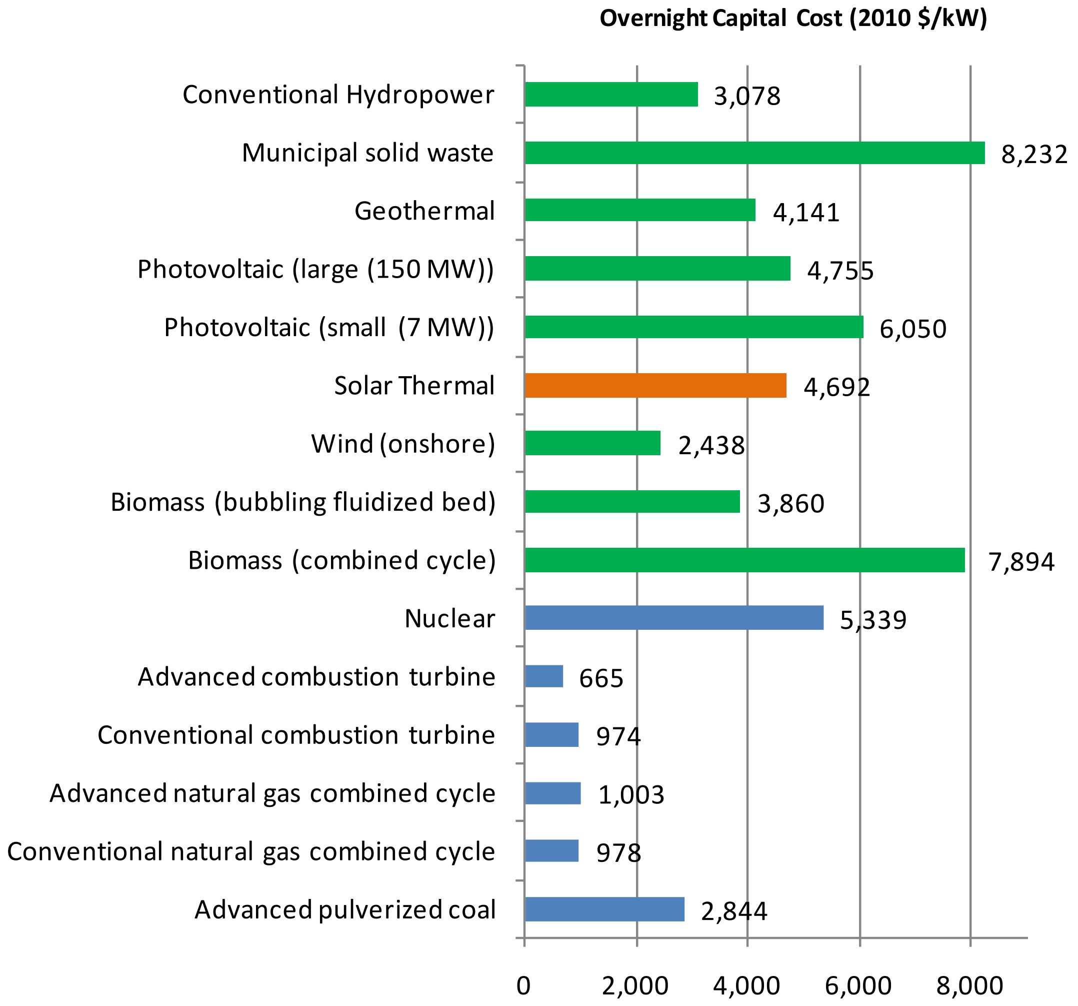


Figure 5-4: Capital cost of generating technologies (Data source: EIA [8])

As can be seen in Figure 5-5 solar thermal technology has moderate O&M cost, with a zero variable O&M cost and a fixed annual O&M cost of $64 /kW. This fixed annual O&M cost is higher than that of photovoltaic technologies which is estimated at $17 /kW for large scale photovoltaic plants and $26 /kW for small utility scale photovoltaic systems.

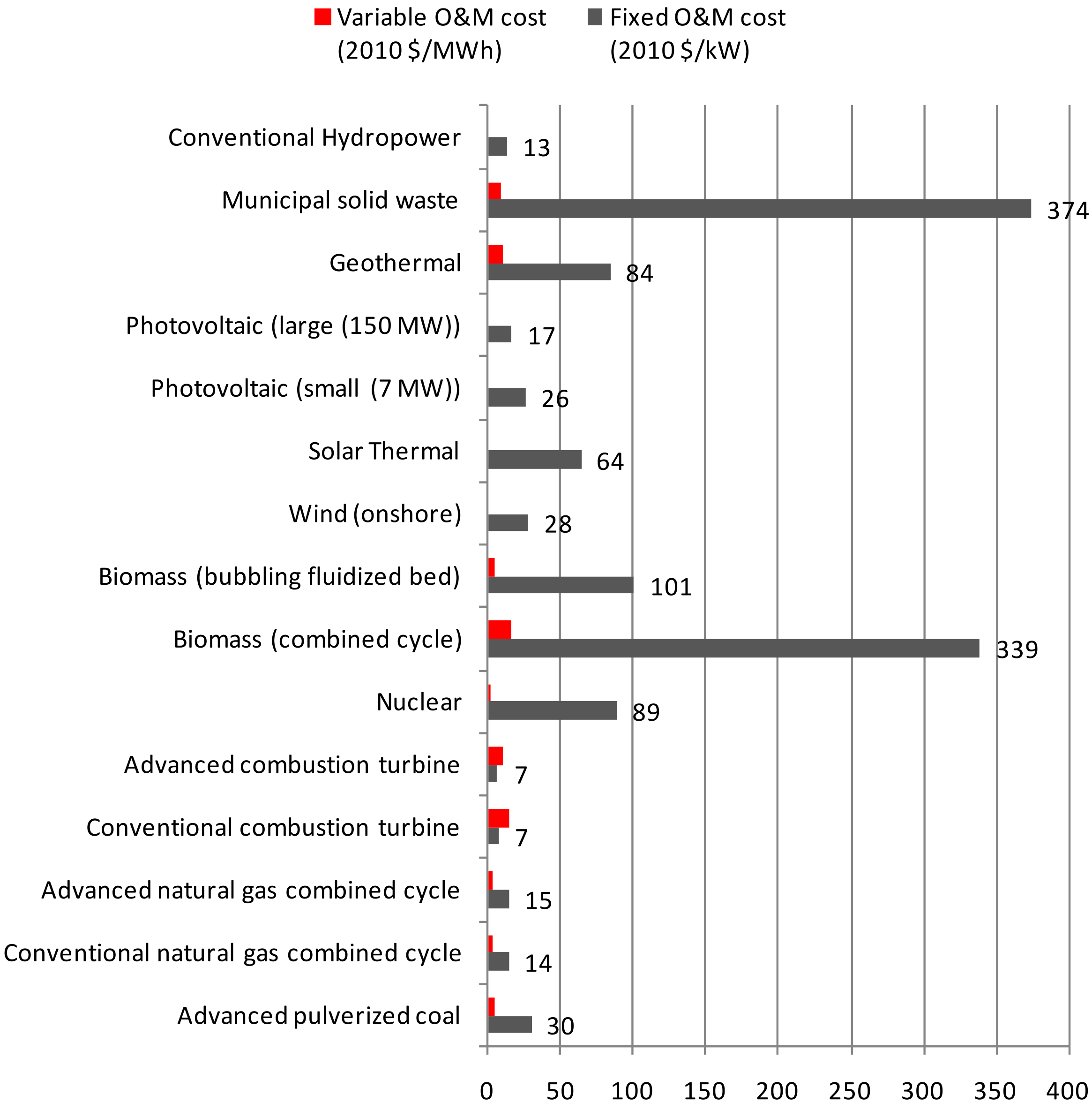


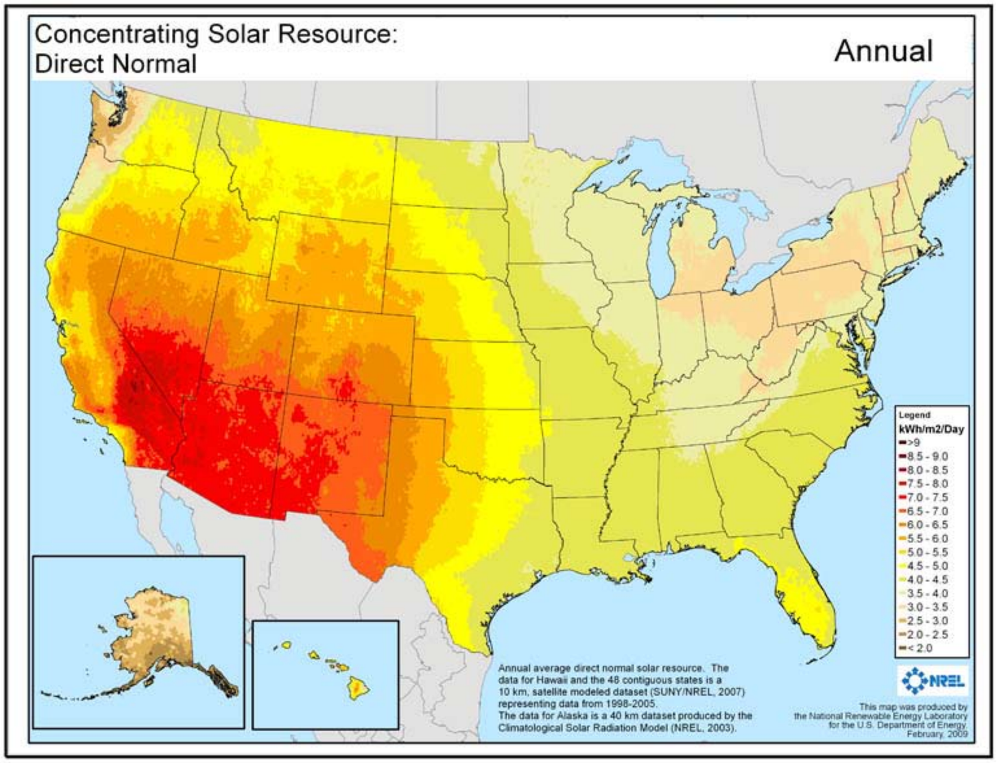
Figure 5-5: Operating and maintenance cost of generating technologies (Data source: EIA [8])

Table 5-1 shows the relative costs of the three common concentrating solar power systems. Although the power tower has the lowest capital cost of the three it is not yet a proven technology. The trough system, and in particular the parabolic trough system, is a commercially proven technology. Most of the CSP systems in commercial operation in the U.S. today, including the 354 MW SEGS system in California are based on parabolic trough technology [7, 9]. More details about the SEGS and other solar thermal systems in the U.S. are given in Section 5.3 of this report.

5.3 State of solar energy nationally

The combined effect of high capital cost and the intermittent nature of solar energy has kept its contribution to the national energy portfolio very low, lowest among all energy conversion technologies. In 2010 solar energy supplied approximately 0.1 percent of the total energy consumed in the U.S. and 0.03 percent of the electricity generated.

As can be seen in Figures 5-6 and 5-7, there are substantial solar resources available in the U.S., especially in the Southwestern region. Figure 5-6 shows the solar resources available to a stationary concentrating collector, and Figure 5-7 shows the solar resource available to a concentrating collector that tracks the sun throughout the day.



Annual average direct normal solar resource. The data for Hawaii and the 48 contiguous states is a 10 km, satellite modeled dataset (SUNY/NREL, 2007) representing data from 1998-2005. The data for Alaska is a 40 km dataset produced by the Climatological Solar Radiation Model (NREL, 2003).

This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy. February, 2009

Figure 5-6: Concentrating solar power resource in the U.S. (Source: NREL [10])

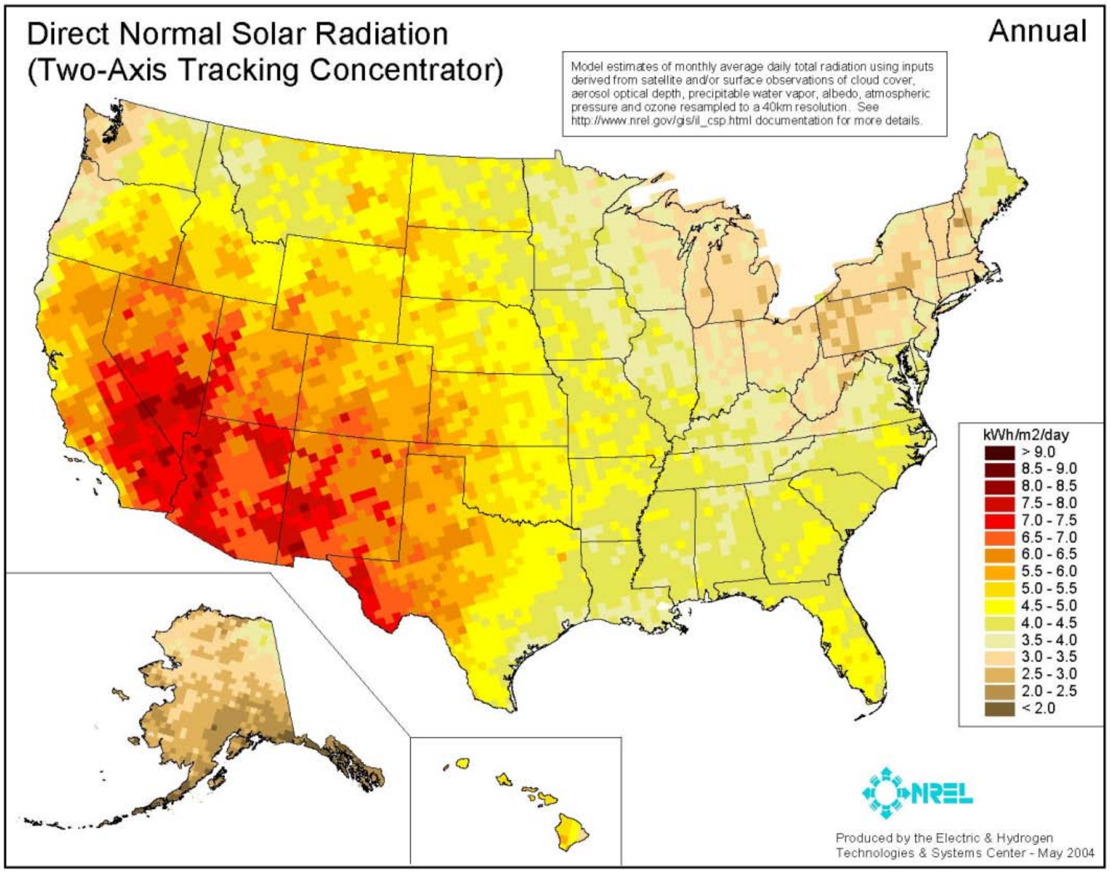


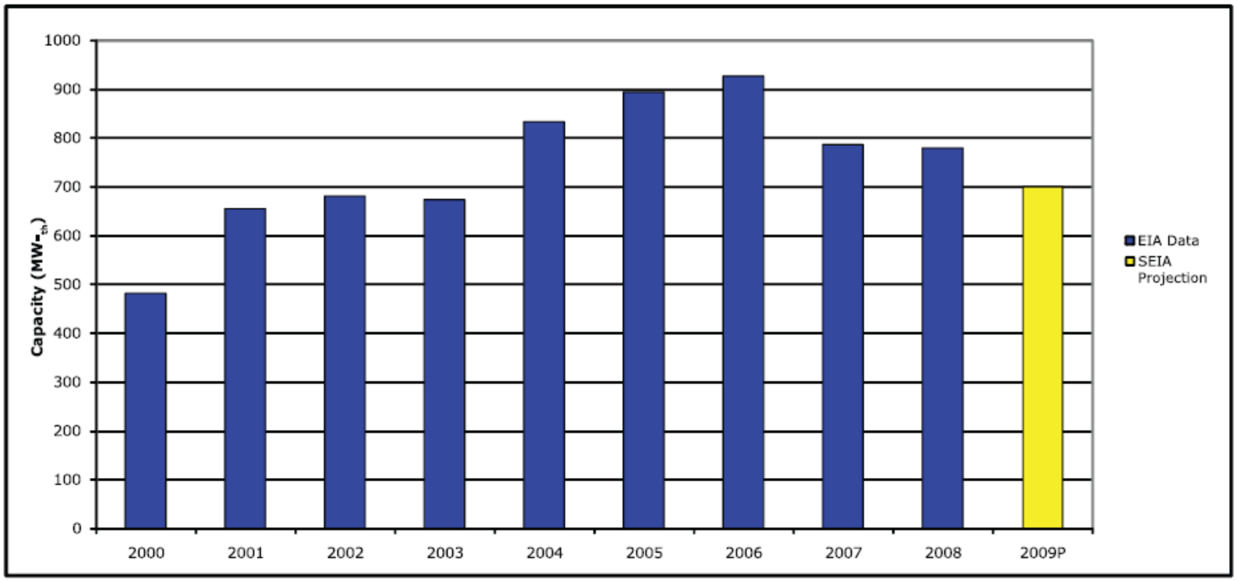
Figure 5-7: Solar resource available to a tracking concentrator (Source: NREL [10])

According to the *CSP today* website [11], there was a total of 433 MW of CSP capacity installed in the U.S. at the end of 2010. The largest and oldest of these is the 354 *MW Solar Electric Generation System* (SEGS) located in the Mojave Desert in California. SEGS consists of nine parabolic trough collector systems with associated power plants built between 1982 and 1991. The SEGS power plants are hybrid stations, equipped with natural gas fired boilers to supplement electricity generation when solar production is low [3, 9]. The next largest CSP is the 64 MW *Nevada Solar One* plant located in Boulder City, Nevada completed in 2007. Table 5-2 is a list of CSP power plants in the U.S. at the end of 2010. Four out of the seven systems with a total 421 MW capacity are of the parabolic trough type, one 5 MW facility is a linear Fresnel trough system, one 5 MW plant is a power tower system, and one 1.5 MW system is a dish/engine facility.

Name	Location	Developer	Capacity (MW)	Technology	Year online
Solar Energy Generating Systems (SEGS I - VIII)	Dagett, Kramer Junction, & Harper Lake California	NextEra Energy	354	Parabolic Trough	1982 -1991
Saguaro Power Plant	Red Rock, Tucson Arizona	Acciona (Solargenix)	1.2	Parabolic Trough	2005
Nevada Solar One	Boulder City Nevada	Acciona Solar Power	64	Parabolic Trough	2007
Holaniku, Keyhole Point	Kona, Hawaii	Sopogy	2	Parabolic Trough	2009
Kimberlina	Bakersfield California	AREVA /Ausra	5	Linear Fresnel	2008
Sierra SunTower	Lancaster California	eSolar	5	Power Tower	2009
Maricopa Solar Project	Peoria Arizona	Tessera Solar	1.5	Dish Engine	2010

Table 5-2: Concentrating solar power plants in the U.S. (Data source: CSP today [11])

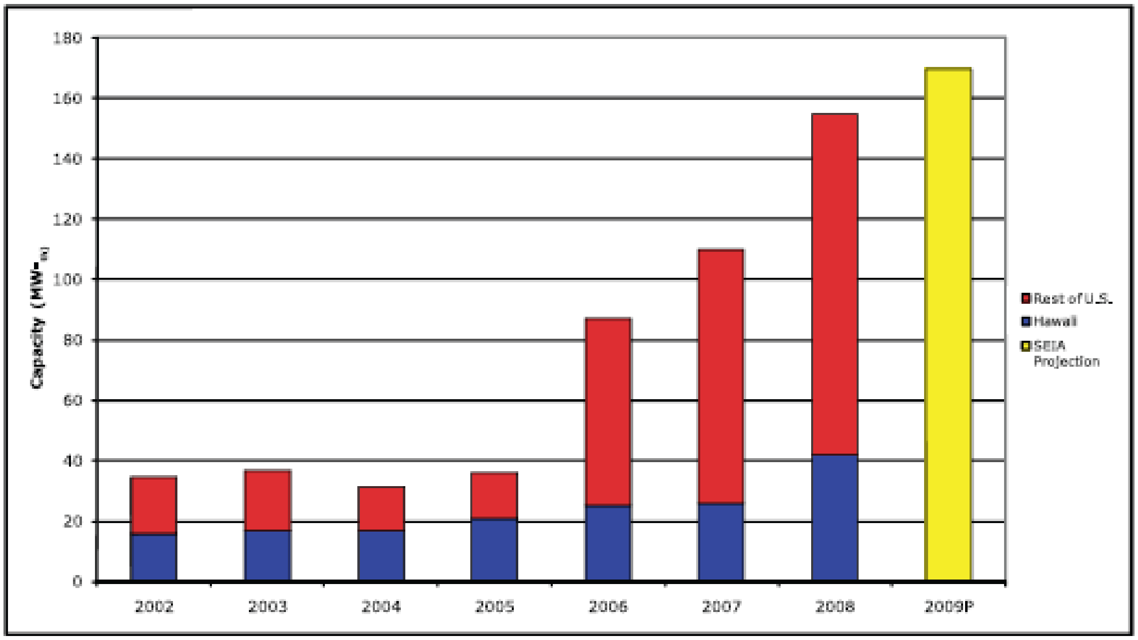
According to the *Solar Energy Industries Association* (SEIA) [12], the most widely used application for solar thermal energy in the U.S. is for heating of swimming pools. These solar pool heating systems can either be stand alone units or in parallel with a conventional heater [12]. Figure 5-8 shows the capacity installed annually, in thermal megawatts (MW_{th}), of solar thermal systems used for heating swimming pools.



*Capacity in thermal megawatts (MW_{th})

Figure 5-8: Annual installed U.S. capacity for solar pool heating (2000-2009) (Source: IREC [13])

The other major users of solar thermal energy are water heating and space heating/cooling. Figure 5-9 shows the annual installed capacity of solar thermal systems used for water heating and space heating/cooling from 2002 to 2009.



*Capacity in thermal megawatts (MW$_{th}$)

Figure 5-9: Annual installed U.S. capacity for solar heating and cooling (2002-2009) (Source: IREC [13])

5.4 Solar energy in Indiana

As can be seen in the U.S. solar radiation maps (Figures 5-5 and 5-6) Indiana is in a region of the country that has the lowest annual average solar radiation. It is therefore very unlikely that it would be the location of choice for multi-megawatt electricity generating plants such as the 354 MW SEGS facility in California or the 64 MW Nevada Solar One plant referred to in Section 5.3. However there is some potential for water heating application of solar thermal technologies. According to the EIA 2011 solar thermal collector manufacturing report, Indiana was the 20th top destination for solar thermal collectors in 2009 [14].

Figure 5-10 shows the solar radiation available to a concentrating collector in Indiana and Figure 5-11 the radiation available to a flat collector facing south. As can be seen in Figure 5-11, the Southern half of the state has more radiation available to flat plate collectors typically used for water heating applications.

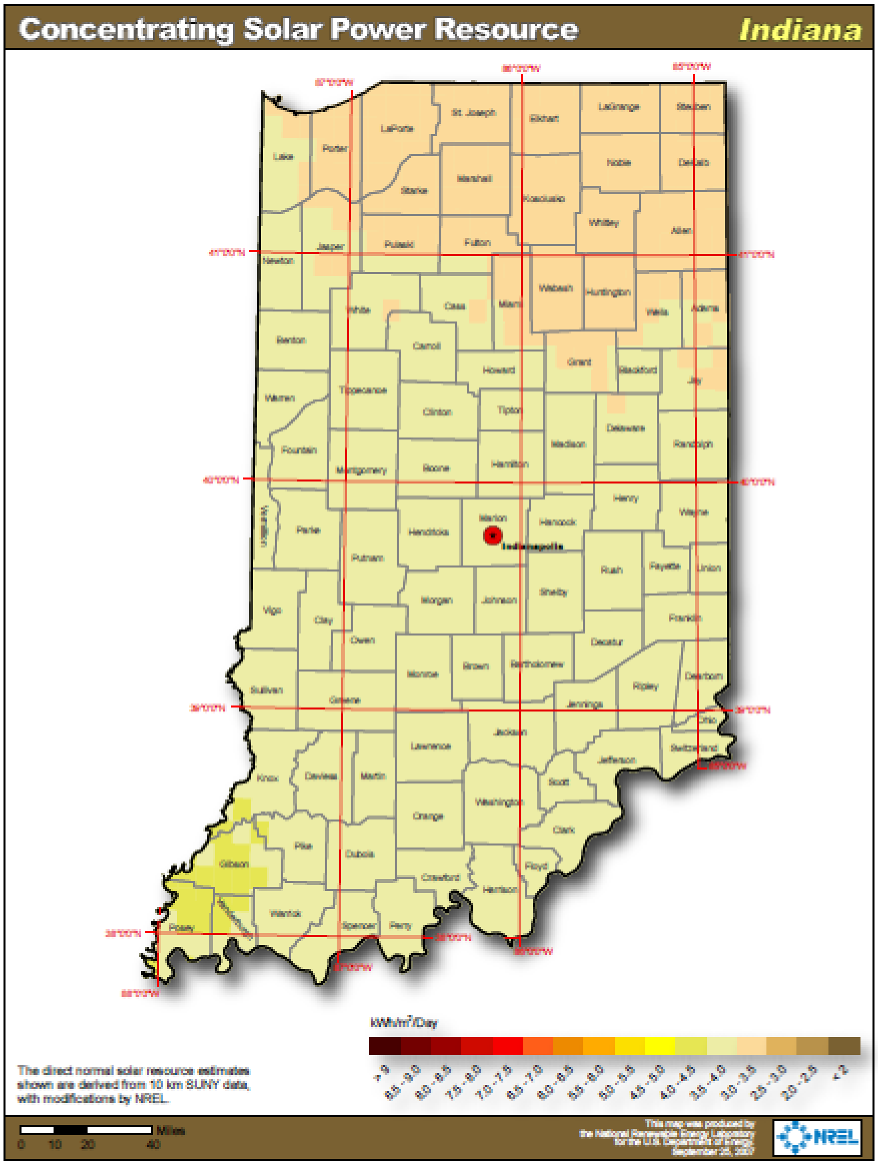


Figure 5-10: Direct normal solar radiation (two-axis solar concentrator)
(Source: NREL [15])

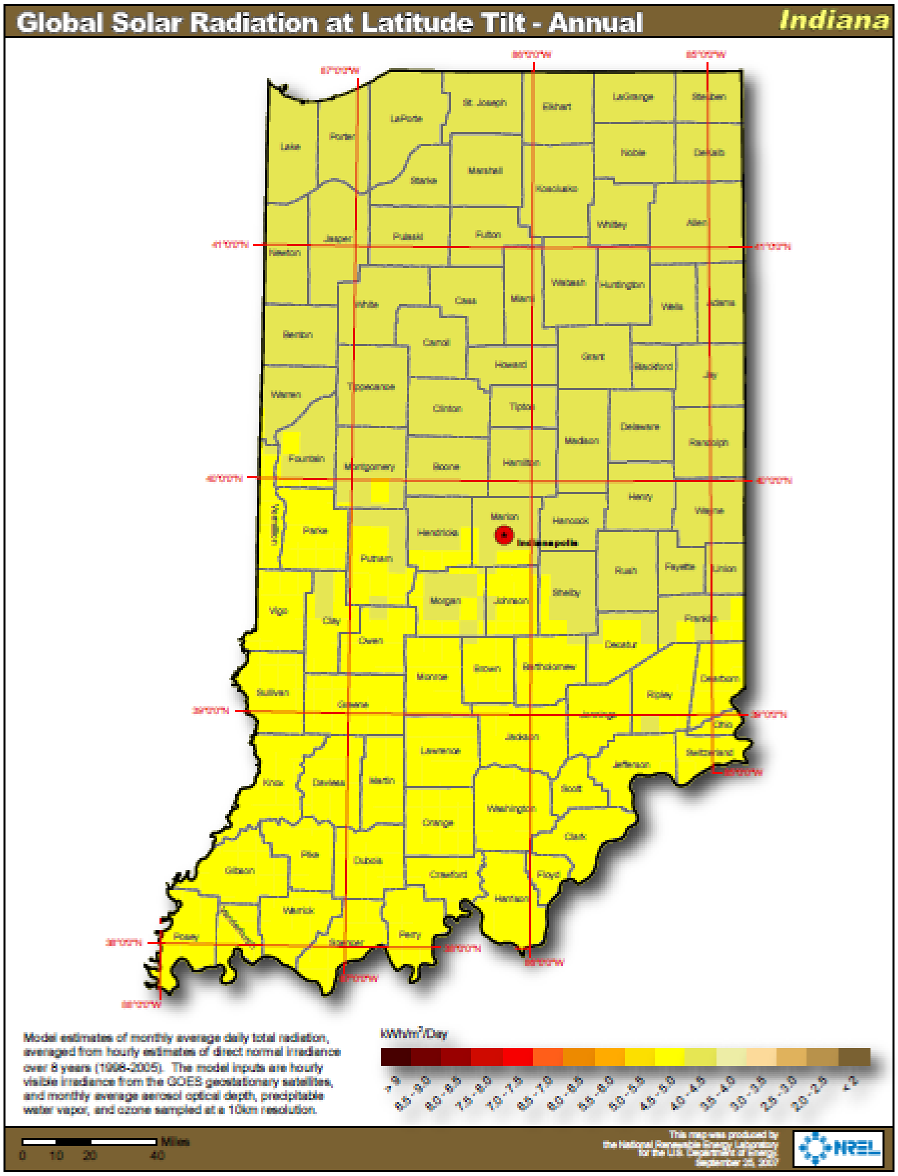


Figure 5-11: Direct normal solar radiation (flat-plate collector) (Source: NREL [15])

5.5 Incentives for solar energy

The following available incentives could help increase use of solar energy within Indiana:

Federal Incentives

- Business Energy Investment Tax Credit (ITC) credits up to 30 percent of expenditures on solar systems. 2009 American Recovery and Reinvestment Act provided for treasury cash grant in lieu of the ITC [16].

- Energy Efficiency Mortgage can be used by homeowners to finance a variety of energy efficiency measures, including renewable energy technologies, in a new or existing home. The federal government supports these loans by insuring them through FHA or VA programs. This allows borrowers who might otherwise be denied loans to pursue energy efficient improvements, and it secures lenders against loan default and provides them with confidence in lending to customers who would usually have been denied credit [16].
- Modified Accelerated Cost-Recovery System (MACRS) allows businesses to recover investments in solar, wind and geothermal property through depreciation deductions. The MACRS establishes a set of class lives for various types of property, ranging from three to fifty years, over which the property may be depreciated. For solar, wind and geothermal property placed in service after 1986, the current MACRS property class life is five years [16].
- Qualified Energy Conservation Bonds (QECBs) are qualified tax credit bonds and are allocated to each state based upon their state's percentage of the U.S. population. The states are then required to allocate a certain percentage to "large local governments". In February 2009, these funds were expanded to $3.2 billion [16].
- Renewable Energy Production Incentive (REPI) provides financial incentive payments for electricity produced and sold by renewable energy generation facilities owned by non-profit groups, public utilities, or state governments [16].
- Residential Energy Conservation Subsidy Exclusion established by Section 136 of the IRS Code, makes direct and indirect energy conservation subsidies provided by public utilities nontaxable [16].
- Rural Energy for America Program (REAP) covers up to 25 percent of costs for eligible projects at certain types of institutions [26]. Eligible renewable energy projects include wind, solar, biomass and geothermal; and hydrogen derived from biomass or water using wind, solar or geothermal energy sources. REAP incentives are generally available to state government entities, local governments, tribal governments, land-grant colleges and universities, rural electric cooperatives and public power entities, and other entities, as determined by USDA.
- Value-Added Producer Grant Program support planning activities and provide working capital for farm-based renewable energy projects. Independent producers, agricultural producer groups, farmer or rancher cooperatives, and majority-controlled producer-based business ventures are eligible for the program. Previously awarded grants supported energy generated on-farm through the use of agricultural commodities, wind power, water power, or solar power [17].
- High Energy Cost Grant Program administered by the U.S. Department of Agriculture (USDA) is aimed at improving the electricity supply infrastructure in rural areas having home energy costs exceeding 275 percent of the national average. Eligible infrastructure includes renewable resources generation [18].

Indiana Incentives

- Net metering rule: Renewable resource facilities with a maximum capacity of 1 MW are qualified for net metering. The net excess generation is credited to the customer in the next billing cycle [16].
- Renewable Energy Property Tax Exemption provides property tax exemptions for solar thermal, wind, hydroelectric and geothermal systems [16].
- 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 [16].
- Clean Energy Portfolio Standard (CPS) passed in May 2011 sets a voluntary goal of 4 percent between 2013 and 2018, 7 percent between 2019 and 2024, and 10 percent clean energy by 2025, based on 2010 retail sales. Participation in CPS makes utilities eligible for incentives in order to pay for the compliance projects [16].
- Emissions Credits are available by electricity generators that do not emit NO_x and that displace utility generation are eligible to receive NO_x emissions credits under the Indiana Clean Energy Credit Program [28]. These credits can be sold on the national market.
- Indiana Solar Thermal Grant Program provides cost share grants to public, non-profit and business sectors for solar water heating systems [20].
- Northern Indiana Public Service Company – The NIPSCO feed-in tariff offers incentive rates for electricity generated from renewable resources. The payments for solar facilities are \$0.30/kW for solar facilities with a capacity below 10 kW and \$0.26/kW for facilities up to 2 MW. The tariff is experiment running until December 31, 2013. The allowable generator generating unit size under the tariff is between 5 and 5,000 kW and the total system-wide capacity allowed is 30 MW. 500 kW of the total system-wide cap is reserved for solar projects of capacity less than 10 kW [21].

5.6 References

6. U.S. Department of Energy, Energy Efficiency and Renewable Energy (EERE). http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=12850
7. State of Texas.Window on State Government.Solar Energy. http://www.window.state.tx.us/specialrpt/energy/renewable/solar.php
8. National Renewable Energy Laboratory (NREL). Fuel from the sky: solar energy's potential for Western energy supply. www.nrel.gov/docs/fy02osti/32160.pdf
9. 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

10. Sandia National Laboratory, Concentrating Solar Power. http://www.sandia.gov/csp/cspoverview.html
11. International Energy Agency. SolarPACES solar thermal power systems network. http://www.solarpaces.org/CSP_Technology/csp_technology.htm
12. EERE. Renewable Energy Technology Characterizations. http://www1.eere.energy.gov/ba/pba/tech_characterizations.html
13. U.S. Energy Information Administration (EIA). Updated capital cost estimates for electricity generation plants. November 2010. http://www.eia.gov/oiaf/beck_plantcosts/pdf/updatedplantcosts.pdf
14. NEXTERA Energy Resources. Solar Electric Generating Systems. www.nexteraenergyresources.com/pdf_redesign/segs.pdf
15. NREL. http://www.nrel.gov/gis/solar.html
16. CSP today. http://www.csptoday.com/usa/pdf/CSPTodayUSMap2011.pdf
17. Solar thermal industries association. Solar thermal factsheet. http://www.seia.org/cs/solar_heating_cooling
18. Interstate Renewable Energy Council (IREC). U.S. solar market trends 2009. http://irecusa.org/wp-content/uploads/2010/07/IREC-Solar-Market-Trends-Report-2010_7-27-10_web1.pdf
19. EIA. Shipments of Solar Thermal Collectors by Destination. http://www.eia.gov/cneaf/solar.renewables/page/solarreport/table2_6.html
20. NREL. MapSearch. http://www.nrel.gov/gis/mapsearch/
21. Database of State Incentives for Renewables and Efficiency (DSIRE). http://www.dsireusa.org/
17. Center for Rural Affairs. Value added producer grants program fact sheet, 2007. http://www.cfra.org/resources/vapg/fact_sheet
18. U.S. Department of Agriculture, Rural Development, Electric Programs. http://www.usda.gov/rus/electric/hecgp/overview.htm
19. Indiana Department of Environmental Management. Indiana clean energy credit program. http://www.in.gov/idem/4134.htm
20. Indiana Office of Energy Development. State energy plane - current programs. http://www.in.gov/oed/2588.htm
21. Northern Indiana Public Service Company. http://www.nipsco.com/About-us/Rates-Tariffs/Electric-Service-Tariff.aspx

6. Photovoltaic Cells

6.1 Introduction

Unlike solar thermal systems, photovoltaic (PV) cells allow for the direct conversion of sunlight into electricity. The photovoltaic cell is a non-mechanical device constructed from semiconductor materials (see Figure 6-1). 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].

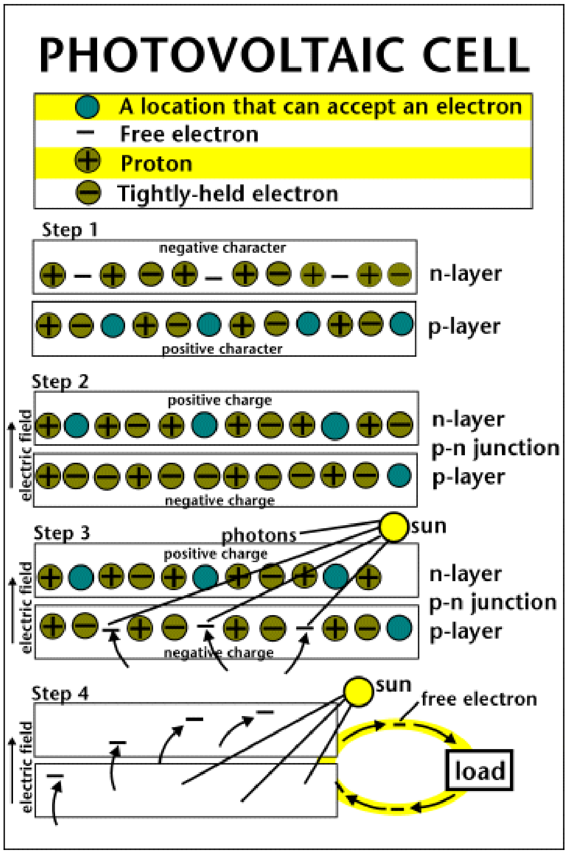


Figure 6-1: Photovoltaic cell operation (Source: EIA [1])

The photovoltaic cell is the basic building block of a PV system. The individual cells range in size from 0.5 to 4 inches across with a power output of 1 to 2 watts. To increase the power output of the PV unit, the cells are usually electrically connected into a packaged weather-tight module. About 40 cells make up a module, providing enough power for a typical incandescent light bulb. These modules could further be connected into arrays to increase the power output. Hundreds of arrays could be connected together for larger power applications. The performance of PV units depends upon sunlight, with more sunlight leading to higher power output. Figure 6-2 illustrates how cells can combine to make a module, and how modules are combined to make an array [2].

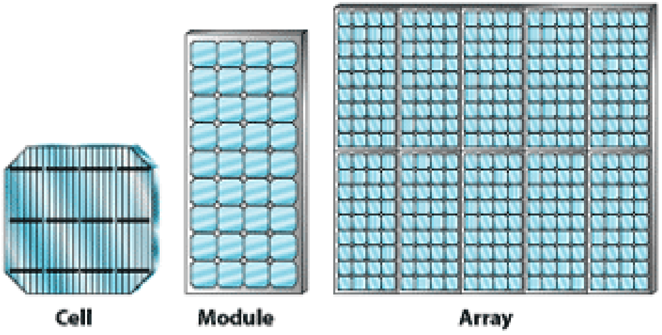


Figure 6-2: Illustration of a cell, module and array of a PV system (Source: EERE [2])

Simple PV systems are used to power calculators and wrist watches, whereas more complicated systems are used to provide electricity to pump water, power communication equipment, and even provide electricity to houses and buildings.

There are currently three major types of PV cells: crystalline silicon-based, thin film-based, and concentrator-based. A new experimental type of cell, the spheral cell, aims to reduce the amount of silicon used to construct solar cells; spheral cells remain mostly in the research phase. Silicon PV cells, the most common type, typically cost more than thin film cells but are more efficient [3]. Efficiency ranges of 13 to 17 percent are normal, though Sanyo announced in 2007 that they had built a silicon-based cell that achieves 22 percent efficiency [4]. Thin-film cells have a normal efficiency of 10 percent. Concentrator cells and modules utilize a lens to gather and converge sunlight onto the cell or module surface [3].

PV cells can be arranged into two different types of arrays: flat-plate PV arrays and concentrating PV arrays. Flat-plate PV arrays can be mounted at a fixed-angle facing south, or they can be mounted on a tracking device that follows the sun throughout the day. Concentrating PV (CPV) arrays use a lens to focus sunlight onto cells. CPV arrays cannot use diffuse sunlight and as such are generally installed on tracking devices. The advantage of CPV arrays is that they use less semiconductor material than flat-plate arrays to produce the same output. A disadvantage, though, is that because they are unable to make use of indirect sunlight, CPV arrays can only be used in the sunniest parts of the country, unlike the broad geographical range of flat-plate PV arrays [5].

NREL is actively researching CPV technology, especially as an alternative to the dish/engine solar thermal system discussed in Section 5. CPV systems have no moving parts (besides the tracking device) and no heat transfer, making them potentially more reliable than dish/engine systems. Also, CPV systems result in efficiencies greater than 40 percent and a reduction in the use of expensive semiconductor materials, lowering the effective total cost compared to flat-plate PV systems. The cost of CPVs is similar to that of solar thermal technologies, and CPVs may eventually be used at the utility-scale. NREL is currently focusing on the development of multi-cell packages (dense arrays) to improve overall performance and reliability [6].

Figure 6-3 illustrates the historical progress of solar cell efficiencies until 2009. As shown in the graph, experimental multi-junction concentrator-based PV cells reported the highest efficiency levels, approximately 40 percent.

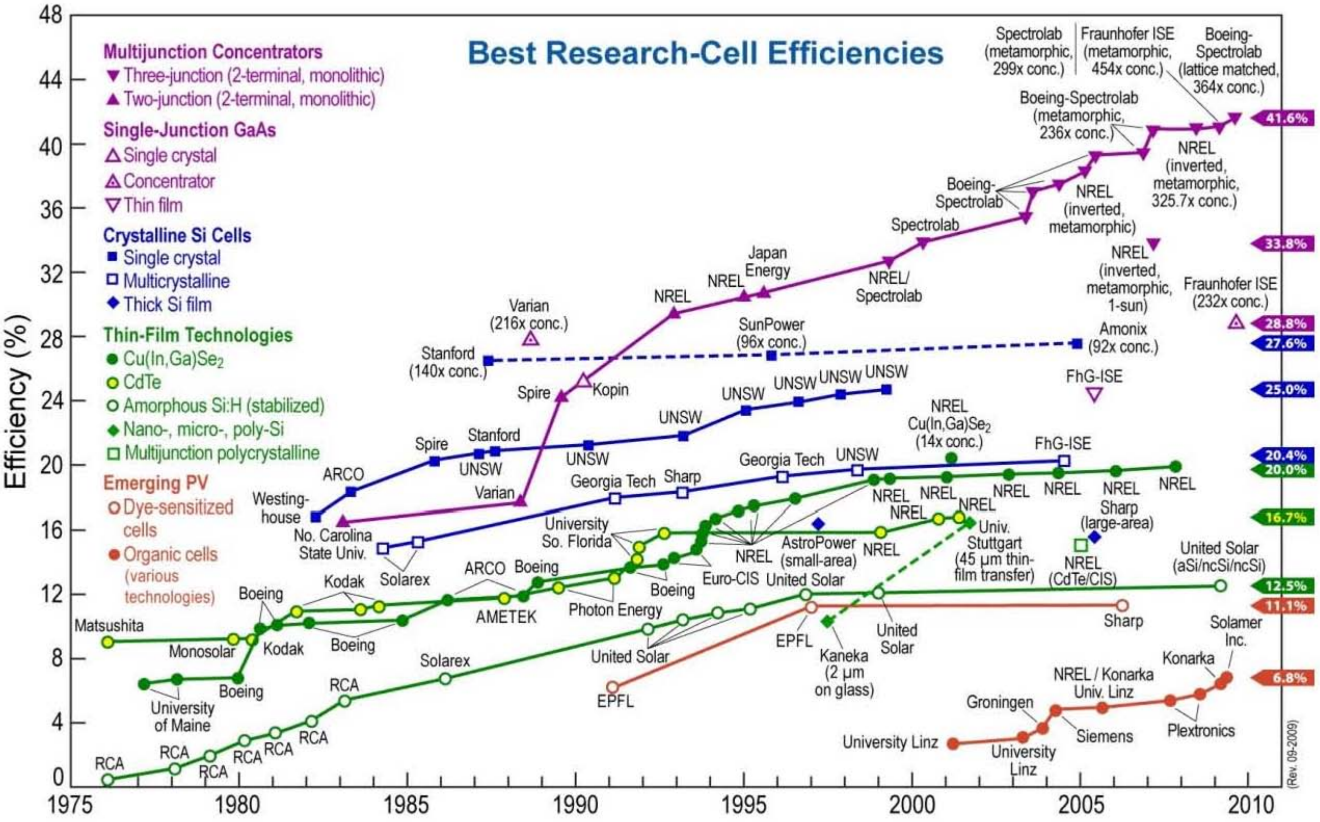


Figure 6-3: Improvements in solar cell efficiency, by system, from 1976 to 2009 (Source: NREL [7])

In addition to multi-junction CPV cells, other advanced approaches to solar cells are under investigation. For example, dye-sensitized solar cells use a dye-impregnated layer of titanium dioxide to generate a voltage as opposed to the semiconducting materials used in most solar cells currently in the industry. Because titanium dioxide is fairly inexpensive, it offers the potential to significantly reduce the cost of solar cells. Other advanced approaches include polymer (or plastic) solar cells and photo electrochemical cells, which produce hydrogen directly from water in the presence of sunlight [8].

Flat-plate PV arrays, CPVs, and other types of solar PV technology are used in many different ways across the U.S. In 1998, a study was carried out by EIA to determine trends in the U.S. photovoltaic industry. The report divided the national PV market into several niche markets that were labeled and described as follows [9]:

- <u>Building Integrated Photovoltaics (BIPV):</u> These are PV arrays mounted on building roofs or facades. For residential buildings, BIPV capacities may reach up to 4 kW per residence. Systems may consist of conventional PV modules or PV shingles. This market segment includes hybrid power systems, combining diesel generator, battery, and photovoltaic generation capacity for off-grid remote cabins.
- <u>Non-BIPV Electricity Generation (grid interactive and remote):</u> This includes distributed generation (e.g., stand-alone PV systems or hybrid systems including diesel generators, battery storage, and other renewable technologies), and water pumping power for irrigation systems. The U.S. Coast Guard has installed over 20,000 PV-powered navigational aids (e.g., warning buoys and shore markers) since 1984.
- <u>Communications:</u> PV systems provide power for remote telecommunications repeaters, fiber-optic amplifiers, rural telephones, and highway call boxes. Photovoltaic modules provide power for remote data acquisition for both land-based and offshore operations in the oil and gas industries.
- <u>Transportation:</u> Examples include power on boats, in cars, in recreational vehicles, and for transportation support systems such as message boards or warning signals on streets and highways.
- <u>Consumer Electronics:</u> A few examples are calculators; watches; portable and landscaping lights; portable, lightweight PV modules for recreational use; and battery chargers.

Some advantages of using PV systems are:

- Sunlight is a free and inexhaustible resource;
- The lack of moving parts[4] results in lower maintenance costs; and
- The modular nature of PV arrays allow for variable output power configurations.

The main disadvantages to using PV systems are:

- The sun is an intermittent source of energy, not available at night and reduced output on cloudy days; and
- They have high capital cost relative to traditional technologies.

---

[4] There are no moving parts for fixed-orientation PV units and minimal slow-moving parts for tracking PV units.

Despite the intermittent nature of sunlight, PV has the added potential as a supplier of electricity during periods of peak demand, since it produces more electricity on sunny days when air conditioning loads are the greatest.

6.2 Economics of PV systems

Figure 6-4 shows EIA's estimates of the overnight[5] capital cost of a utility scale photovoltaic electricity generating plant alongside other utility scale electricity generating technologies. As can be seen in the figure, the photovoltaic capital cost is one of the highest. The smaller of the two systems (7 MW) considered by EIA has a capital cost of $6,050 /kW, which is third highest after municipal solid waste's estimated cost of $8,232/kW and biomass combined cycle's estimated cost of $7,894 /kW. The larger of the two PV systems (150 MW) considered by EIA has a lower estimated capital cost of $4,755/kW, which is still among the highest, ranking fourth after municipal solid waste, biomass combined cycle, large PV and nuclear, with nuclear power's estimated cost at $5,339 /kW.

---

[5] Overnight capital cost "*is an estimate of the cost at which a plant could be constructed assuming that the entire process from planning through completion could be accomplished in a single day*" [10]. The overnight cost concept is used to avoid the impact of the differences in financing methods chosen by project developers on the estimated costs.

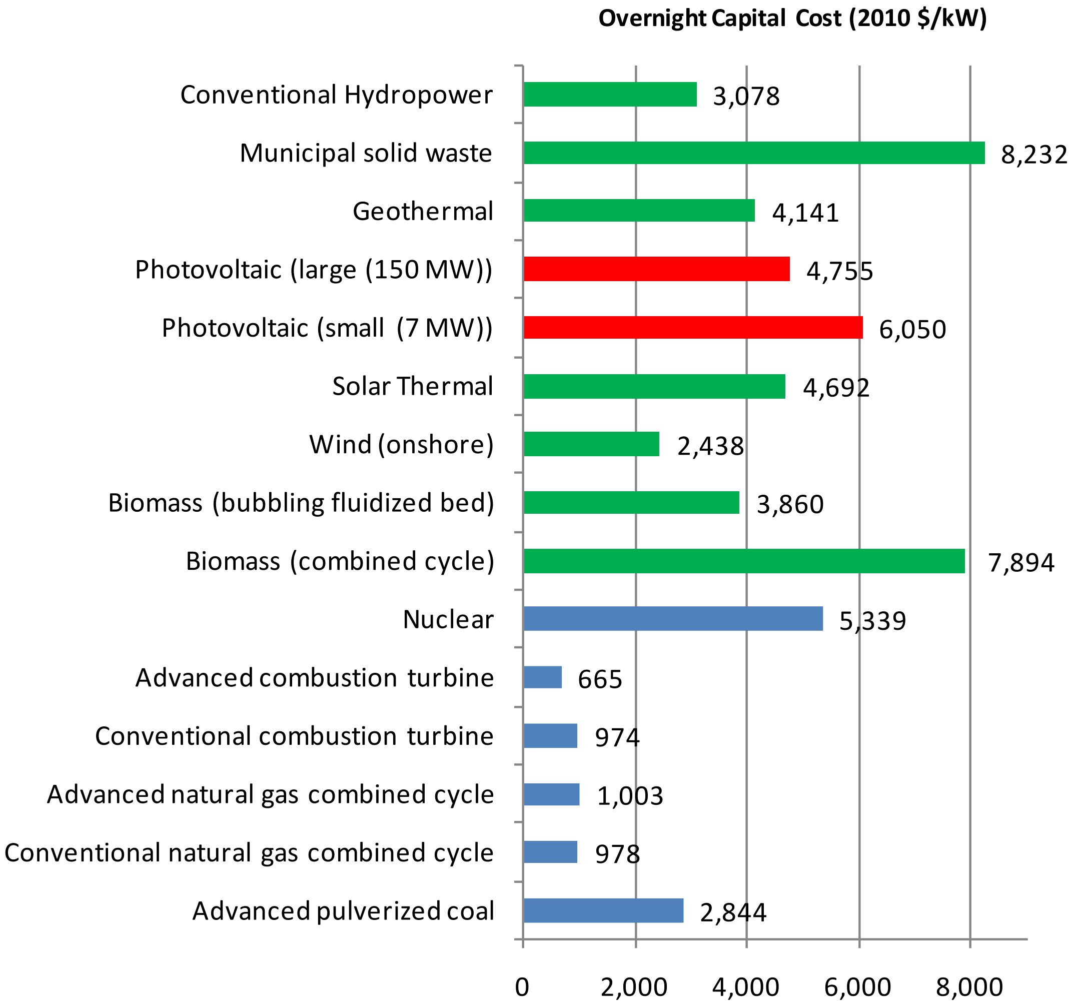


Figure 6-4: Capital cost of generating technologies (Data source: EIA [10])

Figure 6-5 shows the capacity-weighted average costs of actual systems installed in the U.S. between 1998 and 2009 compiled by the Lawrence Berkeley National Laboratory [11]. According to the Berkeley report, the approximately 78,000 PV systems in the dataset represent 70 percent of all grid-connected PV systems installed in the U.S. through 2009. The size of the systems in the dataset range from as small as 100 watts to 2.3 MW with approximately 90 percent of the systems in the dataset having a capacity of 10 kW or less. As can be seen from the Figure, the capacity-weighted average installed cost prior to any financial incentives has been dropping steadily from $10,800/kW in 1998 to $7,500/kW in 2009.

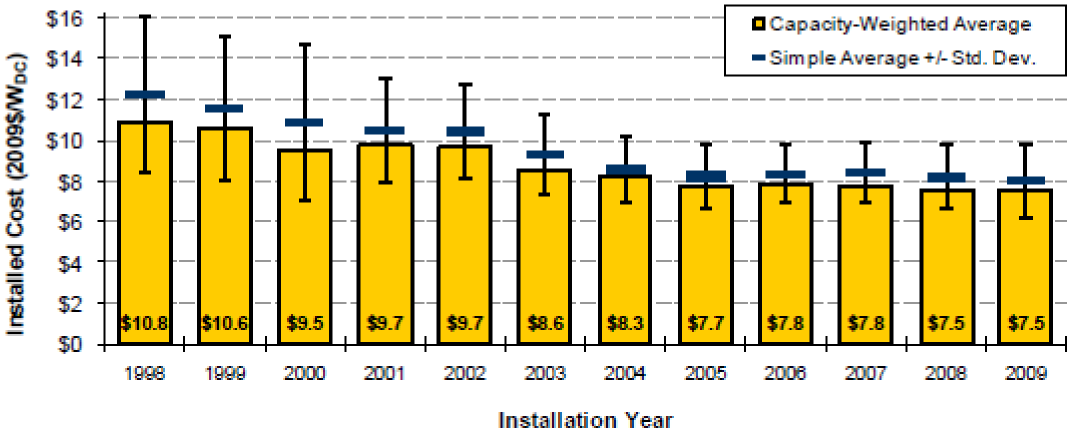


Figure 6-5: Installed cost trends over time (Source: Berkeley [11])

Figure 6-6 shows the breakdown of the installed costs for PV systems installed in 2009 for the three system ranges in the dataset. In all three size ranges the cost of the PV module was slightly over half the total system's installed cost. The 'other' costs category ranges from 36 to 42 percent of the total system cost and includes such items as mounting hardware, labor, overhead and installer profit.

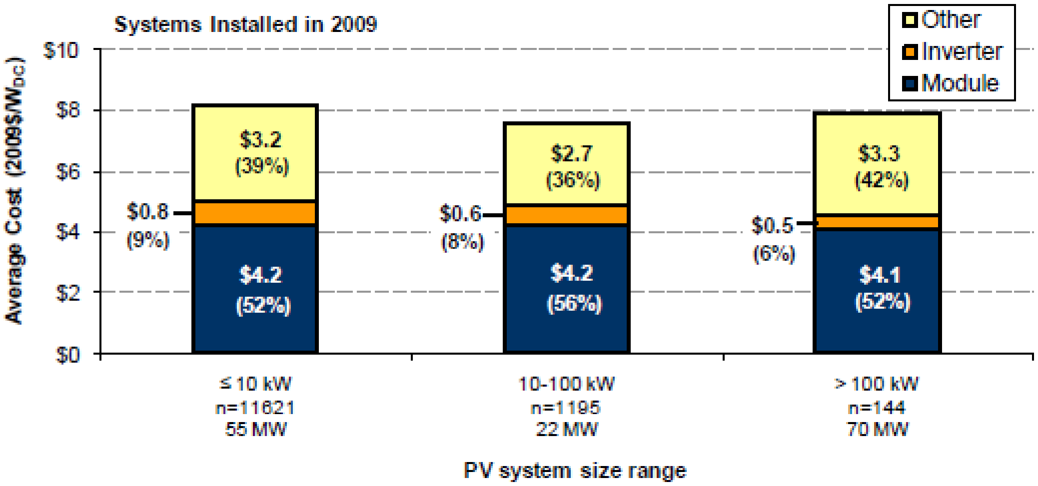


Figure 6-6: Module, inverter, and other costs (Source: Berkeley [11])

6.3 State of PV systems nationally

Most PV systems in use today use non-concentrating flat plate collectors. Since flat plate collectors can absorb and make use of both direct and indirect solar radiation, the potential areas where they can be used extends across a much wider geographical region of the U.S. than the sunny Southwest. Figure 6-7 shows the solar resource availability across the U.S. for a flat plate solar collector facing south at the appropriate angle. Figure 6-8 shows the solar resource availability for a two-axis tracking concentrating collector. At the writing of this report SUFG was aware of only one grid-connected PV power plant in operation in the U.S. using concentrating lens technology, the 1 MW Chevron Mining plant in Questa, New Mexico.

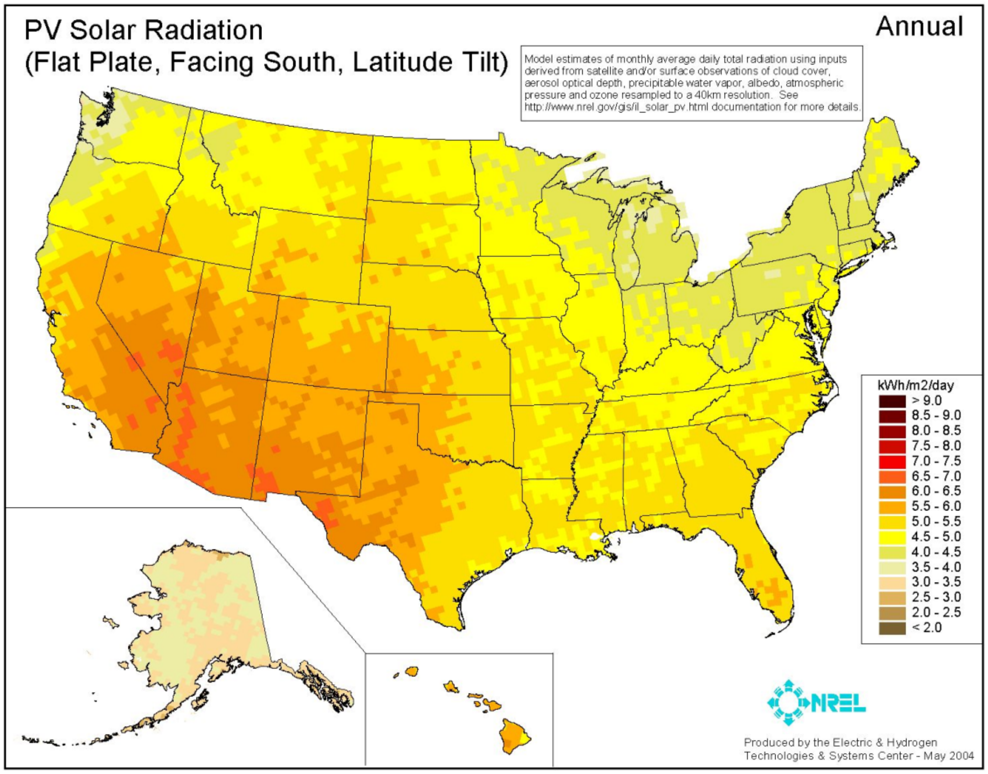


Figure 6-7: Annual average solar radiation for a flat-plate collector (Source: NREL [12])

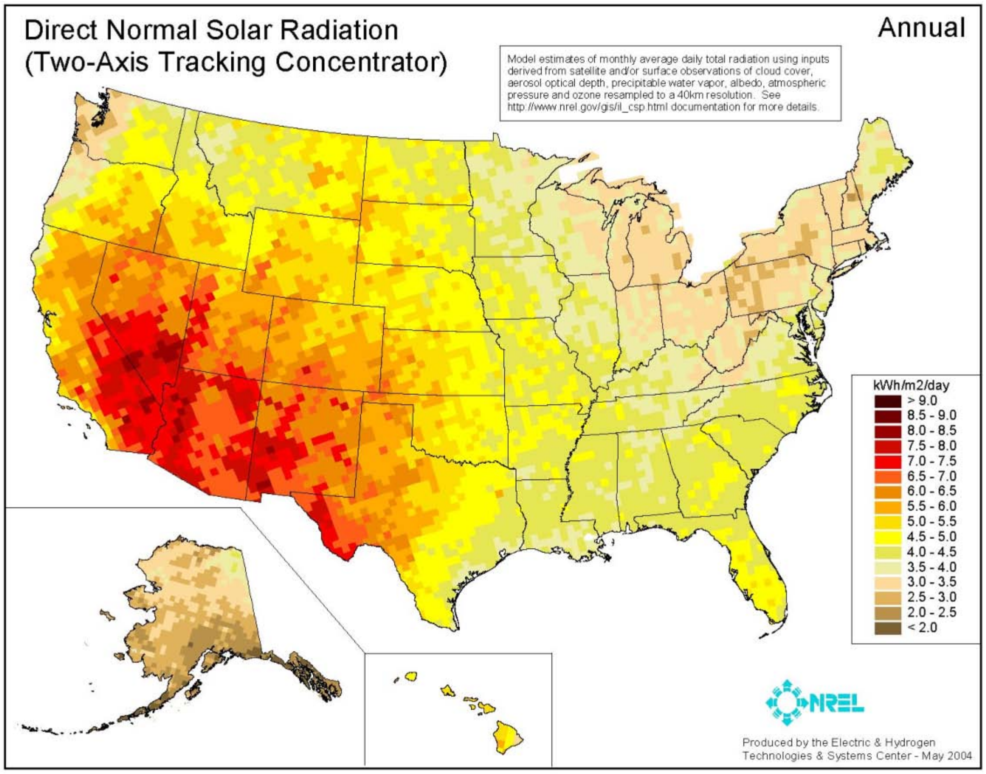


Figure 6-8: Direct normal solar radiation (two-axis solar concentrator) (Source: NREL [12])

PV installations have been growing rapidly in the last decade. Figure 6-9 shows the annual and the cumulative installed capacity of grid-connected PV in the U.S. The main factors influencing the rapid growth in the last few years are federal and state financial incentives and state renewable portfolio standards that have specific solar-electric provisions. Top among the federal financial incentives is the 30 percent investment tax credit (ITC) that was extended in 2008 and 2009 to remove the $2,000 cap on personal ITC, to allow electric utilities access to the ITC and to provide for an alternative 30 percent investment cash grant in lieu of the tax credit. In addition, the American Recovery and Reinvestment Act provided funds for a DOE loan guarantee program targeted towards renewable energy projects [13, 14, 15].

At the state level, sixteen states have renewable portfolio standards that have a specific quota for solar-electric technologies or for customer-side distributed generation. PV systems are the most common renewable energy technologies in use for residential customer-side distributed generation. In addition several states, including California, New Jersey, Florida, Colorado, New York, Connecticut and Massachusetts, have rebates with various types of funding mechanisms targeted at solar-electric systems [13, 14, 15].

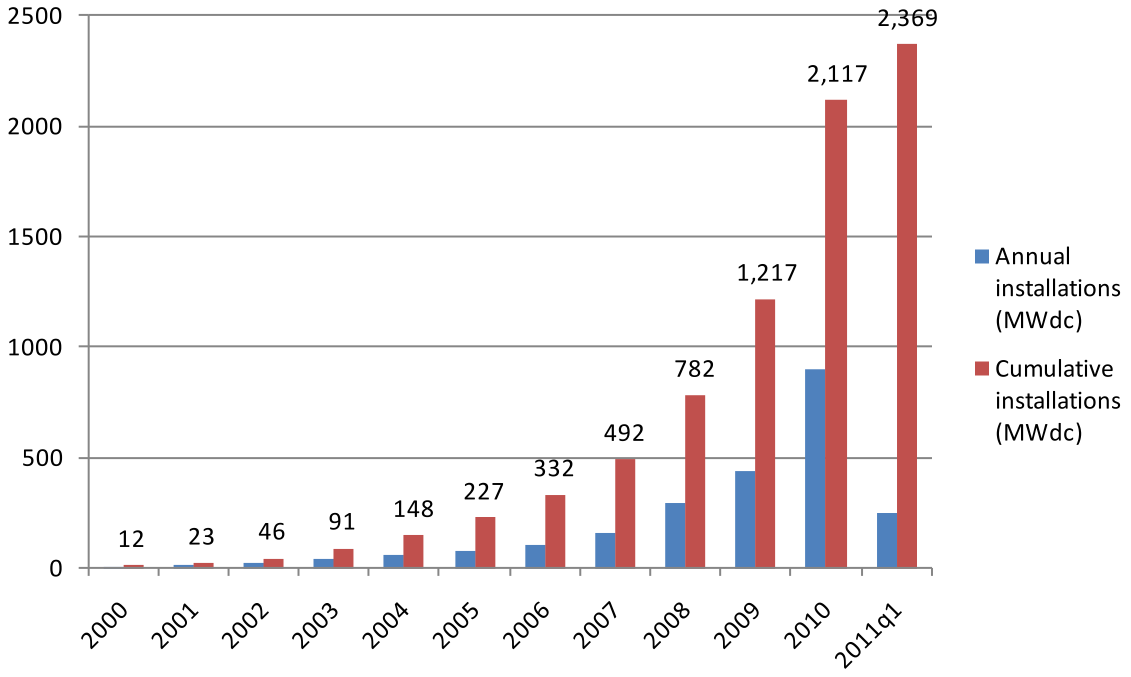


Figure 6-9: Grid-connected U.S. PV installed 2000 to 2011 first quarter (Data source SEIA [14, 16])

Part of the rapid expansion in PV capacity in the last decade stems from the installation of several major utility scale projects such as the 55 MW Copper Mountain PV power plant in Boulder, Nevada commissioned in 2010, the 30 MW Cimarron I plant in Cimarron, New Mexico commissioned in 2010, and the 25 MW DeSoto plant in Arcadia, Florida. Table 6-1 lists PV projects of one MW and above capacity in operation in the U.S. as of May 2011.

Project Name	Developer	Capacity (MW)	Online Date	Electricity Purchaser	City/County	State
Rancho Seco	ARCO Solar/Siemens	3	1984	Sacramento Municipal Utility District	Herald	CA
Springerville	Global Solar Energy	5	2003	Tuscon Electric Power	Springerville	AZ
Prescott	Arizona Public Service	3	2006	Arizona Public Service	Prescott	AZ
Nellis	MMA Renewable Ventures	14	2007	Nellis Air Force Base	Clark County	NV
Alamosa	SunEdison	8	2007	Xcel Energy	Alamosa	CO
Exelon-Conergy	Conergy	3	2008	Exelon Generation LLC	Philadelphia	PA
Soleil	enXco	1	2008	Sacramento Municipal Utility District	Sacramento	CA
El Dorado	First Solar/Sempra	10	2008	Pacific Gas & Electric	Boulder City	NV
Fort Carson	Three Phases /Green Rock Capital	2	2008	Fort Carson Army Base	Colorado Springs	CO
Vineland Solar One	Conectiv Energy	4	2009	Vineland Municipal Electric Utility	Vineland	NJ
FSE Blythe	First Solar	21	2009	Southern California Edison	Blythe	CA
DeSoto	Florida Power & Light	25	2009	Florida Power & Light Co.	Arcadia	FL
CalRENEW-1	Cleantech America Inc.	5	2010	Pacific Gas & Electric	Mendota	CA
	Efficient Energy of Tennessee	1	2010	Tennessee Valley Authority	Knox County	TN
Cimarron I	First Solar	30	2010	Tri-State Generation and Transmission	Cimarron	NM
Copper Mountain	First Solar/Sempra	55	2010	Pacific Gas & Electric	Boulder City	NV
Space Coast	Florida Power & Light	10	2010	Florida Power & Light Co.	Kennedy Space Center	FL
Jacksonville	juwi solar Inc.	15	2010	Jacksonville Electric Authority	Jacksonville	FL
Wyandot	juwi solar Inc.	12	2010	American Electric Power Co. Inc.	Salem Township	OH
Blue Wing	juwi solar Inc.	16	2010	CPS Energy	San Antonio	TX
Vaca-Dixon	Solon	2	2010	Pacific Gas & Electric	Vacaville	CA
West Pullman	SunPower	10	2010	Exelon Generation LLC	Chicago	IL
Shelby	SunPower/Duke	1	2010	NCMPA1	Shelby	NC
William Stanley	Western Massachusetts Electric	2	2010	Western Massachusetts Electric Co.	Pittsfield	MA
	ESA Renewables /Suniva	1	2011	Tennessee Valley Authority	Blairsville	GA
	SunEdison	17	2011	Duke Energy	Davidson County	NC
Greater Sandhil	SunPower	19	2011	Xcel Energy	Alamosa	CO
Chevron Technology Ventures*		1	2011	Kit Carson Electric Cooperative	Questa	NM

*The Chevron Technology Ventures project is the only project in the list using concentrating photovoltaic (CPV) technology

Table 6-1: PV systems of one megawatt and above installed in the U.S. (Data source: SEIA [17])

6.4 PV systems in Indiana

In keeping with the nationwide trend, PV installations have been growing rapidly in Indiana with 75 installations totaling over 2.6 MW of capacity entered into the NREL *Open PV* [18] database at the time this report was written. The largest of these installations is the 2.1 MW PV system installed on the Emmett Building at the Fort Harrison Federal Compound in Indianapolis completed in April 2011. The next largest unit is the 100 kW project at the Johnson Melloh renewable energy demonstration site in Indianapolis. Table 6-2 is a list of the 16 photovoltaic systems with at least 10 kW capacity installed in Indiana as of July 2011.

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 recently enacted expansion of the Indiana net metering rule to include all customer classes and systems up to 1 MW is expected to improve the financial viability of customer side PV systems. In Addition two Indiana utilities, Indianapolis Power and Light (IPL) and Northern Indiana Public Service Company (NIPSCO), offer feed-in tariffs for electricity generated from renewable resources. IPL offers a feed-in tariff of $0.24/kWh for PV systems between 20 and 100 kW and $0.20/kWh for systems greater than 100kW up to 10 MW and NIPSCO offers $0.30/kWh for electricity and the associated renewable credits for units less than 10 kW and $0.26 for solar facilities up to 2 MW.

Owner /Developer	**Capacity (kW)**	**Location**	**Date Installed**	**Cost ($/Watt)**
US General Services Administration	2,010	Emmett Bean Building, Fort Benjamin Harrison, Indianapolis	4/2011	n/a
Johnson Melloh	99.96	Indianapolis Marion County	2/2011	n/a
Bus Station	93	South Bend, St. Joseph County	2010	n/a
Stinson-Remick Hall Notre Dame	50	University of Notre Dame, St. Joseph County	2010	10
Cool Creek Park	15.68	Carmel, Hamilton County	2010	8.35
International Brotherhood of Electrical Workers	14.1	Terre Haute, Vigo County	2010	6.04
Residential	13.68	Connersville, Fayette County	2007	14.25
Residential	13.4	Terre Haute, Vigo County	2009	7.76
Newburgh Library	11	Newburgh, Warrick County	2007	10
Evansville-Vanderburgh Public Library	10.8	Evansville, Vanderburgh County	2010	7.94
Evansville-Vanderburgh Public Library	10.8	Evansville, Vanderburgh County	2010	7.94
Commercial	10.75	Kokomo	2009	7.93
Fitzpatrick Hall Notre Dame	10	University of Notre Dame, St. Joseph County	7/2011	n/a
Big Fish'n Campground	10	Lafayette	2010	n/a
Residential	10	New Harmony, Posey County	2010	8.13
Residential	10	New Harmony, Posey County	2010	8.32

Table 6-2: PV systems in Indiana of 10kW and above capacity (Data source: NREL [18])

6.5 Incentives for PV systems

Federal Incentives

- Business Energy Investment Tax Credit (ITC) credits up to 30 percent of expenditures on solar systems. 2009 American Recovery and Reinvestment Act provided for treasury cash grants in lieu of the ITC [19].
- Energy Efficiency Mortgage program provides mortgages that can be used by homeowners to finance a variety of energy efficiency measures, including renewable energy technologies, in a new or existing home. The federal government supports these loans by insuring them through FHA or VA programs. This allows borrowers who might otherwise be denied loans to pursue energy efficient improvements, and it secures lenders against loan default, providing them confidence in lending to customers whom they would deny without the federal insurance [19].
- Modified Accelerated Cost-Recovery System (MACRS) allows businesses to recover investments in solar, wind and geothermal property through depreciation deductions. The MACRS establishes a set of class lives for various types of property, ranging from three to fifty years, over which the property may be depreciated. For solar, wind and geothermal property placed in service after 1986, the current MACRS property class life is five years [19].
- Qualified Energy Conservation Bonds (QECBs) are qualified tax credit bonds that are allocated to each state based upon their state's percentage of the U.S. population. The states are then required to allocate a certain percentage to "large local governments". In February 2009, these funds were expanded to $3.2 billion [19].
- Renewable Energy Production Incentive (REPI) provides financial incentive payments for electricity produced and sold by renewable energy generation facilities owned by non-profit groups, public utilities, or state governments [19].
- Residential Energy Conservation Subsidy Exclusion established by Section 136 of the IRS Code, makes direct and indirect energy conservation subsidies provided by public utilities nontaxable [16].
- Rural Energy for America Program (REAP) covers up to 25 percent of costs for eligible projects at certain types of institutions. Eligible renewable energy projects include wind, solar, biomass and geothermal; and hydrogen derived from biomass or water using wind, solar or geothermal energy sources. REAP incentives are generally available to state government entities, local governments, tribal governments, land-grant colleges and universities, rural electric cooperatives and public power entities, and other entities, as determined by USDA [26].

- Value-Added Producer Grant Program support planning activities and provide working capital for farm-based renewable energy projects. Independent producers, agricultural producer groups, farmer or rancher cooperatives, and majority-controlled producer-based business ventures are eligible for the program. Previously awarded grants supported energy generated on-farm through the use of agricultural commodities, wind power, water power, or solar power [17].
- 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 [21].

Indiana Incentives

- Emissions Credits are available by electricity generators that do not emit NO_x and that displace utility generation are eligible to receive NO_x emissions credits under the Indiana Clean Energy Credit Program [28]. These credits can be sold on the national market.
- Net Metering Rule: Renewable resources with a maximum capacity of 1 MW are qualified for net metering in Indiana. The net excess generation is credited to the customer in the next billing cycle [19].
- Renewable Energy Systems Property Tax Exemption provides property tax exemptions for the entire renewable energy device and affiliated equipment. The exemption applies to both real property and mobile homes equipped with renewable energy systems and may only be claimed by property owners [19].
- 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 [16].
- Clean Energy Portfolio Standard (CPS) passed in May 2011 sets a voluntary goal of 4 percent between 2013 and 2018, 7 percent between 2019 and 2024, and 10 percent clean energy by 2025, based on 2010 retail sales. Participation in CPS makes utilities eligible for incentives in order to pay for the compliance projects [19].
- Indianapolis Power & Light Co. – Rate REP (Renewable Energy Production) offers a "feed-in tariff" to solar, wind and biomass electricity generating facilities located in their service territory. IPL will purchase renewable energy and contract the production for up to 10 years. Solar compensation is \$0.24/kWh for systems between 20 and 100 kW and \$0.20/kWh for systems greater than 100kW up to 10MW [19, 23].
- Indianapolis Power & Light Co. – Small Scale Renewable Energy Incentives Program offers compensation for new photovoltaic installations for residential and small-business customers. The compensation for solar is \$2 per watt up to \$4,000. Eligible solar systems are between 1kW and 19.9 kW [19, 24].

- Northern Indiana Public Service Company – The NIPSCO feed-in tariff offers incentive rates for electricity generated from renewable resources. The payments for solar facilities are $0.30/kW for solar facilities with a capacity below 10 kW and $0.26/kW for facilities up to 2 MW. The tariff is an experimental tariff running until December 31, 2013. The maximum allowed generating unit size is 5 MW and the total system-wide capacity allowed under the tariff is 30 MW. 500 kW of the system-wide cap is reserved for solar projects of capacity less than 10 kW [25].

6.6 References

1. U.S. Department of Energy, Energy Information Administration (EIA). Solar energy—energy from the sun. http://www.eia.doe.gov/kids/energyfacts/sources/renewable/solar.html
2. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Department of Energy (EERE). PV systems. http://www.eere.energy.gov/basics/renewable_energy/pv_systems.html
3. European photovoltaic technology platform. Introduction to PV. http://www.eupvplatform.org/index.php?id=47
4. Gizmag. SANYO develops world's highest energy conversion efficiency solar cells. http://www.gizmag.com/go/7480/
5. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Department of Energy (EERE). http://www.eere.energy.gov/basics/renewable_energy/concentrator_pv_systems.html
6. National Renewable Energy Laboratory (NREL). Concentrating photovoltaic technology. http://www.nrel.gov/csp/concentrating_pv.html
7. NREL. Opportunities and challenges for development of a mature concentrating photovoltaic power industry. http://www.nrel.gov/pv/pdfs/43208.pdf
8. U.S. Department of Energy, Office of Science. Basic research needs for solar energy utilization. www.nrel.gov/pv/thin_film/docs/kaz_best_research_cells.ppt
9. EIA. Renewable Energy 2000: Issues and trends. http://tonto.eia.doe.gov/ftproot/renewables/06282000.pdf
10. EIA. Updated capital cost estimates for electricity generation plants. November 2010. http://www.eia.gov/oiaf/beck_plantcosts/pdf/updatedplantcosts.pdf
11. Lawrence Berkeley National Laboratory. Tracking the sun III: The installed cost of photovoltaics in the U.S. from 1998-2009. http://eetd.lbl.gov/ea/emp/re-pubs.html
12. NREL. Solar maps. http://www.nrel.gov/gis/solar.html
13. Interstate Renewable Energy Council. U.S. solar market trends 2009. http://www.irecusa.org/wp-content/uploads/2010/07/IREC-Solar-Market-Trends-Report-2010_7-27-10_web1.pdf
14. Solar Energy Industries Association, U.S. solar market insight, first quarter 2011. http://www.seia.org/galleries/pdf/SMI-Q1-2011-ES.pdf

15. International Energy Agency. Photovoltaic Energy Systems Programme. Annual report 2010. http://www.iea-pvps.org/fileadmin/dam/public/report/annual/ar_2010.pdf
16. Solar Energy Industries Association, U.S. solar market insight, second quarter 2010. http://www.seia.org/galleries/pdf/SEIA_Q2_2010_EXEC_SUMMARY.pdf
17. Solar Energy Industries Association, Utility-scale solar projects in the United States: operating, under construction, or under development. http://www.seia.org/galleries/pdf/Major%20Solar%20Projects.pdf
18. NREL. The open PV Project. http://openpv.nrel.gov/search
19. Database of State Incentives for Renewables and Efficiency (DSIRE). http://www.dsireusa.org/
20. Center for Rural Affairs. Value added producer grants program fact sheet. http://www.cfra.org/resources/vapg/fact_sheet
21. U.S. Department of Agriculture, Rural Development, Electric Programs. http://www.usda.gov/rus/electric/hecgp/overview.htm
22. Indiana Department of Environmental Management. Indiana clean energy credit program. http://www.in.gov/idem/4134.htm
23. Indianapolis Power and Light Company. Renewable Energy Production. http://www.iplpower.com/ipl/index?page=IPLGeneral&Menu=01000000&DocID=020391af33d6012801538fc10057cb
24. Indianapolis Power and Light Company. Small Scale Renewable Energy Incentive Program. http://www.iplpower.com/ipl/index?page=IPLGeneral&Menu=01000000&DocID=020391af33d6012801538fc1004513
25. Northern Indiana Public Service Company. http://www.nipsco.com/About-us/Rates-Tariffs/Electric-Service-Tariff.aspx

7. Hydropower

7.1 Introduction

Hydroelectric energy is produced by converting the kinetic energy of falling water into electrical energy [1]. The moving water rotates a turbine, which in turn spins an electric generator to produce electricity. There are several different types of hydropower facilities, including [2]:

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

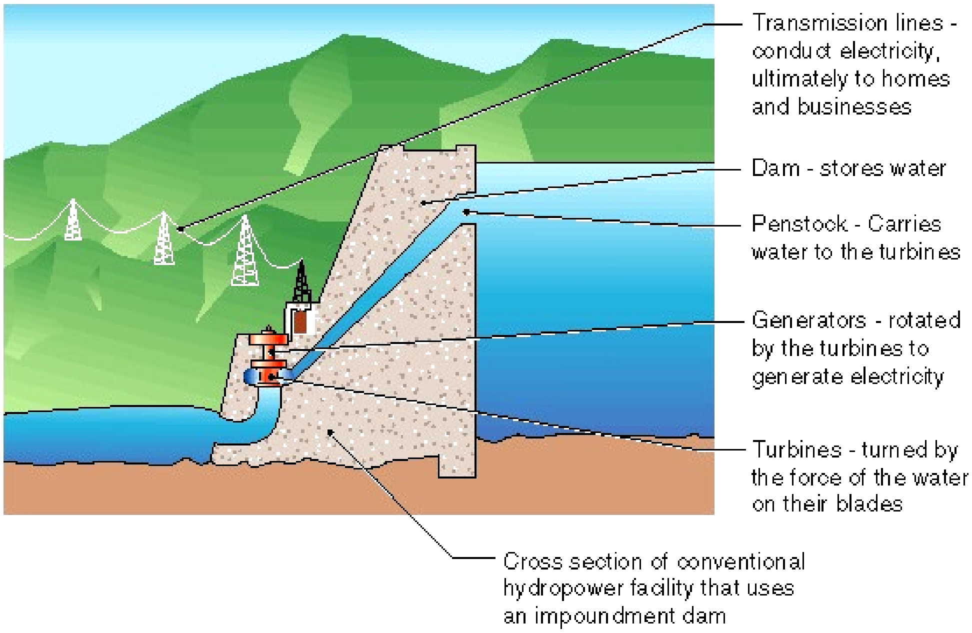


Figure 7-1: Schematic of impoundment hydropower facility (Source: INEL [2])

---

[6] Head is the elevation difference between the water level above the turbine and the turbine itself.

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. The turning part of the turbine is called the runner, and the most common types of turbines are listed below [3]:

- Pelton Turbines: The Pelton turbine has multiple jets of water impinging on the buckets of a runner that looks like a water wheel. These turbines are used for high-head sites (50 feet to 6,000 feet) and can be as large as 200 MW.
- Francis Turbines: These turbines have a runner with a number of fixed vanes (usually nine). The water enters the turbine in a radial direction with respect to the shaft, and is discharged in an axial direction. Francis turbines usually operate with head from 10 feet to 2,000 feet and can be as large as 800 MW.
- Propeller Turbines: These turbines have a runner with three to six fixed blades, much like a boat propeller. The water passes through the runner and provides a force that drives the blades. These turbines can operate with head from 10 feet to 300 feet and can be as large as 100 MW.

Hydropower is a renewable resource that has many benefits, including [4]:

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

Hydropower facilities also provide recreational opportunities for the community such as fishing, swimming, and boating in its reservoirs. Other benefits may include water supply and flood control. It has been estimated that of the 82,000 U.S. dams, only 3 percent have electricity production as their primary function [5].

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

- Blockage of upstream fish passage;
- Fish injury and mortality from passage through the turbine; and
- Changes in the quality and quantity of water released below dams and diversions, including low dissolved oxygen levels [6].

Other factors may also act as deterrents to potential hydropower projects, including the increasingly costly and uncertain process of licensing or relicensing of hydropower projects. About 300 hydroelectric facilities will have to be relicensed through 2017 [7]. Though the Energy Policy Act of 2005 helped reform the licensing procedure, many still consider the process to be burdensome and complicated [8]. Obtaining a license for a new facility, or renewing the license of an older facility, can take 8-10 years or longer [7].

7.2 Economics of hydropower

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

Project		**Time**[*]	**Initial Capital Costs ($/kW)**
Idaho National Lab estimates		1996	1,700-2,300
EIA estimates	Hydroelectric	2010	3,076
	Pumped Storage	2010	5,595
Hawaii Pumped Storage Hydroelectric Project (Maui Electric Co.)	Umauma	2005	1,966
	East/WestWailuaiki		3,011
	Big Island		2,432-2,842
	Maui		3,477
Susitna Project (Alaska)		2008	7,713-13,833
American Municipal Power (AMP)	Belleville	1999	2,857
	Cannelton	2009	4,951
	Smithland	2010	5,898
	Meldahl	2010	4,260
	Willow Island	2011	6,275
	Robert C. Byrd	2015	6,250
	Pike Island	2016	7,414

[a] Time the project's cost estimate was made or the project's expected start date

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

According to the EIA November 2010 updated plant costs [11] hydroelectric plants have one of the lowest O&M costs among electricity generating technologies. Figure 7-2 shows the variable and fixed O&M costs of various generating technologies. As can be seen in the Figure 7-2, hydroelectricity's variable O&M costs are estimated at zero and the fixed O&M cost of $13/kW is the second lowest after natural gas combustion turbines.

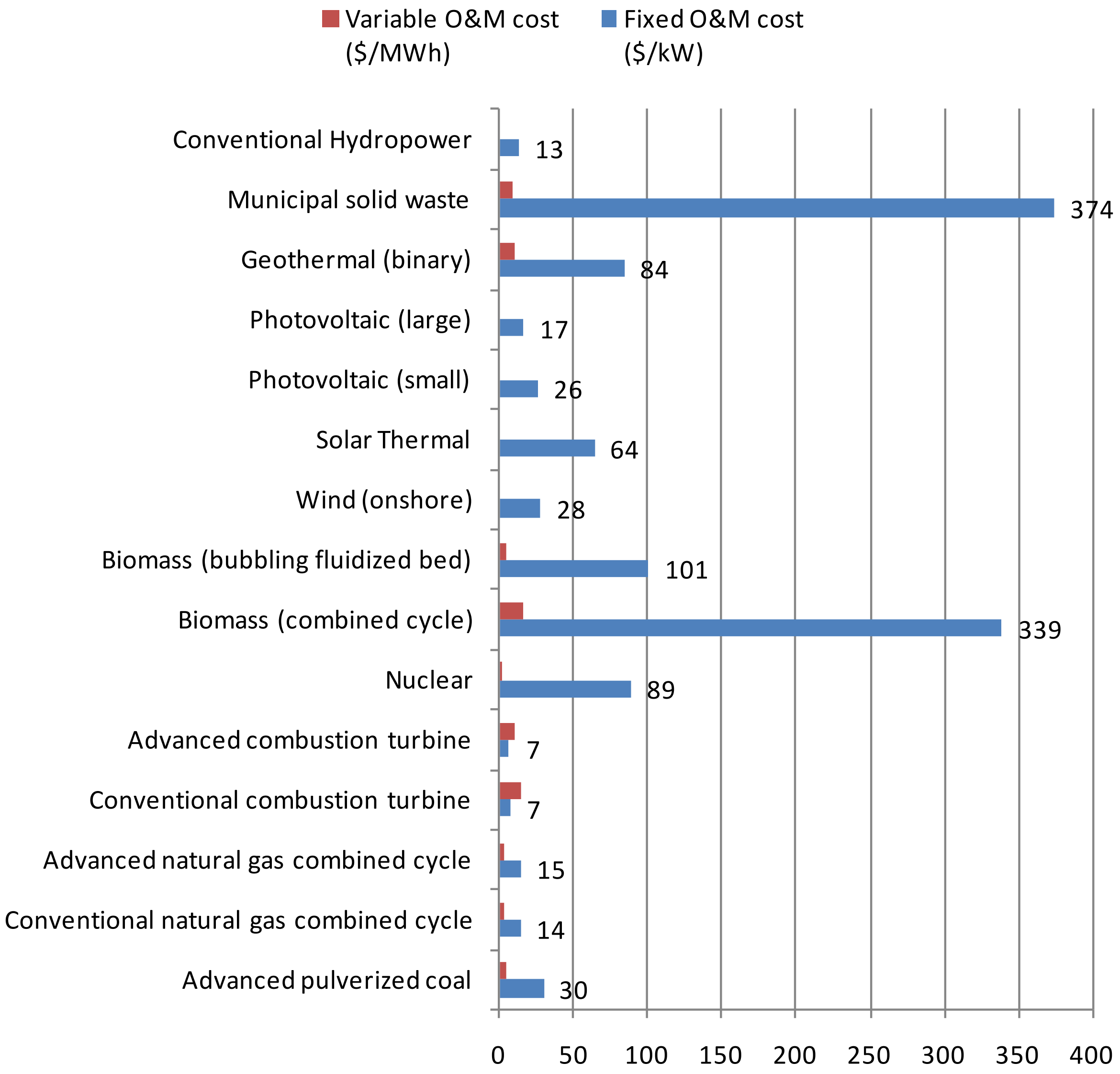


Figure 7-2: Variable and fixed O&M costs of generating technologies (Data source: EIA [11])

7.3 State of hydropower nationally

In 2010, hydroelectricity accounted for 2.5 (31 percent) of the 8 quads of renewable energy consumed in the U.S. and 6 percent of the total electricity generated. In 2009 the total conventional hydropower generation in the U.S. was 273,445,095 MWh. The states of Washington, Oregon, and California account for 49 percent of total hydropower capacity in the country [15].

1.Washington	72,932,704		6.Idaho	10,434,264
2.Oregon	33,033,513		7.Tennessee	10,211,962
3.California	27,888,036		8.Montana	9,505,940
4.New York	27,615,016		9.Arizona	6,427,345
5.Alabama	12,535,373		10.North Carolina	5,171,257

Table 7-2: Top ten U.S. hydropower generating states in 2009 (MWh) (Data source: National Hydropower Association [15])

The Idaho National Laboratory launched an effort to catalogue untapped hydropower potential in the U.S. in 1989. The U.S. Hydropower Resource Assessment Final Report was issued in 1998 with subsequent revisions in 2004 and 2006. At the heart of this assessment effort is a computer model known as the Hydropower Evaluation Software, which identified 5,677 sites with a total undeveloped capacity of 30 GW. Of this capacity, 57 percent (17.0 GW) is at sites with some type of existing dam or impoundment but with no power generation. Another 14 percent (4.3 GW) exists at projects that already have hydropower generation but are not developed to their full potential; only 28 percent (8.5 GW) of the potential would require the construction of new facilities. Therefore the potential for hydropower from existing dams is about 21.4 GW [16]. The breakdown of the state-by-state contribution to the total 30 GW identified is shown in Figure 7-3 [17].

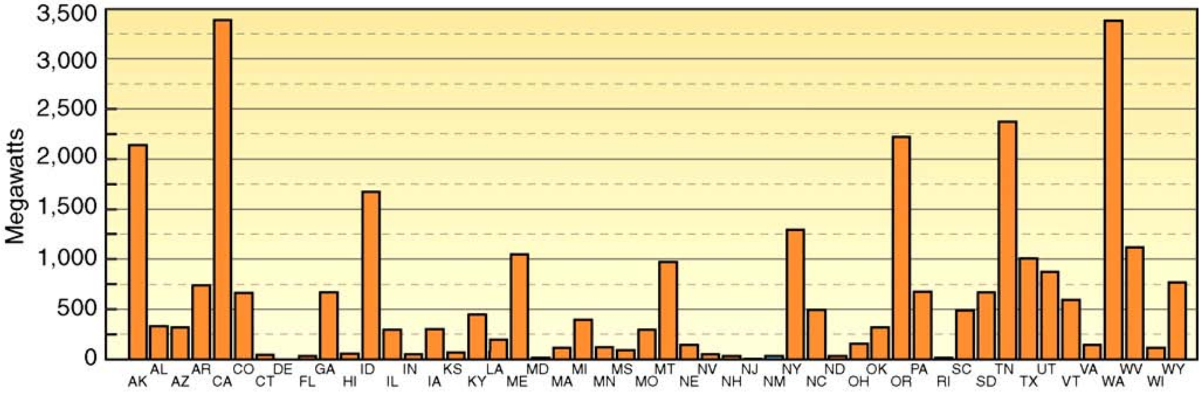


Figure 7-3: State breakdown of potential hydropower capacity (Source: INEL [17])

The National Hydropower Association estimates that more than 4,300 MW of additional or “incremental” hydropower capacity could be brought on line by upgrading or augmenting existing facilities [18]. Oak Ridge National Laboratory (ORNL) is updating hydropower potential assessments based on INEL’s study. ORNL concentrates on existing, non-powered dams, predicting that 54,000 such dams could supply 12.6 GW of power. Of this total power, 3,000 MW would come from 10 large dams on the following rivers: 4 Ohio River Dams, 1 Mississippi River Facility, 1 Alabama River Facility, 2 Tombigbee River Facilities, and 2 Arkansas-Red River Facilities [19]. Figure 7-4 shows the distribution of non-powered dams in the U.S.

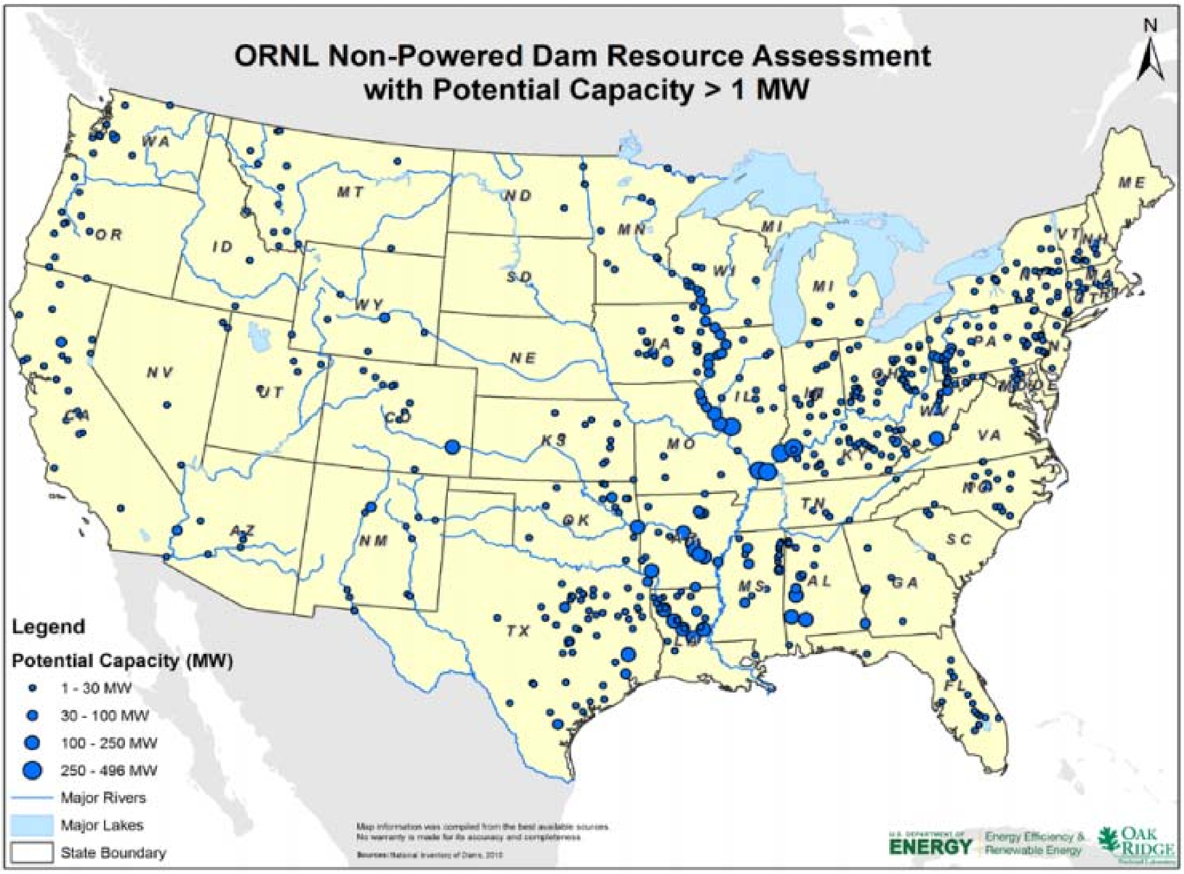


Figure 7-4: Non-powered dams with potential capacity over 1 MW (Source: ORNL [19])

Although there are substantial undeveloped resources for hydropower, its share of the nation's total electricity production is predicted to decline through 2020, with minimal capacity increases, due to a combination of environmental issues, regulatory complexities and pressures, and changes in economics [6]. The most viable hydropower capacity addition in the coming years will be the 4.3 GW of "incremental" capacity available at existing facilities. Improvements in turbine design to minimize environmental impacts and federal and state government incentives could help further develop potential hydropower projects at existing dams.

Currently, DOE is researching technologies that will enable existing hydropower projects to generate more electricity with less environmental impact. The main objectives are to develop new turbine systems with improved overall performance, develop new methods to optimize hydropower operations, and conduct research to improve the effectiveness of the environmental mitigation practices required at hydropower projects. Together, these advances in hydropower technology should reduce the cost of implementation and help smooth the hydropower integration process [20]. On April 5, 2011, DOE and DOI announced $26.6 million in funding to develop advanced hydropower technologies. The funding would concentrate on four areas: sustainable small hydropower, environmental mitigation technologies for conventional hydropower, sustainable pumped storage hydropower, and advanced conventional hydropower system testing at a bureau of reclamation facility [21].

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 7-5. With 1,339 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 where there was only 20 kW of grid-connected wind capacity in Indiana.

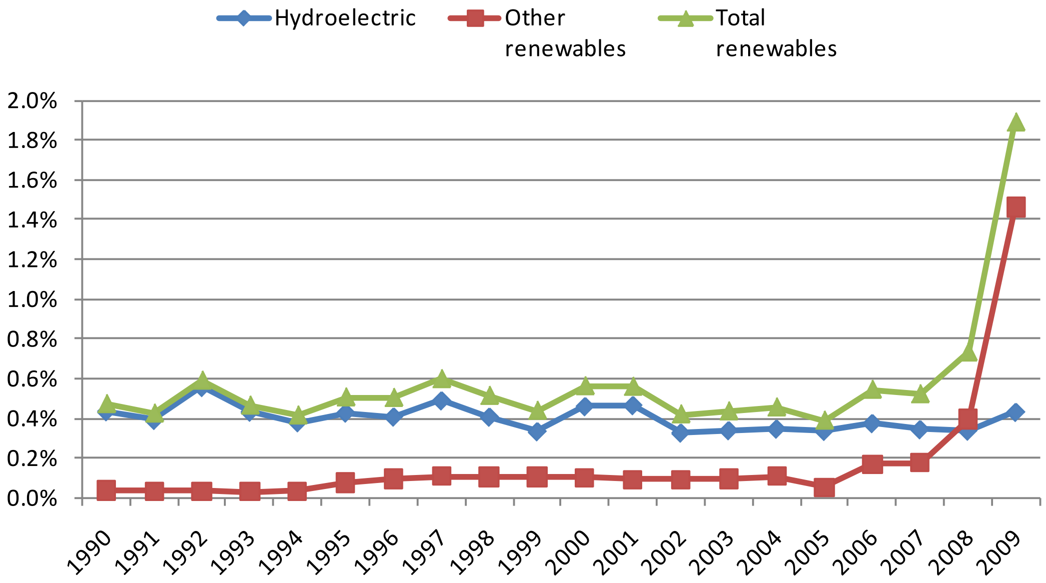


Figure 7-5: Renewables share of Indiana net electricity generation (1990-2009) (Data source: EIA [22])

However when one considers total Indiana energy consumption, wood and more recently ethanol take the more dominant role as sources of renewable energy consumed in Indiana as shown in Figure 7-6. Hydroelectricity comes in third contributing less 0.2 percent of the total energy consumed in Indiana.

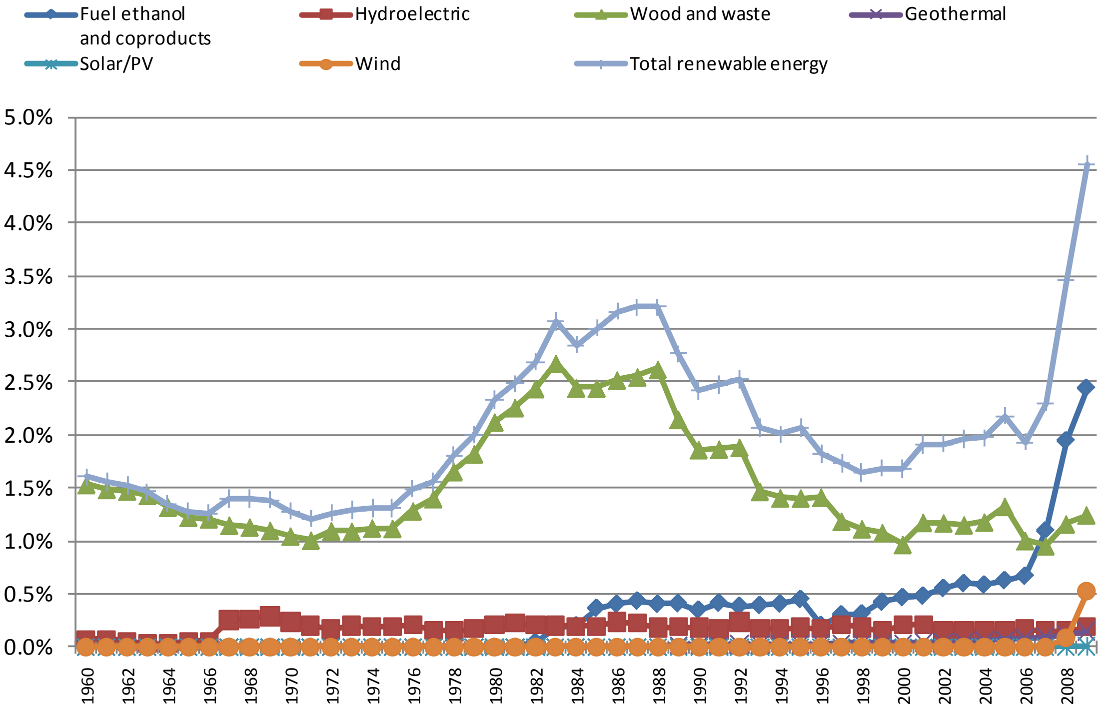


Figure 7-6: Renewables share of Indiana total energy consumption (1960 – 2009) (Data source: EIA [23])

A 1995 national hydro-potential study conducted by DOE estimated Indiana to have the potential for approximately 43 MW of exploitable capacity on 5 of Indiana's river basins as shown in Table 7-3 [24].

	Exploitable hydro potential (MW)	**Number of sites**	**Number of sites with existing power generation**	**Number of sites without existing power generation**	**Number of un-developed sites**
Wabash river basin	22.73	12	0	11	1
St. Joseph river basin	10.32	12	3	9	0
Ohio main stream	9.23	3	0	2	0
Maumee river basin	1.08	2	0	2	0
Cumberland River basin	0.0045	1	0	0	1
Total	**43.4**	**30**	**3**	**24**	**2**

Table 7-3: Hydropower potential in Indiana (Source: INEL [24])

The 43 MW shown in Table 7-3 is the net capacity that can exploited after screening out capacity deemed unsuitable for development due to environmental factors. The gross total capacity before the screening was assessed at 84 MW.

American Municipal Power is in the process of developing five new run-of-the-river hydroelectric projects on existing dams along the Ohio River whose combined capacity will be more than 350 MW. Four of these projects, including the one near Cannelton, Indiana, are under construction. The other four are located at the Smithland, Meldahl, Willow Island and Robert C. Byrd Locks and Dams in the Illinois, Ohio and Pennsylvania sections of the Ohio River. Currently, manufacturing of the equipments, including turbines and generators, gate equipment, cranes, and transformers is ahead of schedule. Additionally, working with one member community of Wadsworth, Ohio, AMP secured a permit from the Federal Energy Regulatory Commission (FERC) for a project at the Robert C. Byrd Locks and Dam in Ohio, and an application for license was filed with the FERC on March 28, 2011 [13, 14]. Table 7-4 lists the general plan and profile of these five projects.

Project	Capacity (MW)	Capital Investment (million $)	Starting Time	Expected Commercial Operation Date
Cannelton	84	415.9	April 2009	Fall 2013
Smithland	76	448.3	April 2010	Spring 2014
Meldahl	111	472.9	April 2010	Summer 2014
Willow Island	44	276.1	June 2011	Spring 2015
Robert C. Byrd	48	300	2015	2017

Table 7-4: AMP hydropower projects along Ohio River (Source: AMP [13, 14, 25])

7.5 Incentives for hydropower

Federal Incentives

- Renewable Electricity Production Tax Credit (PTC) provides a 2.2 cents/kWh tax credit for wind, geothermal and closed-loop biomass and 1.1 cents/kWh for open-loop biomass, landfill gas, municipal solid waste, small hydroelectric and marine energy technologies. As part of the February 2009 American Recovery and Reinvestment Act the PTC was modified to provide the option for qualified producers to take the federal business energy investment credit (ITC) or an equivalent cash grant from the U.S. Department of Treasury [26].

- Conservation Security Program The Conservation Security Program offers a \$200 payment for each renewable energy generation system installed on an eligible farm [27, 28]. The Food, Conservation, and Energy Act of 2008 re-incorporated the program as the "Conservation Stewardship Program" in 2009 and increased funding in the program by \$1.1 billion [29].
- Rural Energy for America Program (REAP) was converted by the Food, Conservation, and Energy Act of 2008 from the USDA Renewable Energy Systems and Energy Efficiency Improvements Program to the Rural Energy for America Program (REAP). Hydroelectric facilities are eligible for grants of up to 25 percent of the cost of the system, and loans for another 50 percent of the cost [26].
- High Energy Cost Grant Program administered by the USDA is aimed at improving the electricity supply infrastructure in rural areas having home energy costs exceeding 275 percent of the national average. Eligible infrastructure includes renewable resources generation. The USDA has allocated a total of \$15.5 million for the 2010 funding cycle. The individual grants range from \$75,000 to \$5 million [30].

Indiana Incentives

- Net metering rule Renewable resource facilities with a maximum capacity of 1 MW are qualified for net metering. The net excess generation is credited to the customer in the next billing cycle [26].
- Renewable Energy Property Tax Exemption provides property tax exemptions for solar thermal, wind, hydroelectric and geothermal systems [26].
- Clean Energy Portfolio Standard (CPS) passed in May 2011 sets a voluntary goal of 4 percent between 2013 and 2018, 7 percent between 2019 and 2024, and 10 percent clean energy by 2025, based on 2010 retail sales. Participation in CPS makes utilities eligible for incentives in order to pay for the compliance projects [26].
- Emissions Credits Electricity generators that do not emit NO_x and that displace utility generation are eligible to receive NO_x emissions credits under the Indiana Clean Energy Credit Program. These credits can be sold on the national market [31].
- Northern Indiana Public Service Company: The NIPSCO feed-in tariff offers incentive rates for electricity generated from renewable resources for up to 10 years. The payment for hydroelectric facilities is \$0.12/kW. The tariff is an experimental one running until December 31, 2013. The total system-wide renewable capacity allowed under the tariff is 30 MW with 500 kW of the cap reserved for solar projects of capacity less than 10 kW and 500 kW reserved for wind projects of capacity less than 10 kW [32].

7.6 References

1. Wisconsin Valley Improvement Company. How hydropower works. http://www.wvic.com/hydro-works.htm
2. Idaho National Laboratory (INEL). Hydropower: Types of hydropower facilities. http://hydropower.inel.gov/hydrofacts/hydropower_facilities.shtml
3. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy (EERE). Types of hydropower turbines.http://www1.eere.energy.gov/windandhydro/hydro_turbine_types.html
4. Colorado River Storage Project (CRSP) Power Office. Benefits of hydropower. http://www.usbr.gov/uc/power/hydropwr/benefits.html
5. Hydro world. Adding hydropower to non-hydro dams offers huge development potential. http://www.hydroworld.com/index/display/article-display/0814332230/articles/hrhrw/hydroindustrynews/newdevelopment/2010/06/adding-hydropower.html
6. EERE. DOE hydropower program annual report for FY 2002. July 2003. http://hydropower.inl.gov/techtransfer/pdfs/hydro_final_fy_02.pdf
7. Church Ciocci, Linda. Power Engineering International. Hydropower licensing reform: What's all the fuss? July 2003. http://pepei.pennnet.com/articles/article_display.cfm?article_id=181517
8. Energy Policy Act of 2005. http://doi.net/iepa/EnergyPolicyActof2005.pdf
9. INEL. Hydropower: Plant costs and production expenses. http://hydropower.inel.gov/hydrofacts/plant_costs.shtml
10. Alaska Energy Authority. Susitna hydroelectric project: Project evaluation. http://www.akenergyauthority.org/SusitnaFiles/031609EvaluationWOappen.pdf
11. U.S. Energy Information Administration (EIA). Updated capital cost estimates for electricity generation plants. November 2010. http://www.eia.gov/oiaf/beck_plantcosts/pdf/updatedplantcosts.pdf
12. 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
13. AMP. Hydro report – May 2011. http://amppartners.org/pdf/project-reports/Hydro_Report-May-2011.pdf
14. AMP. Organization and generation project overview, June 2011. http://amppartners.org/pdf/AMP_Projects_Overview_June_2011.pdf
15. National Hydropower Association. U.S. hydro generating profile. http://hydro.org/why-hydro/available/hydro-in-the-states/
16. Conner, A.M., J.E. Francfort, and B.N. Rinehart. U.S. hydropower source assessment final report. December 1998. http://www.circleofblue.org/waternews/wp-content/uploads/2010/09/US-Hydropower-Resource-Assessment_Idaho-National-Lab.pdf

17. INEL. Undeveloped hydropower potential by state. http://hydropower.inel.gov/hydrofacts/undeveloped_potential.shtml
18. EERE. Hydropower: Setting a course for our energy future. July 2004. http://www.nrel.gov/docs/fy04osti/34916.pdf
19. ORNL. Hydropower assessment. http://hydro.org/wp-content/uploads/2011/04/ORNL-Hydro-Factsheet-final.pdf
20. EERE. Advanced hydropower technology. http://www1.eere.energy.gov/windandhydro/printable_versions/hydro_advtech.html
21. EERE News. Departments of Energy and Interior Announce $26.6 Million in Funding to Develop Advanced Hydropower Technologies. http://apps1.eere.energy.gov/news/progress_alerts.cfm/pa_id=510
22. EIA. Indiana Electricity Profile Table 5, Release date: April 2011. http://www.eia.doe.gov/cneaf/electricity/st_profiles/indiana.html
23. EIA. State Energy Data System (SEDS), Released June 30, 2010, next release June 2012. http://www.eia.gov/state/seds/seds-states.cfm?q_state_a=IN&q_state=Indiana#undefined
24. J.E. Francfort, B.N. Rinehart. INEL.U.S. hydropower resource assessment for Indiana. December 1995. http://hydropower.inl.gov/resourceassessment/pdfs/states/in.pdf
25. American Municipal Power. http://amppartners.org/generation-assets/hydroelectric/, http://amppartners.org/images/Ohio_River_Hydro_map.jpg
26. Database of State Incentives for Renewables and Efficiency (DSIRE). http://www.dsireusa.org/library/
27. Department of Agriculture, National Resources Conservation Service (NRCS). Conservation security program 2008 national payment schedule. June 2008. http://www.nrcs.usda.gov/programs/csp/CSP_2008/2008_pdfs/2008 CSP_Natl_Payment_Schedule.pdf
28. NRCS. Renewable energy generation activity sheet. January 2008. http://www.nrcs.usda.gov/programs/csp/CSP 2008/2008_pdfs/activity_sheets/Renewable_Energy_Generation_Activity_Sheet.pdf
29. Montana Grain Growers Association. Food, Conservation, and Energy Act of 2008. http://www.mgga.org/FarmPolicy/thenewCSP.pdf
30. U.S. Department of Agriculture, High Energy Cost Grant Program overview. http://www.usda.gov/rus/electric/hecgp/overview.htm
31. Indiana Department of Environmental Management. Indiana clean energy credit program. http://www.in.gov/idem/4134.htm
32. Northern Indiana Public Service Company. http://www.nipsco.com/About-us/Rates-Tariffs/Electric-Service-Tariff.aspx