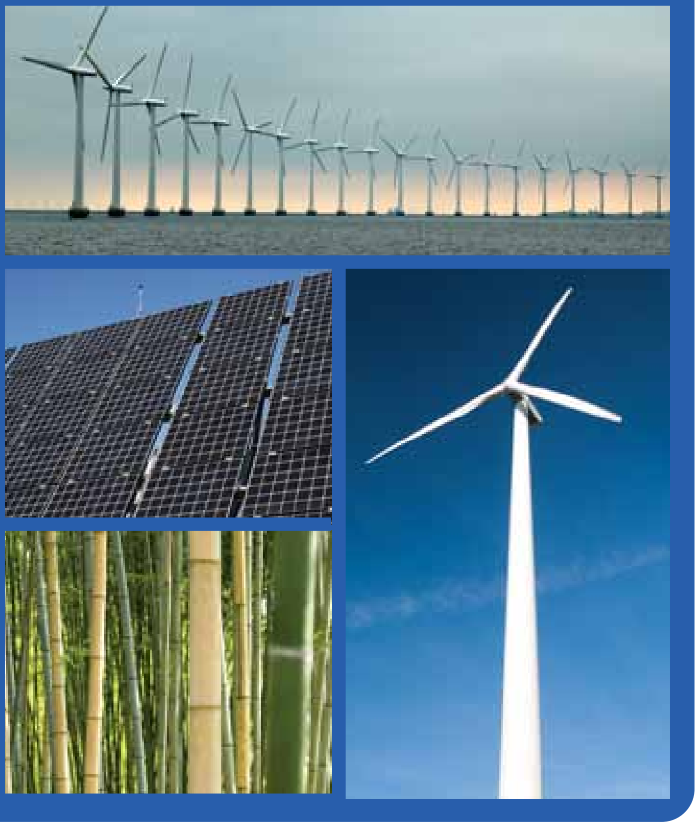
PURDUE UNIVERSITY
Discovery Park Energy Center

September 2012

2012 INDIANA RENEWABLE ENERGY RESOURCES STUDY



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General Assembly Indianapolis, Indiana

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

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Energy Center

Purdue University

West Lafayette, Indiana

David Nderitu

Emrah Ozkaya

Douglas Gotham

Paul Preckel

Darla Mize

Marco Velastegui

Tim Phillips

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Acronyms and Abbreviations

ARRA	American recovery and reinvestment act
AMP	American Municipal Power
AWEA	American Wind Energy Association
Btu	British thermal unit
CO_2	Carbon dioxide
CPV	Concentrating photovoltaic
CREB	Clean renewable energy bonds
CSP	Concentrating solar power
DC	District of Columbia
DOE	U.S. Department of Energy
DOI	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
INL	Idaho National Laboratory, U.S. Department of Energy
IPL	Indianapolis Power and Light Company
IREC	Interstate Renewable Energy Council

ISDA	Indiana State Department of Agriculture
ITC	Business energy investment tax credit
IURC	Indiana Utility Regulatory Commission
kW	Kilowatt
kWh	Kilowatthour
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
mmscfd	Million standard cubic feet per day
MMTCE	Million metric tons of carbon equivalent
mph	Miles per hour
MSW	Municipal solid waste
MTBE	Methyl tertiary butyl ether – a gasoline oxygenating additive
MW	Megawatt
MW_{th}	Thermal megawatt
MWh	Megawatthour
NIPSCO	Northern Indiana Public Service Company
NO_x	Nitrogen oxide
NREL	National Renewable Energy Laboratory, U.S. Department of Energy
O&M	Operation and maintenance
OED	Indiana Office of Energy Development
ORNL	Oak Ridge National Laboratory, U.S. Department of Energy
POLYSYS	Policy analysis system
PTC	Production tax credit
PV	Photovoltaic
REAP	Rural Energy for America Program, U.S. Department of Agriculture
REP	Renewable energy production – Indianapolis Power & Light feed-in tariff for renewable energy

REPI	Renewable energy production incentive
RPS	Renewable portfolio standard
QECB	Qualified energy conservation bonds
SEDS	State Energy Data System, Energy Information Administration, U.S. Department of Energy
SEGS	Solar Electric Generation System
SEIA	Solar Energy Industries Association
SOx	Sulfur oxides
SUFG	State Utility Forecasting Group
USDA	U.S. Department of Agriculture
VA	U.S. Department of Veterans Affairs
VEETC	Volumetric ethanol tax credit
W	Watts
W/m^2	Watts per square meter
WVPA	Wabash Valley Power Association

Foreword

This report represents the tenth 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:

- <u>Introduction:</u> This section gives an overview of the technology and briefly explains how the technology works.
- <u>Economics of the renewable resource technology:</u> This section covers the capital and operating costs of the technology.
- <u>State of the renewable resource technology nationally:</u> This section reviews the general level of usage of the technology throughout the country and the potential for increased usage.
- <u>Renewable resource technology in Indiana:</u> This section examines the existing and potential future usage for the technology in Indiana in terms of economics and availability of the resource.
- <u>Incentives for the renewable resource technology:</u> 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.
- <u>References:</u> 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 2012 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 2011. 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 in gasoline 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, and continued with the proliferation of renewable portfolio standards in a number of states.

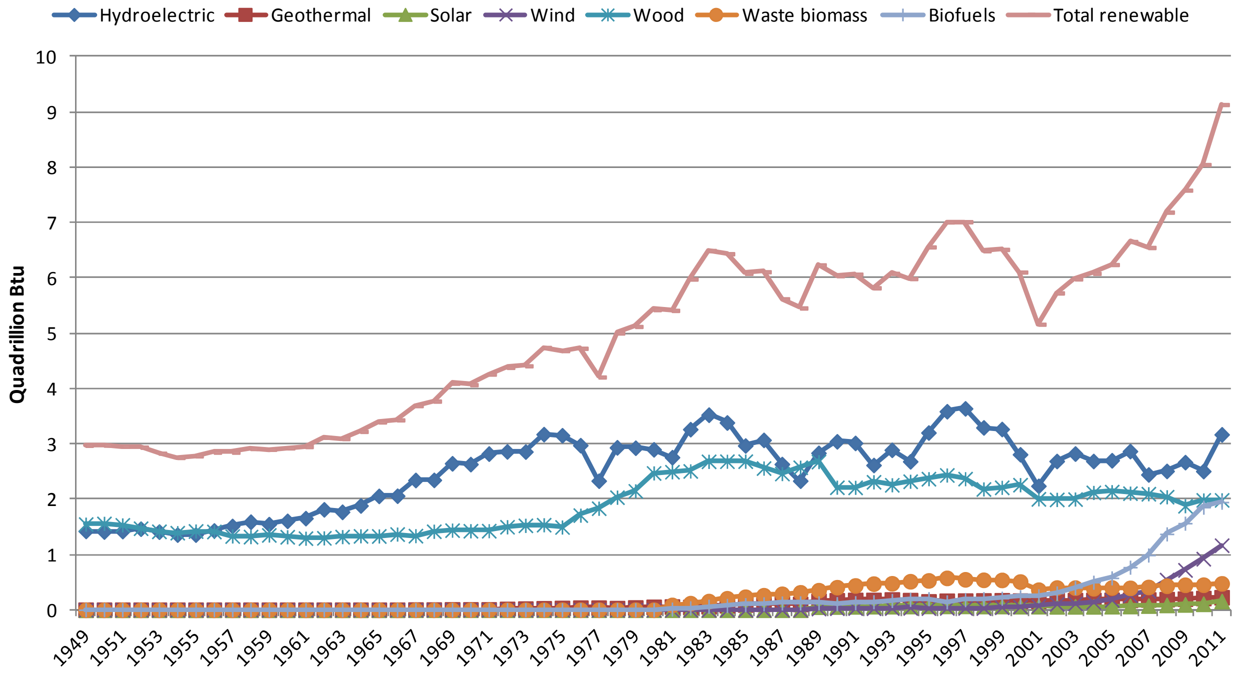

Figure 1-1: Renewable energy consumption in the U.S. (1949-2011) (Data source: EIA [1, 2])

Despite the growth shown in Figure 1-1, renewable energy's share of the total energy consumed in the U.S. remains modest at less than 10 percent. Fossil fuels supply over 80 percent of the energy consumed, while nuclear energy supplies the remainder. Figure 1-2 shows the sources of total energy consumed in the U.S. from 1949 to 2011.

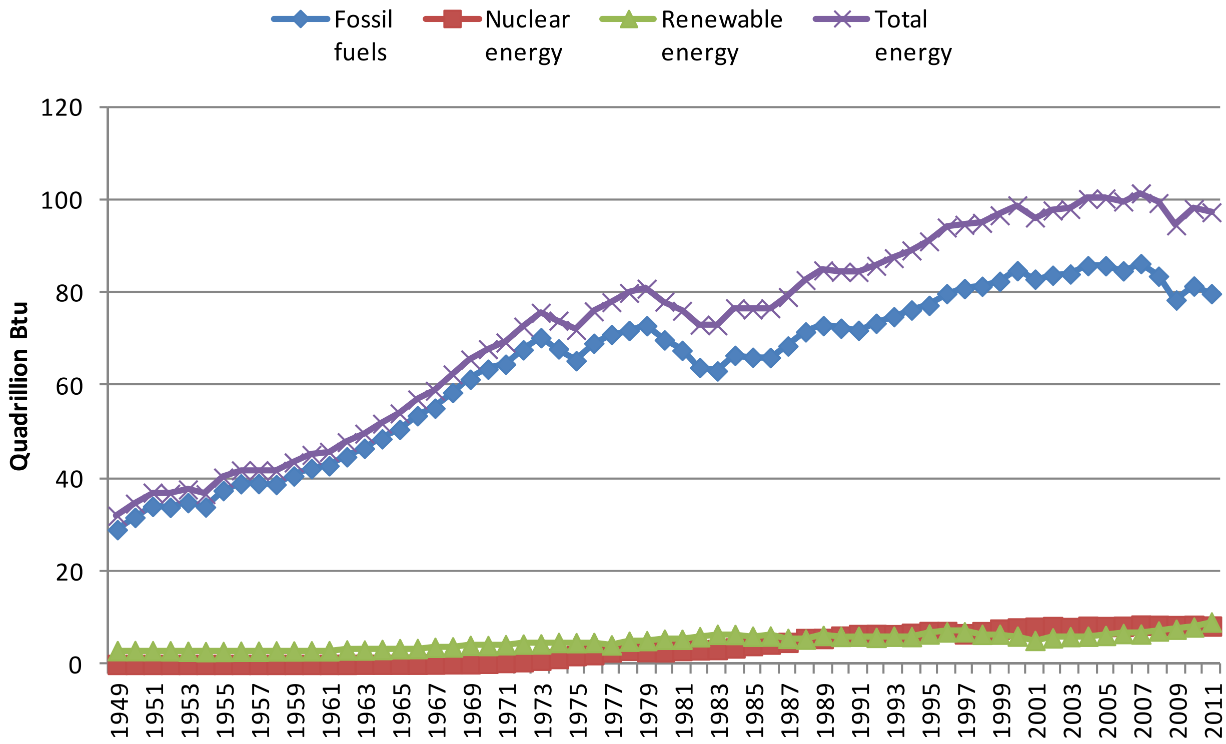

Figure 1-2: U.S. energy consumption by source (1949-2011) (Data source: EIA [3, 4])

Figure 1-3 shows the contribution of the various energy sources to total energy consumed in the U.S. in 2011. Petroleum continues to be the dominant energy source supplying 36 percent, followed by natural gas at 26 percent and coal at 20 percent. Among the renewable resources, biomass (including wood, biofuels, municipal solid waste, landfill gas and others) comprised nearly half of the total renewable energy, followed by hydroelectricity at 35 percent. Wind power's contribution increased to 13 percent from 11 percent in 2010, geothermal dropped from 3 percent in 2009 to 2 percent, and solar rose from 1 percent in 2010 to 2 percent in 2011.

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 woody 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 recent rapid growth. As expected, pumped hydroelectricity's net energy contribution was negative.[1]

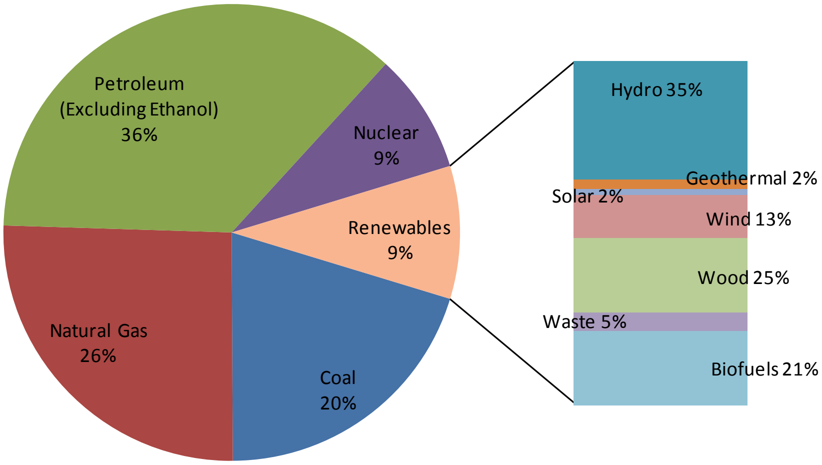

Figure 1-3: U.S. total energy consumption by energy source in 2011 (Data source: EIA [1, 5])

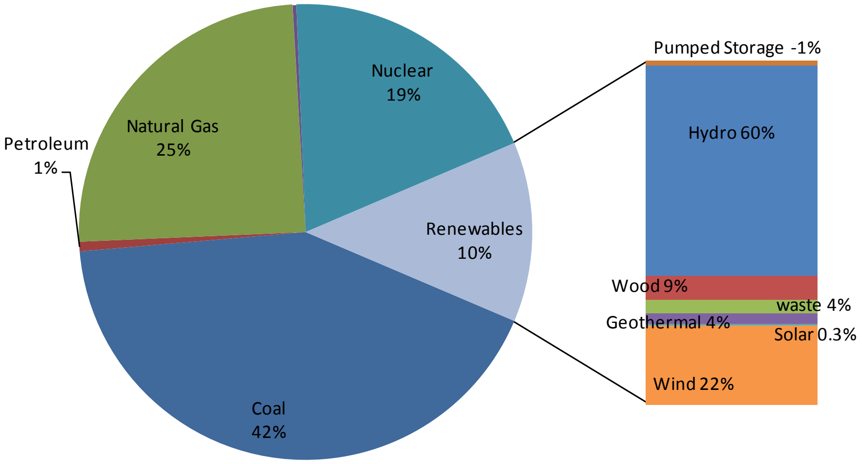

Figure 1-4: Net U.S. electricity generation by energy source in 2011 (Data source: EIA [6])

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

1.2 Trends in renewable energy consumption in Indiana

Figure 1-5 shows renewable energy consumption in Indiana from 1960 to 2010. In the 1980s, renewable resources contributed over 3 percent of total energy consumed in Indiana. In the 1990s the share fell to below 2 percent, before the recent increase in ethanol and wind increased it to over 4.9 percent. 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.

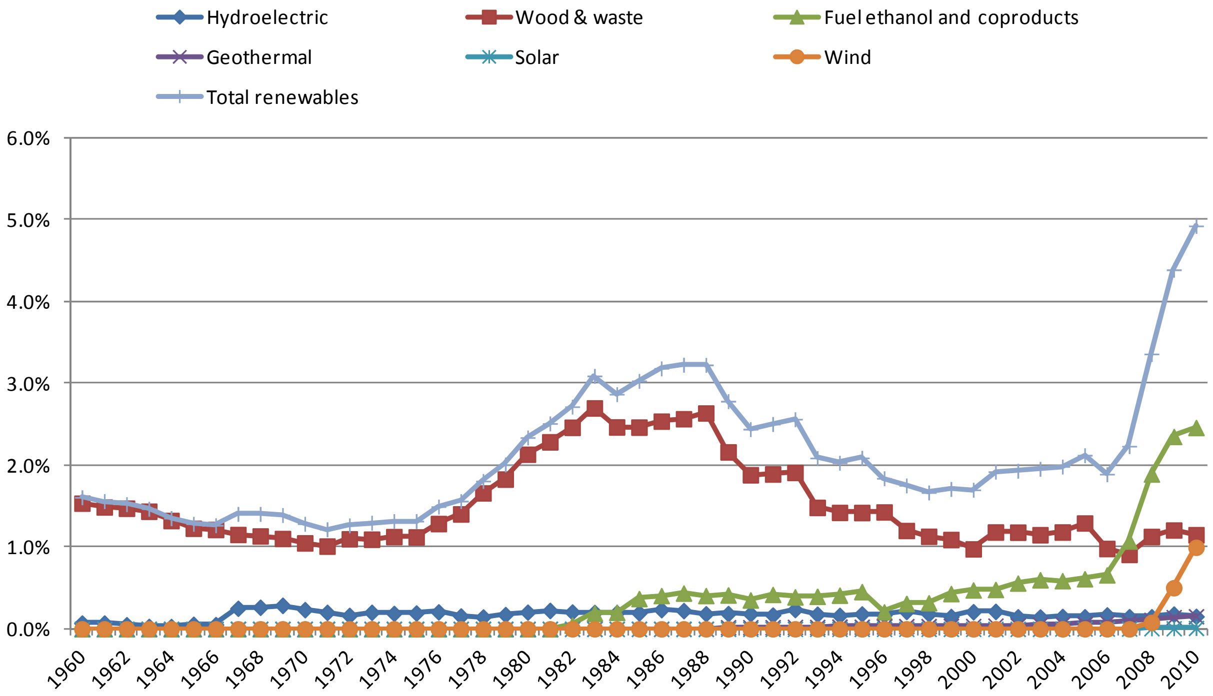

Figure 1-5: Renewables share of Indiana total energy consumption (1960-2010) (Data source: EIA [7])

Figure 1-6 shows the contribution of renewable energy to Indiana's electricity generation from 1990 to 2010. The arrival of utility-scale wind energy projects in 2007 caused a rapid increase in renewable energy's share of Indiana's electricity generation. The share changed from a low of 0.5 percent in 2006 to 1.9 percent in 2009. Wind energy's share of the annual generation was 1.5 percent in 2009 and 2.4 percent in 2010 [8]. Hydroelectricity, which until 2007 was the dominant source of renewable electricity, has maintained its share at approximately 0.4 percent of total generation.

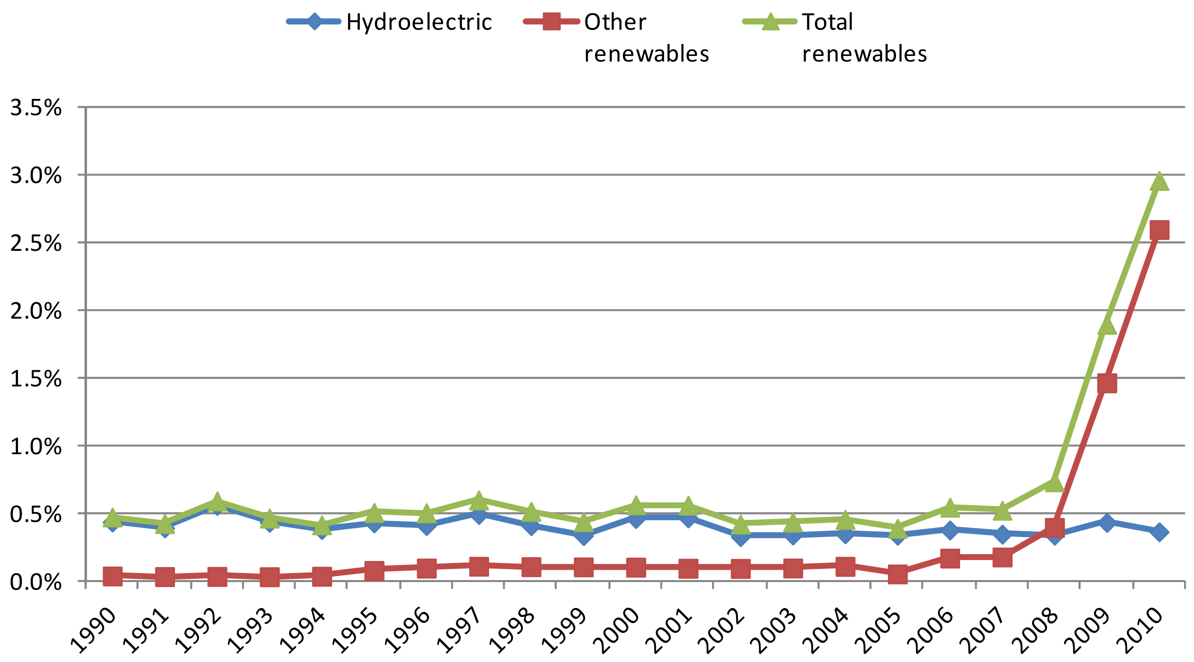

Figure 1-6: Renewables share of Indiana net electricity generation (1990-2010) (Data source: EIA [9])

In keeping with the national trend, the rapid rise in wind energy capacity installation in 2008 and 2009 slowed in 2010 and 2011, dropping from 907 MW installed in 2009 to 301 MW installed in 2010 and no utility scale wind capacity installed in Indiana in 2011. The industry has recovered somewhat with the ongoing construction of the 200 MW Wildcat Wind Farm in Madison and Tipton counties. Figure 1-7 shows the annual and cumulative installed wind energy capacity in Indiana. The extent of recovery will be influenced by the decision on whether or not to extend the 2.2 cents/kWh federal production tax credit, which is set to expire at the end of 2012. Utilities in Indiana have a total of 831 MW of wind contracted in power purchase agreements, 426 from Indiana wind farms and 405 MW from wind farms in Illinois, Iowa, Minnesota and South Dakota.

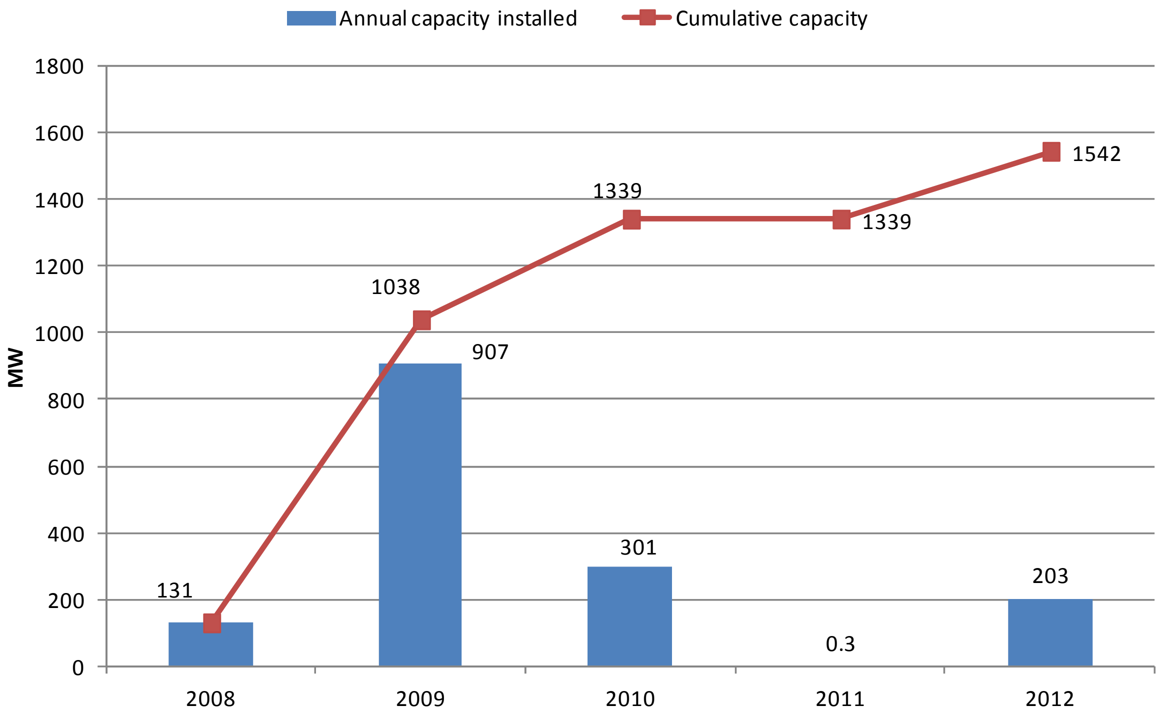

Figure 1-7: Wind energy installed capacity in Indiana (Data sources: IURC, DOE [10-13]).

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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.

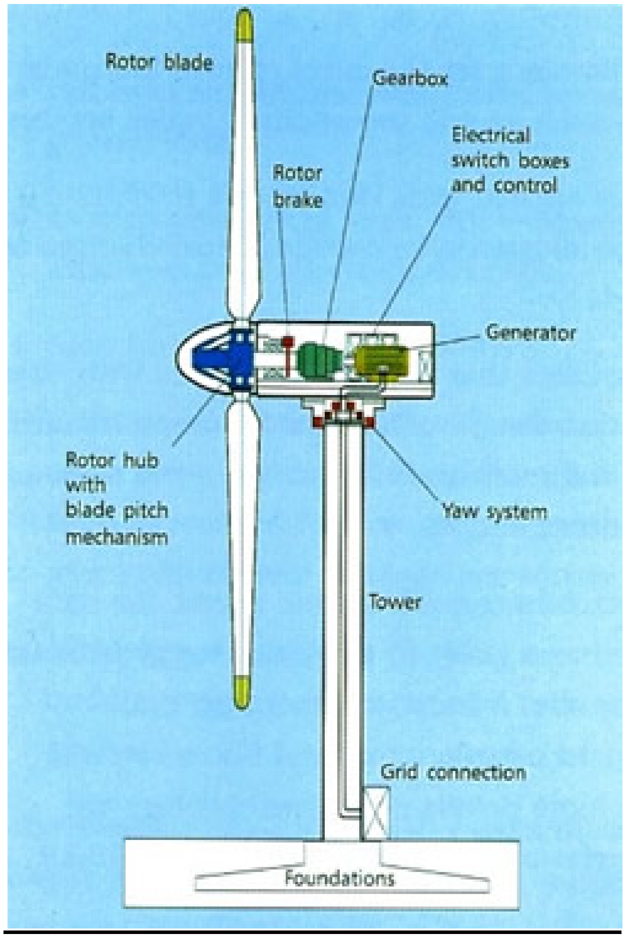

Figure 2-1: Horizontal wind turbine configuration (Source: South Ayrshire Council [1])

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. Turbine capacity 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 Alta Wind Energy Center in California with an active capacity of 1,020 MW [3], while the largest coal power plant in Indiana is composed of five units with capacities greater than 620 MW for a total plant capacity of 3,257 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 20 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 7 miles per hour (mph), or 3 meters per second (m/s), are required for small electric wind turbines not connected to the grid, whereas utility-scale wind plants require a minimum wind speed of 11 mph (5 m/s). The power available to drive wind turbines is proportional to the cube of the speed of the wind. This implies that a doubling in wind speed leads to an eight-fold increase in power output. A measurement called the wind power density 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: NREL [6])

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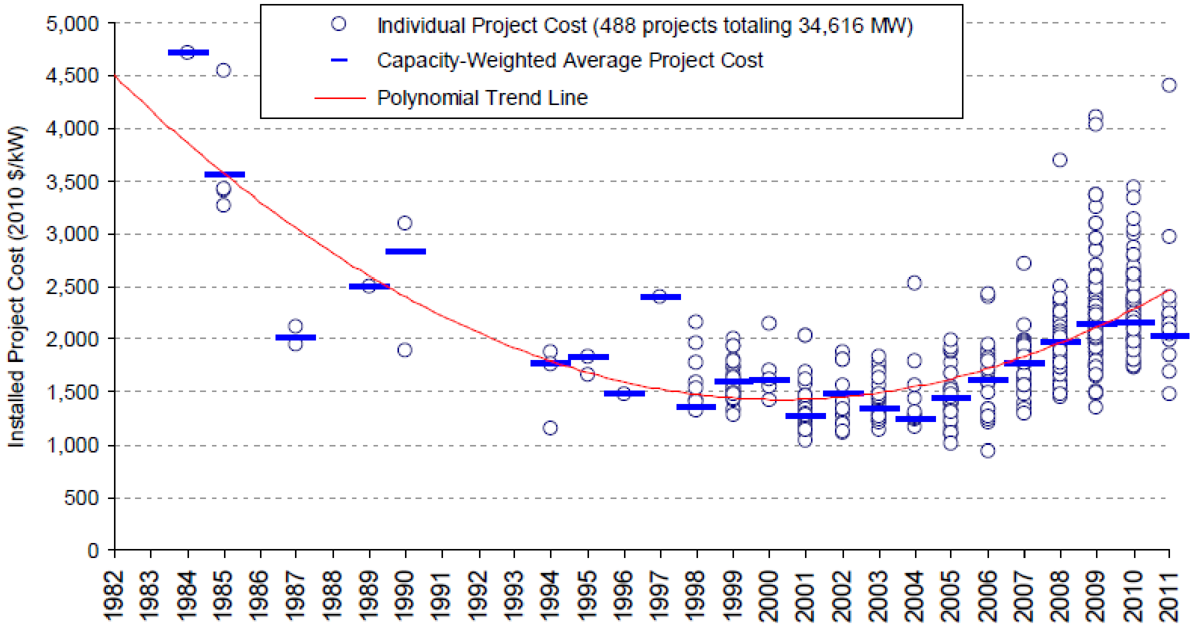
[2] $$\text{Annual capacity factor} = \frac{\text{Actual amount of energy produced in a year}}{\text{Energy that would have been produced if plant operated at full rated capacity all year}}$$

In addition to being a virtually inexhaustible renewable resource, wind energy has the advantage of being modular; that is a wind farm's size can be adjusted by simply adjusting the number of turbines on the farm. A major disadvantage of wind is that the amount of energy available from the generator at any given time is dependent on the intensity of the wind resource at the time. Therefore the electric system operator's range of control of its output is restricted to an ability to curtail. This reduces the wind generator's value both at the operational level and also at system capacity planning level where the system planner needs information about how much energy they can count on from a generator at a future planning date. Another disadvantage of wind energy is that good wind sites tend to be located far from main load centers and transmission lines. Concerns have also been raised about the death of birds and bats flying into wind turbines, the possibility of turbines causing radar interference, and potential adverse effects of the shadow flicker on people living in close proximity.

2.2 Economics of wind energy

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 [7].

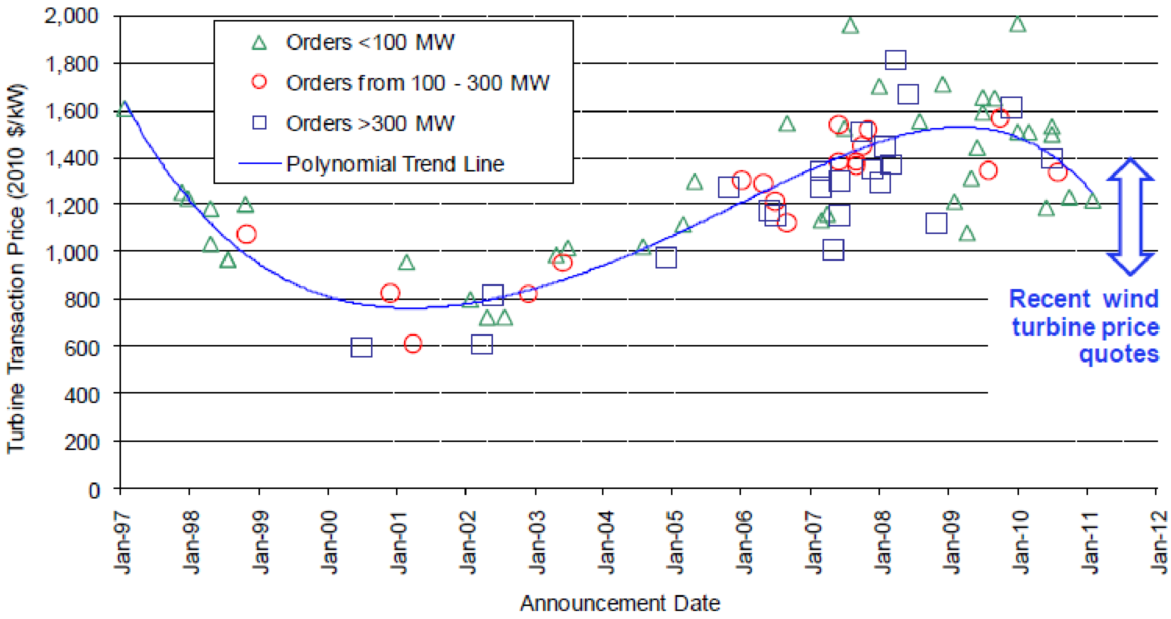


Note: 2011 data represent preliminary cost estimates for a sample of 17 projects totaling 1.1 GW that have either already been or will be built in 2011, and for which reliable cost estimates were available.

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

Figure 2-2: Installed wind project costs over time (Source: EERE [7])

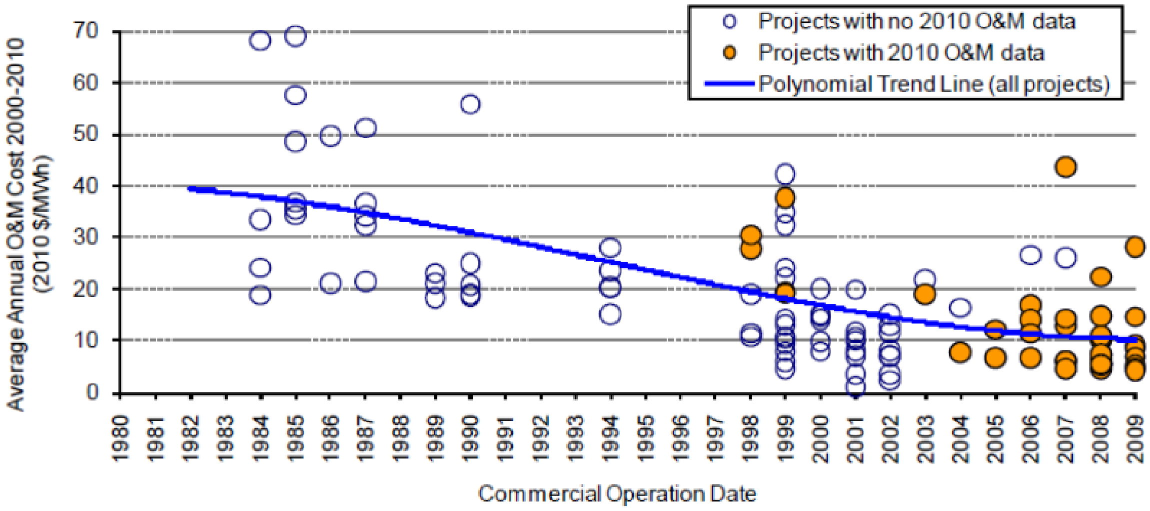
The expected decline in wind farm project costs is already being reflected by a reduction in prices of turbines in the beginning months of 2011. Figure 2-3 shows wind turbine costs over time as calculated for the projects included in the Lawrence Berkeley National Laboratory dataset used in the *2010 Wind Technologies Market Report* [7]. As illustrated in the diagram, turbine prices peaked in 2008 and have steadily decreased since. This decline reflects similar declines in energy and commodity prices, and a shift in the supply-demand balance for turbines towards a buyer’s market. These price reductions are expected to drive down total project costs and wind power prices.



Source: Berkeley Lab

Figure 2-3: Reported U.S. wind turbine prices over time (Source: EERE [7])

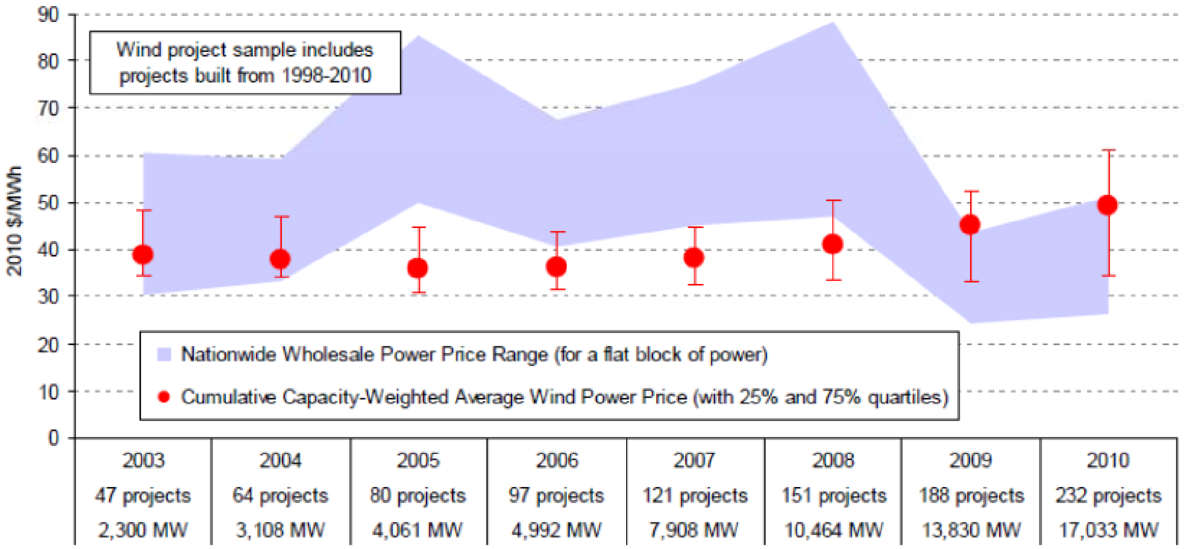
Operation and maintenance (O&M) costs can vary substantially among projects. Figure 2-4 shows O&M costs using data compiled by Berkeley Lab for 126 wind projects installed between 1982 and 2009 with a total capacity of 7,502 MW. It suggests that projects installed recently have incurred lower average 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 [7].



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 [7])

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 [7].



Source: Berkeley Lab, FERC, Ventyx, ICE

Figure 2-5: Average cumulative wind and wholesale electricity prices (Source: EERE [7])

2.3 State of wind energy nationally

After a big drop in wind capacity annual installations from 10,000 MW in 2009 to 5,203 MW in 2010, the annual installed capacity increased to 6,651MW 2011. According to the American Wind Energy Association (AWEA), the total cumulative installed capacity at the end of March 2012 was 48,611 MW [8]. Figure 2-6 shows the capacity installation from 2001 to the first quarter of 2012. Although the rate of capacity installation has recovered somewhat from the big drop in 2010, it has not recovered to the levels in the 2008-2009 period. The combined effect of the reduced electricity demand growth due to the recession and the abundance of natural gas from shale formations have kept wholesale electricity prices at a level with which it is difficult for wind to compete.

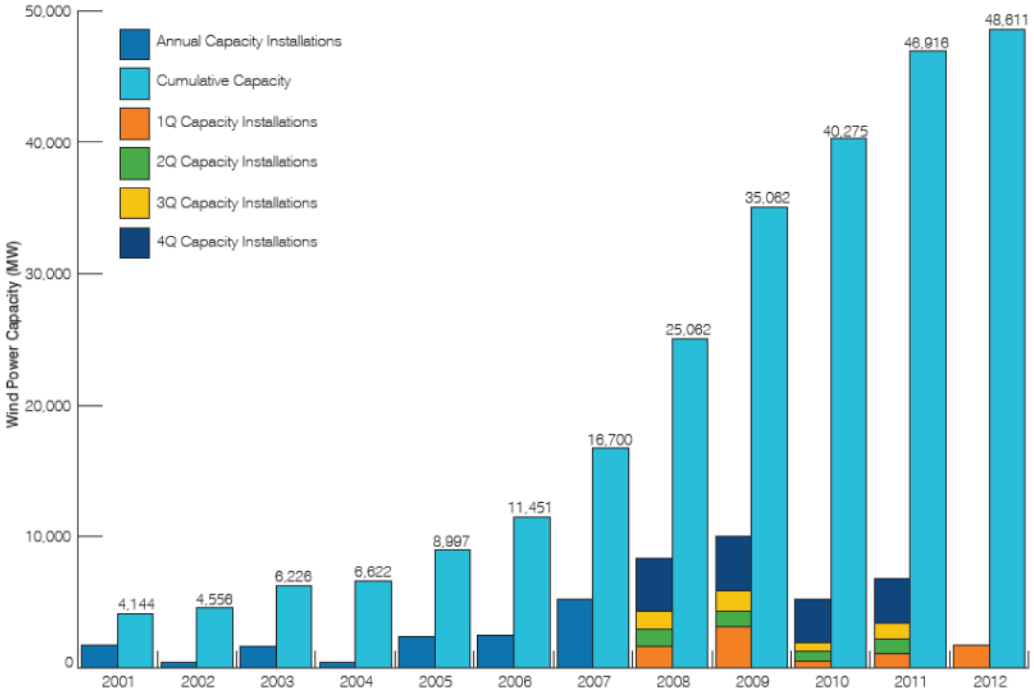


Figure 2-6: U.S. wind capacity growth (Source: AWEA [8])

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

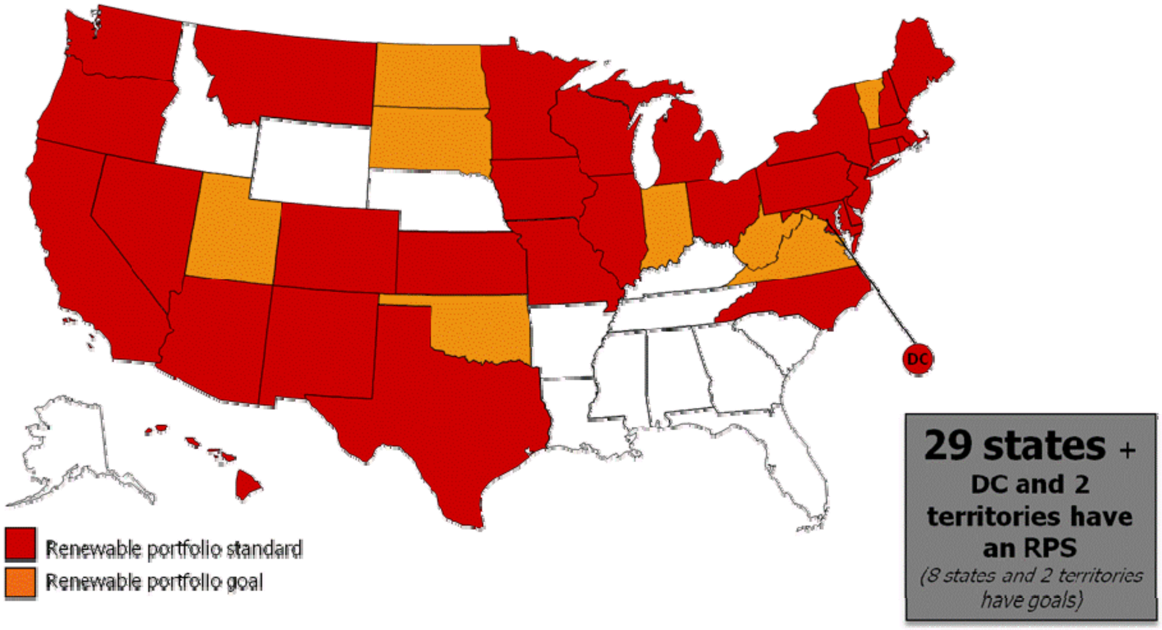


Figure 2-7: Renewable portfolio standards across the U.S. (Source: DSIRE [9])

Figure 2-8 shows the cumulative capacity of wind energy installed in states as of the end of 2011. Texas continued to lead with a total capacity of 10,377 MW installed followed by Iowa with 4,322 MW of cumulative capacity installed. Indiana ranked 19th overall with 1,339 MW of cumulative installed capacity at the end of 2011. In terms of wind capacity added in 2011, Illinois led with 698 MW followed by California with 674 MW added and Iowa with 647 MW added. Indiana had no utility-scale wind energy capacity added.

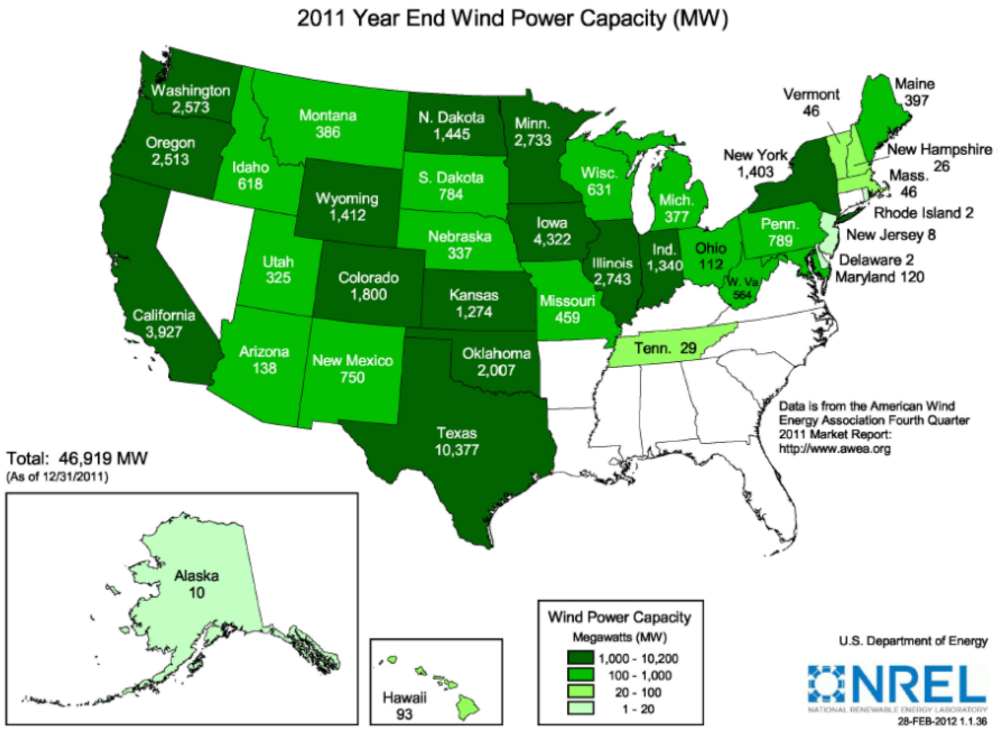
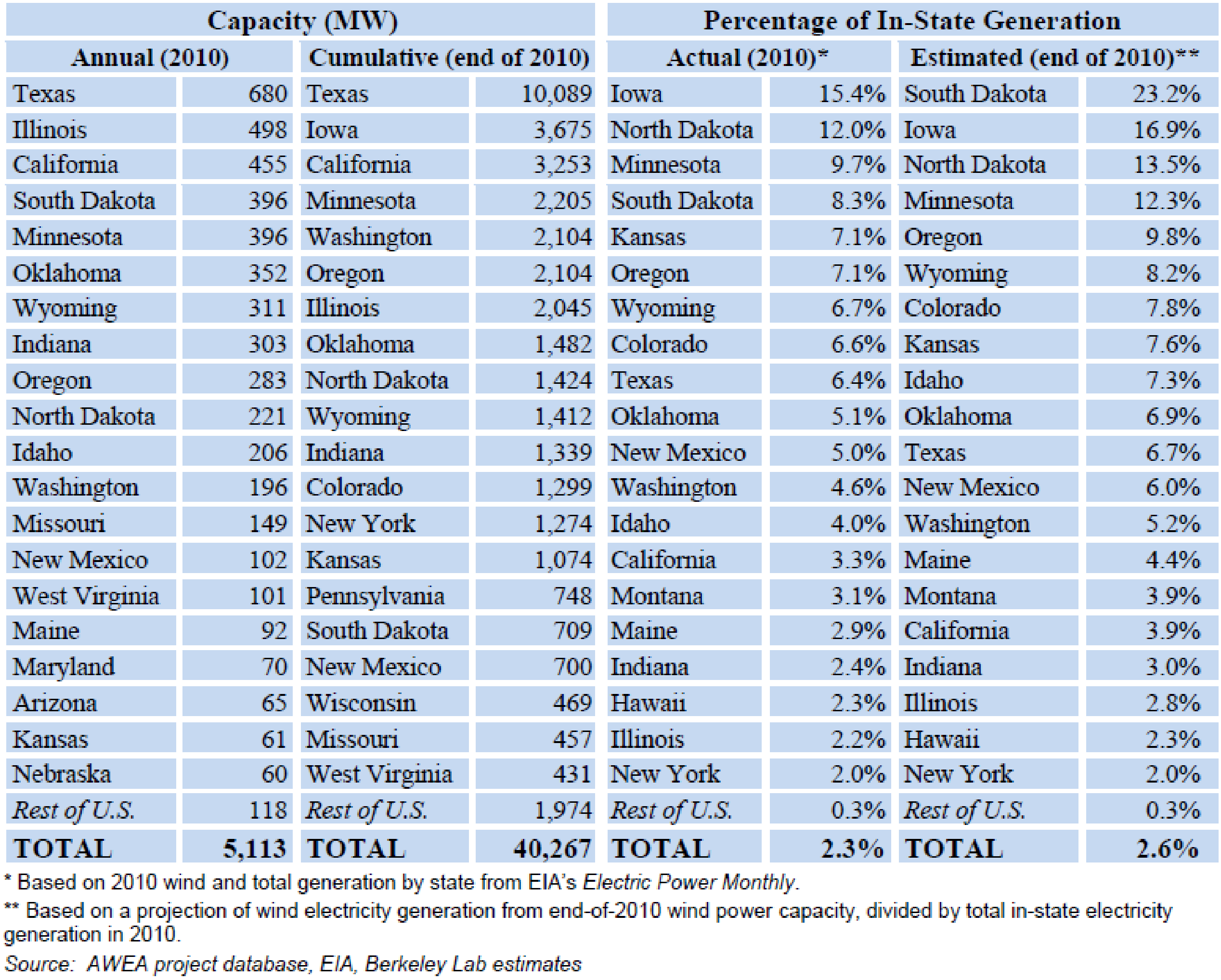


Figure 2-8: Wind power capacity by state at the end of 2011 (MW) (Source: EERE [7])

With regard to the penetration of wind energy as a percent of the total electricity generated in 2010, 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. Data on wind penetration was not available for 2011 at the writing of this the report. 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 was 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 (Source: EERE [7])

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

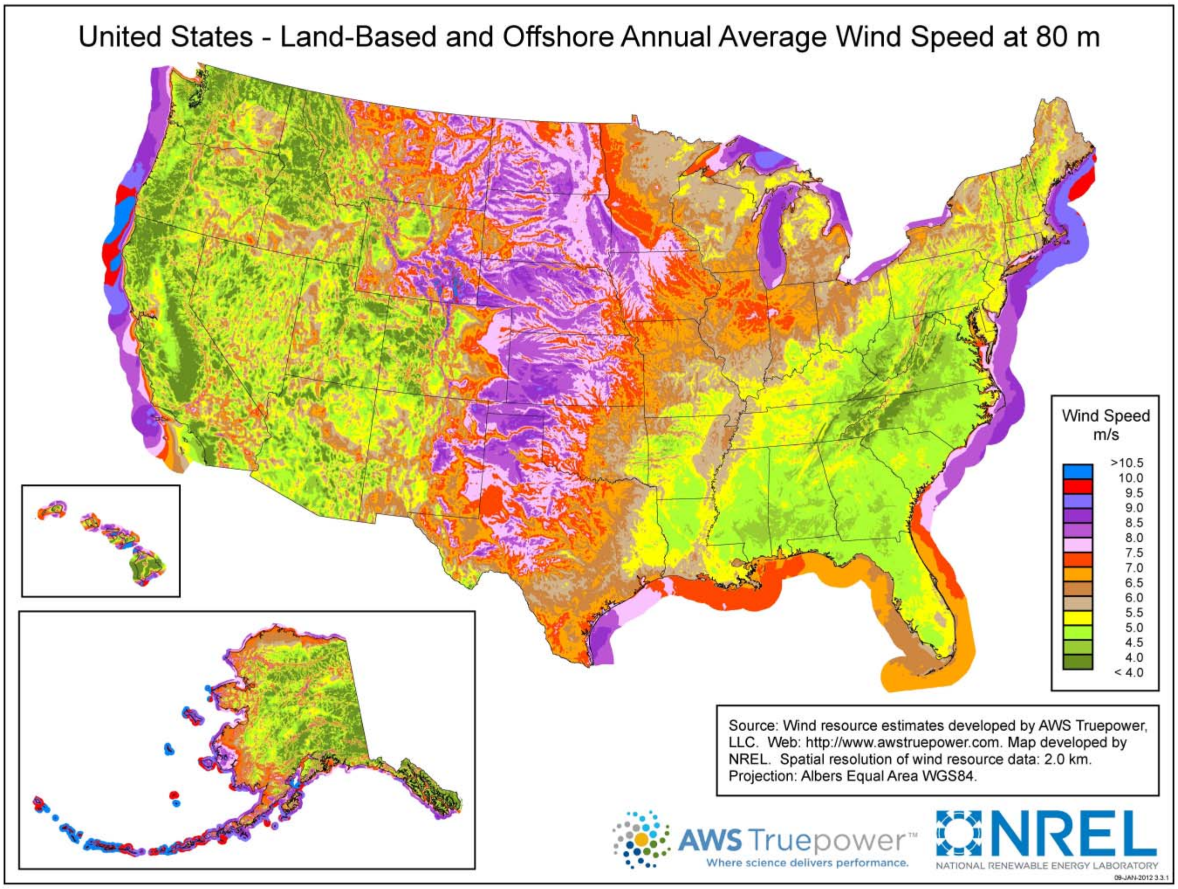


Figure 2-9: <u>80-meter U.S. wind resource map</u> (Source: NREL [10])

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

The federal government, in a combined effort between DOE and the U.S. Department of the Interior, has launched an effort to lower these barriers and expedite the deployment of substantial offshore wind generation capacity. This effort is explained in a document titled *A National*

Offshore Wind Strategy: Creating an Offshore Wind Energy Industry in the United States released in February 2012 [11]. The national strategy aims to help overcome the barriers by investment technology development, market barrier removal, advanced technology demonstration, and the development of a less cumbersome regulatory framework.

2.4 Wind energy in Indiana

Like the rest of the U.S., Indiana experienced rapid growth of wind generation capacity in 2008 and 2009. The 907 MW annual capacity addition in 2009 was reduced to 300 MW added in 2010 and virtually no capacity added in 2011 outside small, stand-alone community wind turbines. Figure 2-10 shows the annual and cumulative capacity additions in Indiana. The 200 MW shown for 2012 is the expected completion of the Wildcat Wind Farm currently under construction in Madison and Tipton counties.

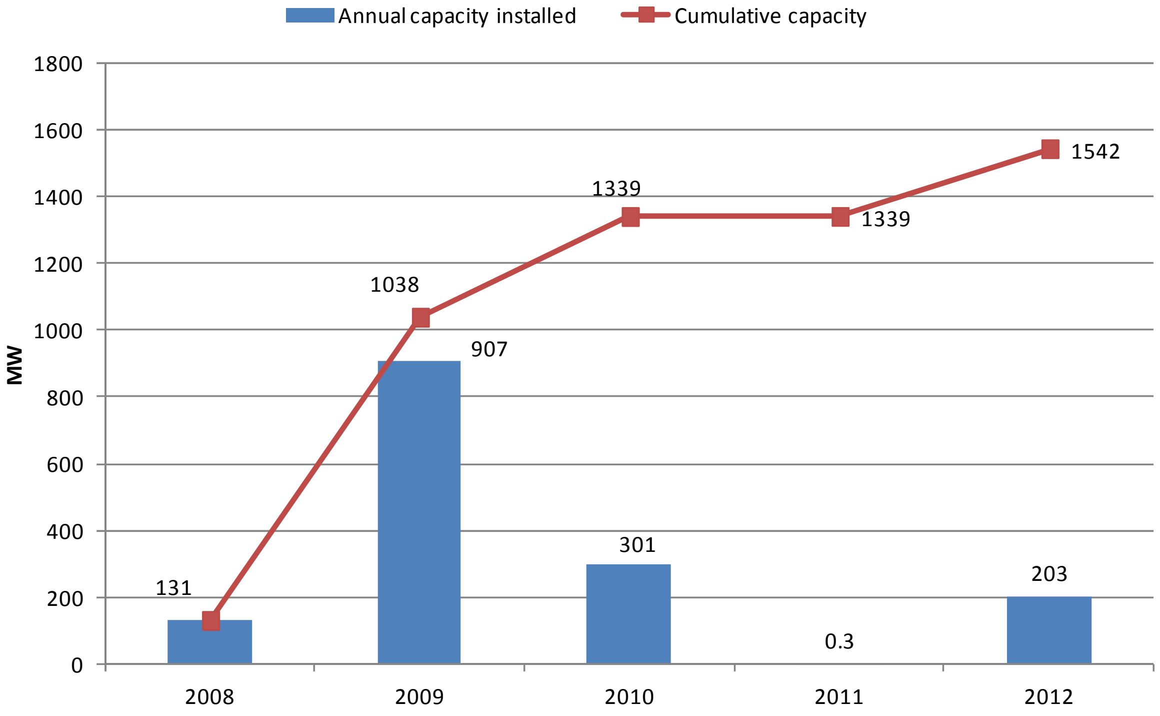


Figure 2-10: Annual wind energy capacity installation in Indiana (Data source: IURC, DOE [12-15]

Table 2-3 shows a list of utility scale wind farms in Indiana. It includes the nine operational wind farms with a combined capacity of 1,337 MW, the 200 MW currently under construction and the 352 MW of proposed capacity that have been approved for construction by the Indiana Utility Regulatory Commission.

Project Name	County	Capacity (MW)	Developer	Date Completed	Power Purchaser
Benton County Wind Farm	Benton	131	Orion	2008	Duke (101 MW) Vectren (30 MW)
Fowler Ridge Wind Farm 1	Benton	301	BP / Dominion	2009	I&M (100 MW), Dominion (201 MW)
Fowler Ridge Wind Farm IIA	Benton	200	BP/Sempra	2009	AEP (50x3 MW), Vectren (50 MW)
Fowler Ridge Wind Farm III	Benton	99	BP/Sempra	2009	AEP Appalachian (99 MW)
Hoosier Wind Project	Benton	106	enXco	2009	IPL (106 MW)
Meadow Lake I	White	200	Horizon (EDP)	2009	Wholesale market COMED (50 MW)
Meadow Lake II	White	99	Horizon (EDP)	2010	Wholesale market COMED (25 MW) Ameren (25 MW)
Meadow Lake III	White	104	Horizon (EDP)	2010	Wholesale market Ameren (25 MW)
Meadow Lake IV	White	99	Horizon (EDP)	2010	Wholesale market Ameren (25 MW)

Under construction

Wildcat Wind Farm 1	Tipton & Madison	200	E.ON	December 2012	Wholesale market I&M (100 MW)

Approved by Indiana Utility Regulatory Commission

Spartan Wind Farm 1	Newton	101	Duke Generation Services		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 [12])

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

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

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

Indiana utilities have a total 831 MW contracted on power purchase agreements, 426 MW from wind farms in Indiana and 405 MW from out of state wind farms in Illinois, Iowa, Minnesota and South Dakota. Table 2-5 shows the capacity contracted to Indiana utilities.

Utility	**Project**	**State**	**Power Purchase Agreement (MW)**
Duke Energy	Benton County Wind Farm	Indiana	101
Vectren	Benton County Wind Farm	Indiana	30
Vectren	Fowler Ridge Wind Farm II	Indiana	50
Indiana Michigan	Fowler Ridge Wind Farm I	Indiana	100
Indiana Michigan	Wildcat Wind Farm	Indiana	40
IPL	Hoosier Wind Farm	Indiana	106
IPL	Lakefield Wind Project	Minnesota	201
NIPSCO	Buffalo Ridge Wind FArm	South Dakota	50
NIPSCO	Barton Windpower	Iowa	50
WVPA	AgriWind	Illinois	8
WVPA	Storey County Wind Farm	Illinois	21
IMPA	Hancock County Wind Farm	Iowa	50
Hoosier Energy	Storey County Wind Farm	Illinois	25

Table 2-5: Wind energy purchase agreements by Indiana utilities (Data source: IURC [12])

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

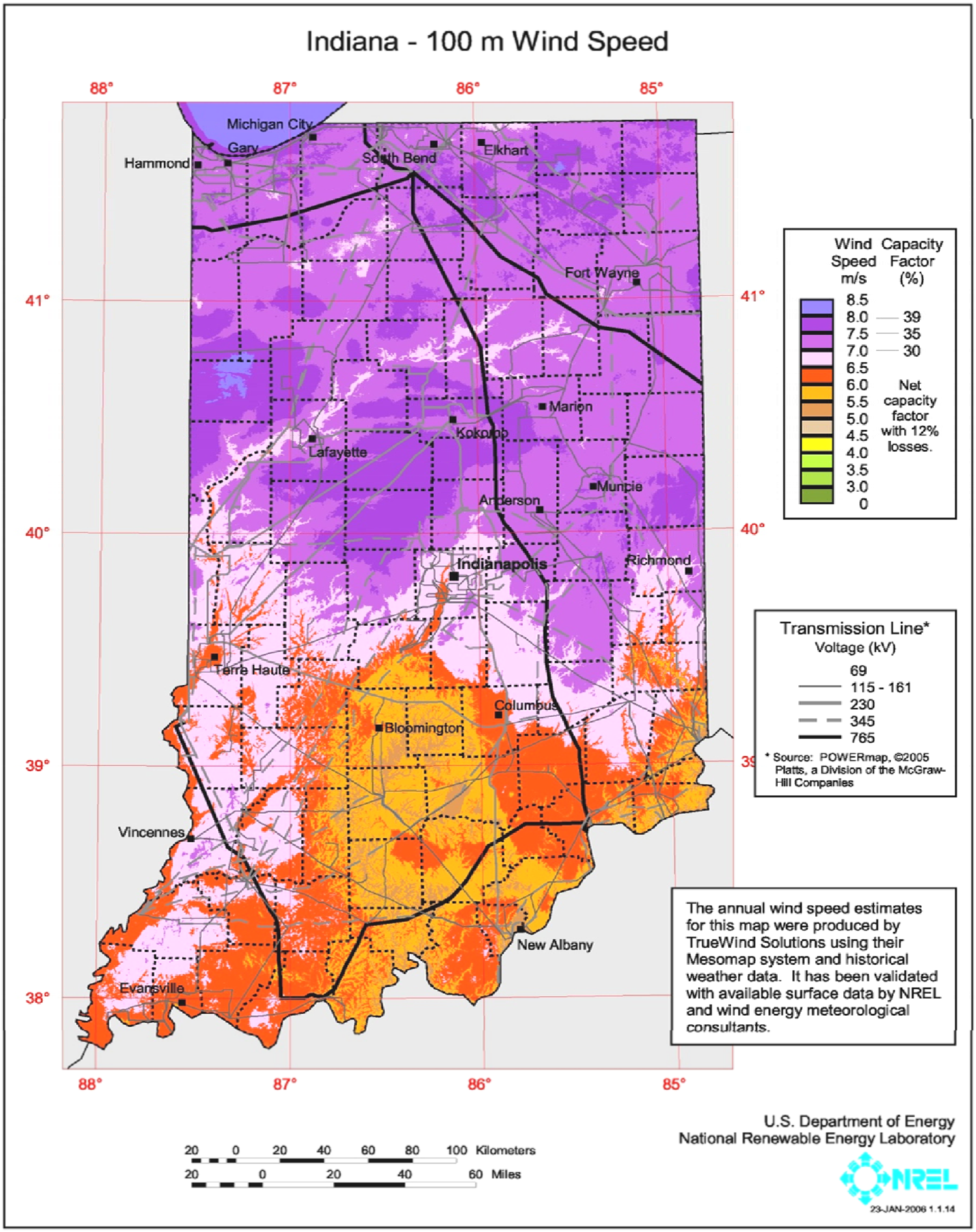


Figure 2-11: Indiana wind speed at 100 meters height (Source: OED/NREL [16])

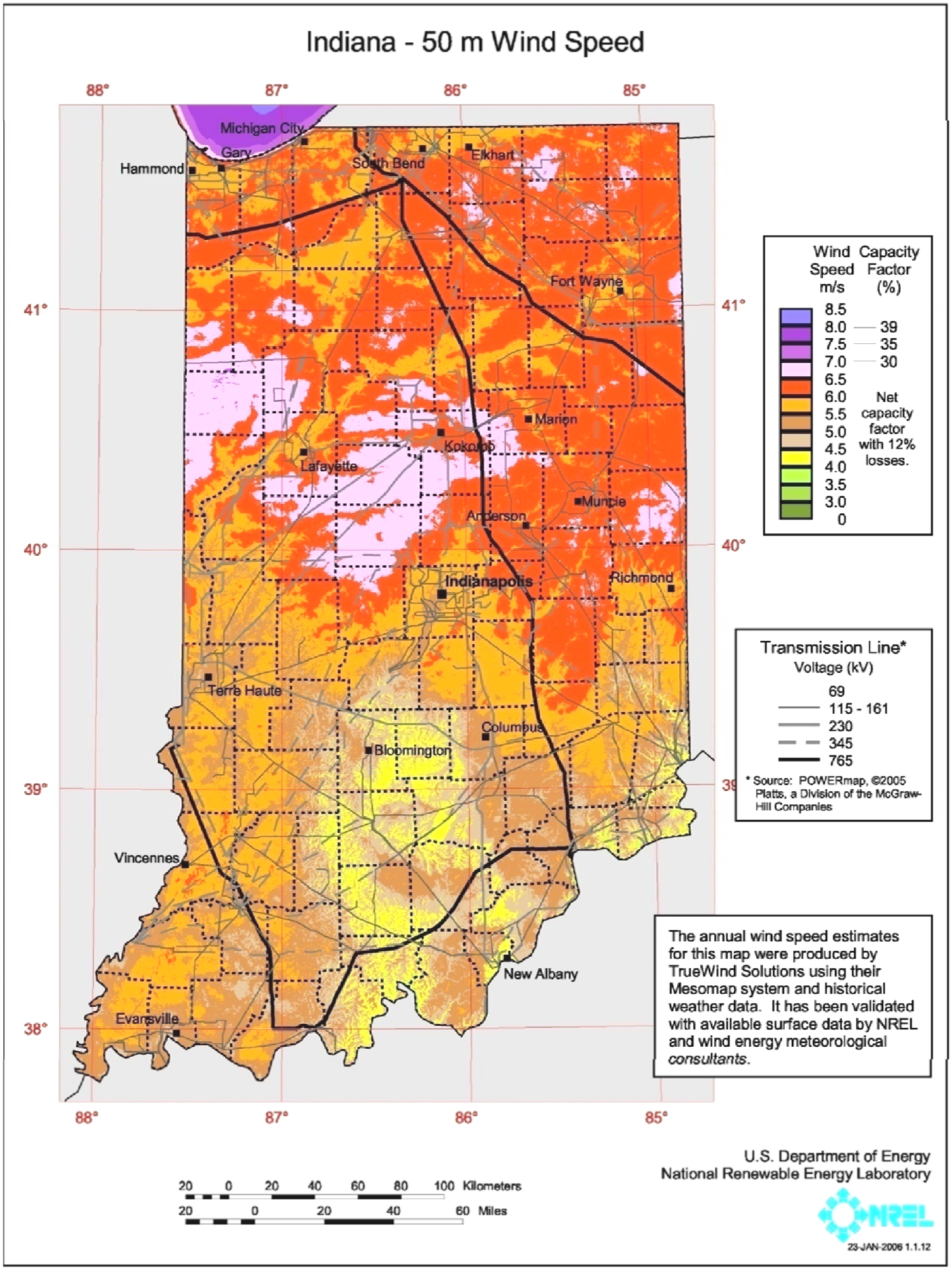


Figure 2-12: Indiana wind speed at 50 meters height (Source: OED/NREL [16])

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). The PTC is available for projects with an in-service deadline of December 31, 2012 [9].

- Business Energy Investment Tax Credit (ITC) credits up to 30 percent of expenditures, with no maximum credit, on qualifying wind energy installations (small wind turbines placed in service after December 31, 2008). Eligible small wind property includes wind turbines up to 100 kW in capacity with an in-service deadline of December 31, 2016 [9].

- 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 [18].

- 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. Systems must be placed in service on or before December 31, 2016 [9].

- Modified Accelerated Cost-Recovery System (MACRS) 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 was 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 [9].

- 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 as of July 1, 2008. 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 [9].

- 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 [9].

- 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 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 [9].

- High Energy Cost Grant Program administered by the U.S. Department of Agriculture (USDA) is aimed at improving the electricity supply infrastructure in rural areas having home energy costs exceeding 275 percent of the national average. Eligible infrastructure includes renewable resources generation. The USDA has allocated $21 million for the 2011 funding cycle. The individual grants range from $75,000 to $5 million [19].

Indiana Incentives

- Net Metering Rule allows utility customers with renewable resource facilities having a maximum capacity of 1 MW to receive a credit for net excess generation in the next billing cycle [9].

- Renewable Energy Property Tax Exemption provides property tax exemptions for solar thermal, PV, wind, hydroelectric and geothermal systems [9].

- Emissions Credits make electricity generators that do not emit nitrogen oxides (NO_x) and that displace utility generation eligible to receive NO_x emissions credits under the Indiana Clean Energy Credit Program [20].

- Clean Energy Portfolio Goal sets a voluntary goal of obtaining 4 percent between 2013 and 2018, 7 percent between 2019 and 2024, and 10 percent by 2025, of electricity from clean energy sources based on 2010 retail sales. Participation in the goal makes utilities eligible for incentives that can be used to pay for the compliance projects [21].

- 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 15 years. Compensation for small wind facilities is $0.14/kWh and for large wind facilities is $0.075/kWh. REP is a pilot rate and no new contracts will be negotiated after March 30, 2013 [9, 22].

- Northern Indiana Public Service Company offers feed-in tariff incentive rates for electricity generated from renewable resources for up to 15 years. The payments for electricity from wind generating facilities are $0.17/kWh for facilities with a capacity less than or equal to 100 kW and $0.10/kW for facilities with capacities between 101 and 2,000 kW. The renewable tariff is experimental and slated to run until December 31, 2013. The generating unit size allowed under the tariff is between 5 and 5,000 kW while the total allowed system-wide capacity is 30 MW. Five hundred kilowatts of the system-wide cap are reserved for wind projects of capacity less than 10 kW, and 500 kW for solar projects of capacity less than 10 kW [9, 23].

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3. Dedicated Energy Crops

3.1 Introduction

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

Unlike the use of organic wastes as an energy source, the dedicated energy crop industry in the U.S. is still in its infancy. A substantial federally-driven research and development effort is under way as part of the national effort to reduce dependence on imported oil. This research effort is detailed in the recently updated report from DOE titled *U.S. Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry* [1]. Among the renewable resources, biomass including energy crops has the advantage in that they can be converted to transportation fuels. The crops being considered and developed as dedicated energy crops can be grouped into three main categories – perennial grasses, woody crops and annual crops.

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

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

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

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

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

Southern pines are already one of the main contributors to bioenergy in the United States. Their barks and the paper processing byproduct *black liquor* are used to produce energy in pulp and paper mills. Their ability to grow rapidly in a wide range of sites have made the southern pine the most important and widely cultivated timber species in the U.S., mainly for lumber and pulpwood.

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

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

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

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

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

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

There are currently 27 such DOE funded integrated biorefinery projects spread across the United States. Twelve of these are small scale pilot projects with a capacity of one dry ton of biomass per day. These pilot plants screen and validate promising bio-processing technologies. Nine of the biorefineries are demonstration plants where the technologies validated at the pilot plants are scaled up to produce at the scale of at least 50 dry tons of feedstock a day. In the six commercial-scale projects currently under construction the bio-processing technologies are scaled up to process at least 700 dry tons of feedstock a day. Table 3-1 is list of DOE funded integrated biorefinery projects [6].

Project	Location	Scale	Conversion Technology
Abengoa	Hugoton, KS	Commercial	Biochemical
Bluefire LLC	Fulton, MS	Commercial	Biochemical
Flambeau	Park Falls, WI	Commercial	Thermo - Gasification
Mascoma	Kinross, MI	Commercial	Biochemical
POET	Emmetsburg, IA	Commercial	Biochemical
Rangefuels	Soperton, GA	Commercial	Thermo - Gasification
Enerkem	Pontotoc, MS	Demonstration	Thermo - Gasification
INEOS New Planet Bioenergy LLC	Vero Beach, FL	Demonstration	Hybrid
Lignol	Washington	Demonstration	Biochemical
New Page	Wisconsin Rapids, WI	Demonstration	Thermo - Gasification
Pacific Ethanol	Boardman, OR	Demonstration	Biochemical
RSA	Old Town, ME	Demonstration	Biochemical
Sapphire Energy Inc.	Columbus, NM	Demonstration	Algae/CO2
Verenium	Jennings, LA	Demonstration	Biochemical
Myriant	Lake Providence, LA	Demonstration	Biochemical
Algenol Biofuels Inc	Fort Myers, FL	Pilot	Algae/CO2
American Process Inc.	Alpena, MI	Pilot	Biochemical
Amyris Biotechnologies Inc.	Emeryville, CA	Pilot	Biochemical
Archer Daniels Midland	Decatur, IL	Pilot	Biochemical
ClearFuels Technology	Commerce City, CO	Pilot	Thermo - Gasification
Haldor Topsoe Inc.	Des Plaines, IL	Pilot	Thermo - Gasification
ICM Inc.	St. Joseph, MO	Pilot	Biochemical
Logos Technologies	Visalia, CA	Pilot	Biochemical
Renewable Energy Institute International	Toledo, OH	Pilot	Thermo - Gasification
Solazyme Inc.	Riverside, PA	Pilot	Algae/Sugar
UOP LLC	Kapolei, HI	Pilot	Thermo - Pyrolysis
ZeaChem Inc.	Boardman, OR	Pilot	Hybrid

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

3.2 Economics of energy crops

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

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

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

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

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

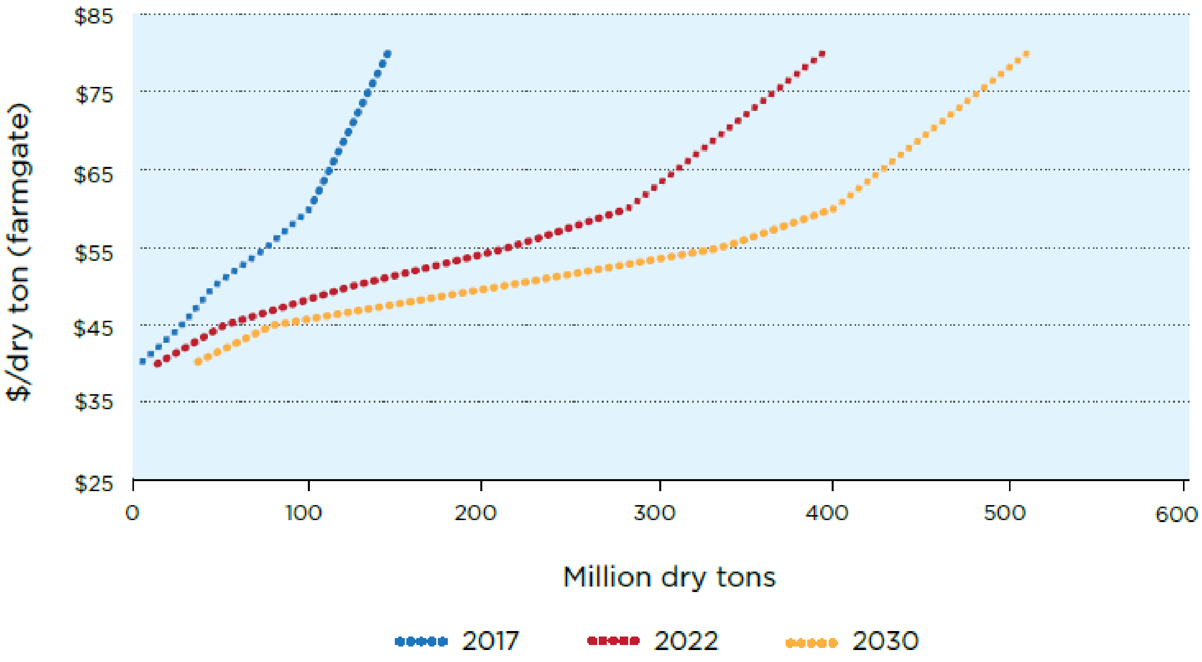

Figure 3-3: Supply curves for all energy crops at selected years (Source: DOE [1])

Corn and soybean use for biofuel production

Although corn and soybeans do not meet the strict definition of dedicated energy crops, they are included in this section in recognition of the rapid growth of corn and soybean biofuel 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. Table 3-2 shows the location and capacities of ethanol plants in Indiana. 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 based biodiesel plants have been constructed bringing the total biodiesel capacity to 118 MGY. Two of these biodiesel plants – the Evergreens Renewables plant in Hammond and the Xenerga waste oils plant in Kingsbury have since shut down. Table 3-3 shows the location and capacities of the three operating biodiesel plants.

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

- The use of corn-ethanol as an oxygenating additive in gasoline in place of the chemical MTBE. The shift from MTBE was due to its being associated with ground water pollution. The replacement of MTBE was mandated both by states and the 2005 Energy Policy Act [7].

- The enactment of the renewable fuel standard under the 2005 Energy Policy Act that required that 7.5 billion gallons of renewable fuel must be blended into gasoline by 2012. This has since been expanded to a requirement of 36 billion gallons of renewable fuel by 2022 (15 billion gallons from corn-ethanol and the balance from advanced biofuels) [8].

- The enactment of the volumetric ethanol excise tax credit (VEETC) in 2004 improved the cost competitiveness of corn-ethanol with gasoline and provided long-term protection for corn-ethanol producers against price volatility in the transportation fuel market. The VEETC allowed for a 45 cents/gallon tax credit to be given to individuals who produce the mixture of gasoline and ethanol. This tax credit expired at the end of 2011.

Company	**Year**	**Town/County**	**Current Capacity (MGY*)**
New Energy Corp	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: Indiana State Department of Agriculture (ISDA) [9])

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

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

3.3 State of energy crops nationally

As discussed previously, the energy crop industry is still in its infancy with a substantial research and development effort under way to establish a sustainable supply of biomass to satisfy the Renewable Fuel Standard mandate of 36 billion gallons of biofuels for the transportation industry per year by 2022 and also increase electricity generation from biomass. As part of this research, DOE has partnered with universities, national laboratories and the U.S. Department of Agriculture to establish a *Regional Biomass Feedstock Partnership* to conduct research, development and outreach at the regional level to address the barriers that associated with the effort to establish a sustainable bioenergy industry. Figure 3-4 shows the biomass feedstock field trial locations established by the *Regional Biomass Feedstock Partnership*.

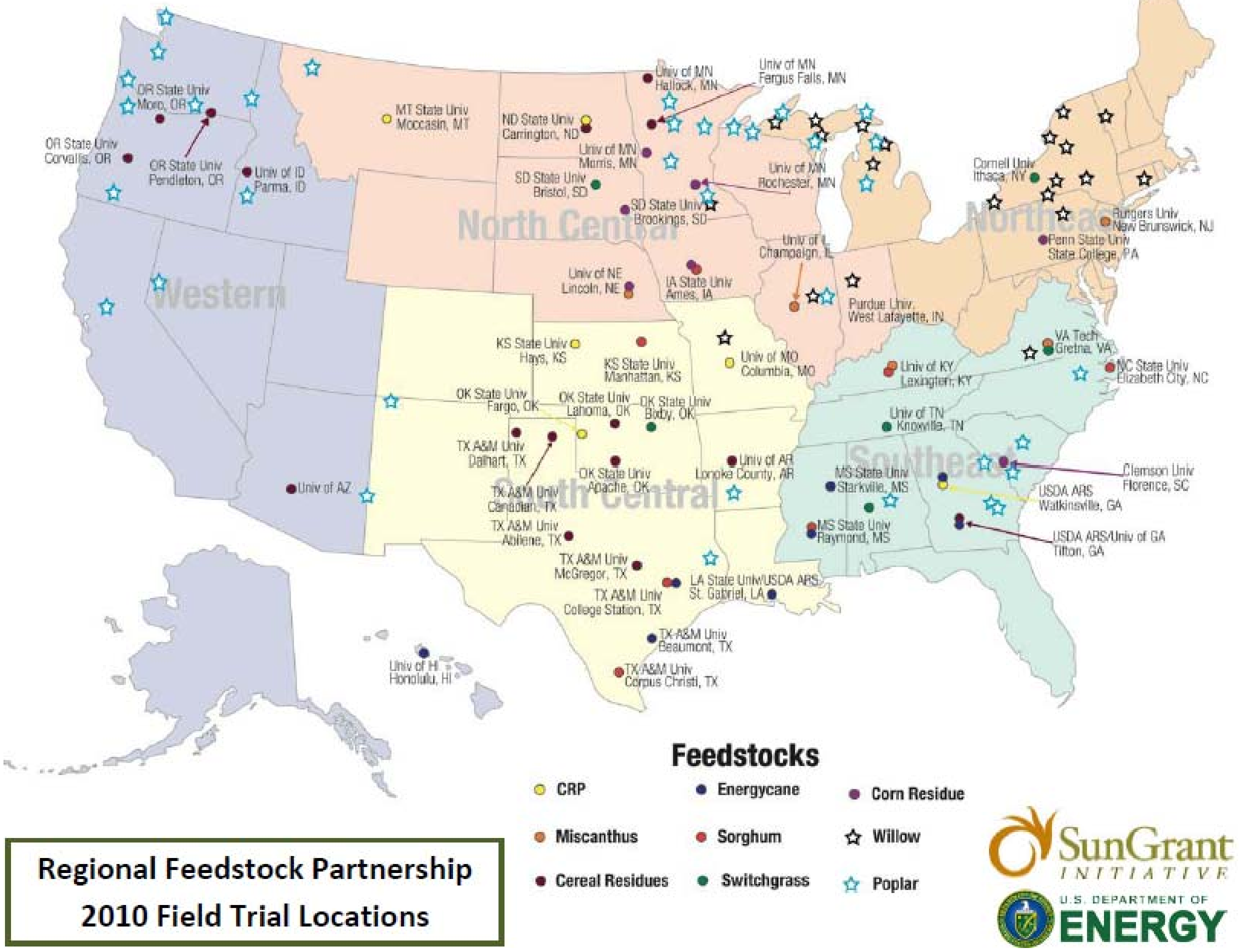

Figure 3-4: 2010 energy crop test stations (Source DOE [10])

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

3.4 Energy crops in Indiana

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

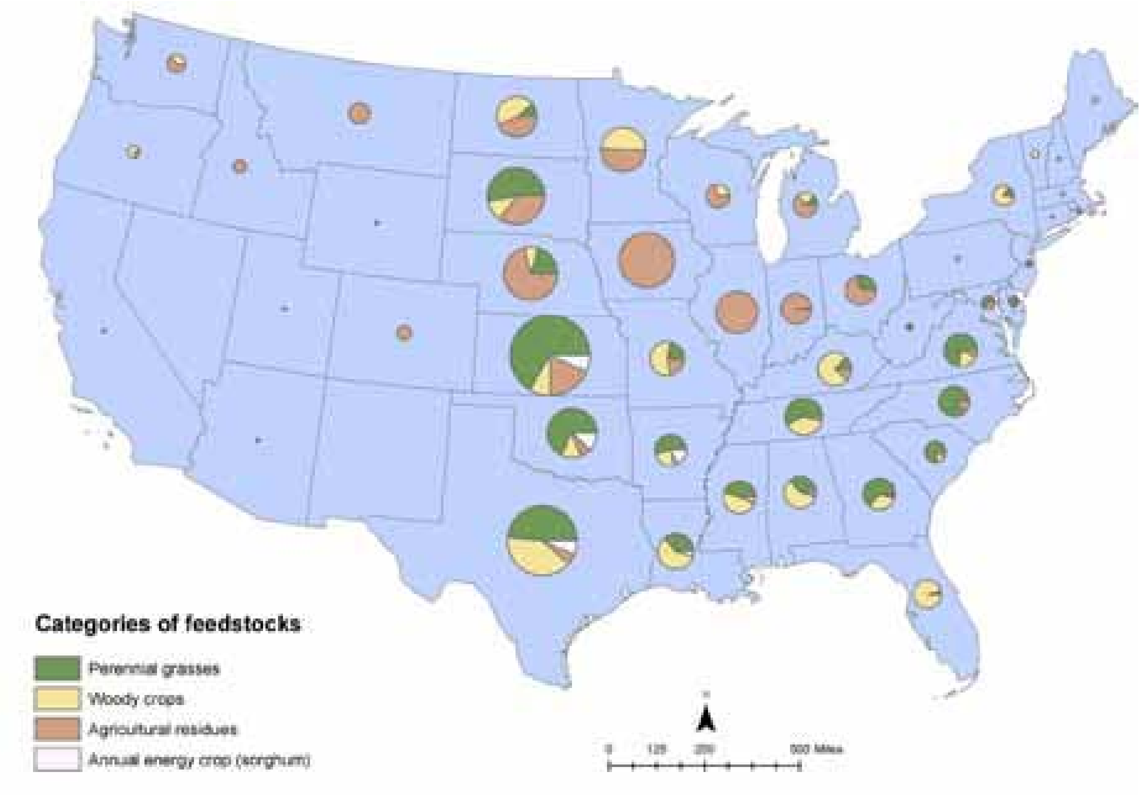

Figure 3-5: Estimated shares of energy crops and agricultural residues supplied at $60 per dry ton in 2030 (Source: DOE [1])

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

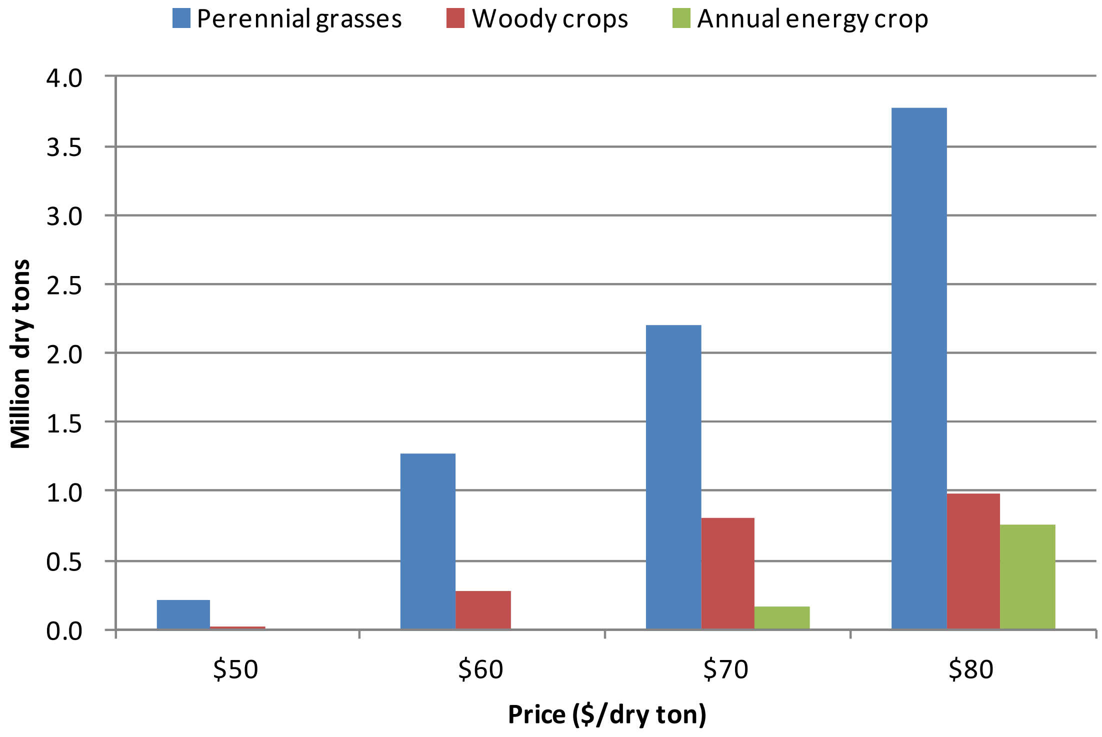

Figure 3-6: Projected production of energy crops in Indiana in 2030 (Data source: DOE [12])

In an April 2008 working paper, Brechbill and Tyner of Purdue's Agricultural Economics Department did an extensive study of the estimated cost of producing switchgrass and harvesting corn stover for the energy industry. Table 3-4 shows the average cost of producing switchgrass given in this study [13]. The table includes the farmer's choice to either: purchase and own the harvesting equipment or hire the services of a specialized custom operator.

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

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

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 closed-loop biomass and 1.1 cents/kWh for open-loop biomass, landfill gas municipal solid waste 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 [14]. The PTC for biomass energy systems expires at the end of 2013.

- Business Energy Investment Tax Credit (ITC) credits up to 30 percent of expenditures on qualified renewable energy systems [14].

- 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 2.1 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 2005 through 2026 [14].

- 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 [14].

- 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 [14].

- Value-Added Producer 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 [15].

- High Energy Cost Grant Program administered by the U.S. Department of Agriculture (USDA) is aimed at improving the electricity supply infrastructure in rural areas having home energy costs exceeding 275 percent of the national average. Eligible infrastructure includes renewable resources generation. The USDA has allocated $21 million for the 2011 funding cycle. The individual grants range from $75,000 to $5 million [16].

Indiana Incentives

- Net Metering Rule allows utility customers with renewable resource facilities with a maximum capacity of 1 MW to receive a credit for net excess generation in the next billing cycle [14].

- Emissions Credits make 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 [17]. These credits can be sold on the national market.

- Clean Energy Portfolio Goal sets a voluntary goal of obtaining 4 percent between 2013 and 2018, 7 percent between 2019 and 2024, and 10 percent by 2025, of electricity from clean energy sources based on 2010 retail sales. Participation in the goal makes utilities eligible for incentives that can be used to pay for the compliance projects [14].

- 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 15 years. Biomass compensation is $6.18/kW per month plus $0.085/kWh. REP is a pilot rate and no new contracts will be negotiated after March 30, 2013 [14, 18].

- Northern Indiana Public Service Company offers feed-in tariff incentive rates for electricity generated from renewable resources on 15 year contracts. Payment for biomass facilities is $0.106/kWh. The tariff is experimental and slated to run until December 31, 2013. The generating unit size allowed under the tariff is between 5 and 5,000 kW while the total allowed system-wide cap is 30 MW. Five hundred kW of the total system-wide cap are reserved for solar projects of capacity less than 10 kW, and 500 kW for wind projects of capacity less than 10 kW [14, 19].

3.6 References

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4. Organic Waste Biomass

4.1 Introduction

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

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

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

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

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

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

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

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

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

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

Algae can be grown in either open ponds or in enclosed bioreactors. Although open pond algae farms are much more cost competitive, they have the disadvantages of being vulnerable to contamination by faster growing native algae, water loss through evaporation and exposure to extreme weather variations. Enclosed bioreactors overcome these drawbacks by growing the algae entirely enclosed in transparent containers of various forms. Not surprisingly, the enclosed bioreactors’ main disadvantage is cost; bioreactors are much more expensive to build than open ponds. One potential application for the use of algae is the coupling of an algae bioreactor with a coal power plant to allow the power plant to provide the carbon dioxide needed for algae growth. In this way a combined benefit of producing bioenergy while reducing carbon dioxide emission is achieved. Such an experiment was conducted at the Arizona Public Service Red Hawk power plant in 2006 and 2007 [4].

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

4.2 Economics of organic waste biomass

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

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

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

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

Agricultural crop residues are not currently being collected for use as bioenergy feedstock because it is not yet profitable for farmers. In 2005 the U.S. Department of Agriculture (USDA) and the U.S. Department of Energy (DOE) issued a joint report from a study investigating the viability of using energy from biomass to replace 30 percent of U.S. petroleum consumption by the year 2030, titled *Biomass Feedstock for a Bioenergy and Bioproducts Industry: the Technical Feasibility of a Billion-Ton Annual Supply* [7], and in 2011 an update to that report was released.

In a 2011 update to this *billion-ton* study the amount of crop residue that would be produced at various farmgate prices was estimated using the agricultural sector model (POLYSYS). Residue production is estimated in conjunction with energy crop production and other cropland uses to account for the competition between uses for the available cropland. Figure 4-1 shows the total crop residue that would be supplied from 2012 to 2030 at six different farmgate prices ranging from $40 to $60 per dry ton. Figure 4-2 shows the supplies with corn stover separated from other residues.

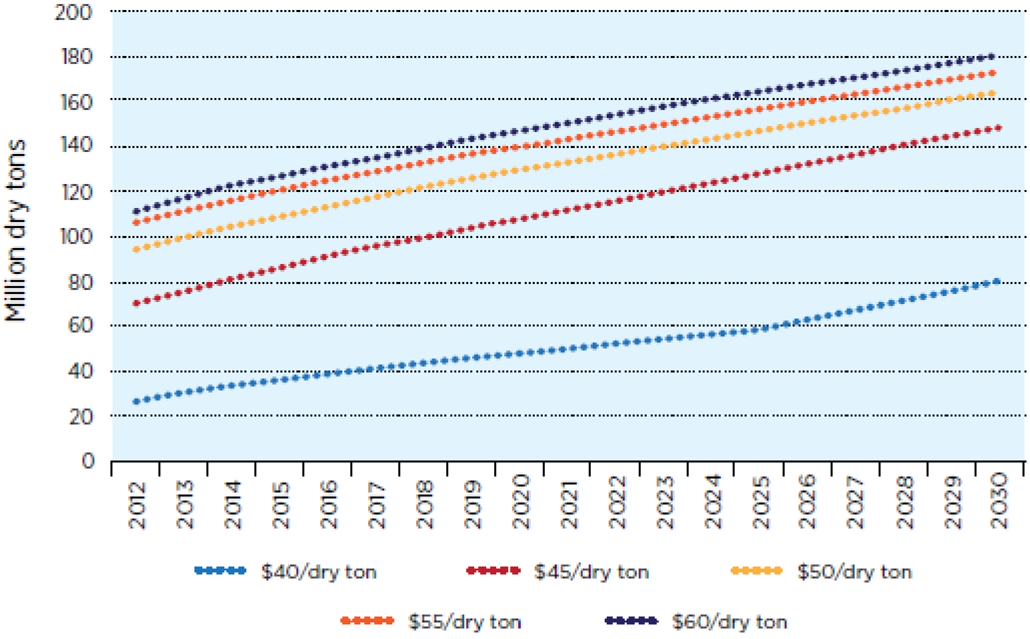


Figure 4-1: Supply of crop residues at various prices under DOE base-case assumptions (Source: DOE [8])

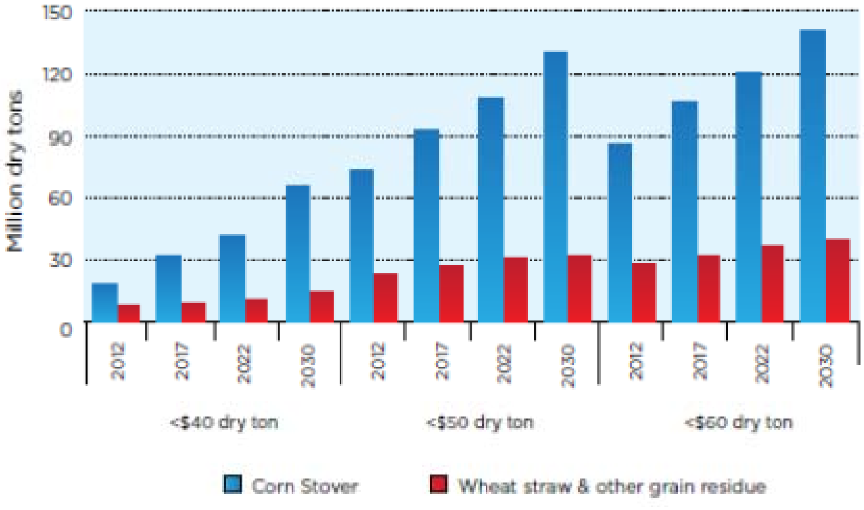


Figure 4-2: Corn stover and grain residue at selected prices in 2012, 2017, 2022 and 2030 under DOE base-case assumptions (Source: DOE [8])

Although the concept of using algae for energy production has been proven at the laboratory level, no commercial scale sustainable production facility has been established. According to the 2010 DOE National Algal Biofuels Technology Roadmap document there was not yet a credible estimate of the cost of algal biofuel [3].

4.3 State of organic waste biomass nationally

Historically organic waste biomass, and in particular residues from the wood products industry, has been one of the main sources of renewable energy in the U.S. As can be seen in Figure 4-3, wood and wood-derived fuels have been second only to hydroelectricity as a source of renewable energy in the U.S. Until the increase in wind and biofuels in the last decade, wood and wood-derived fuels comprised nearly half of the renewable energy consumed in the U.S.

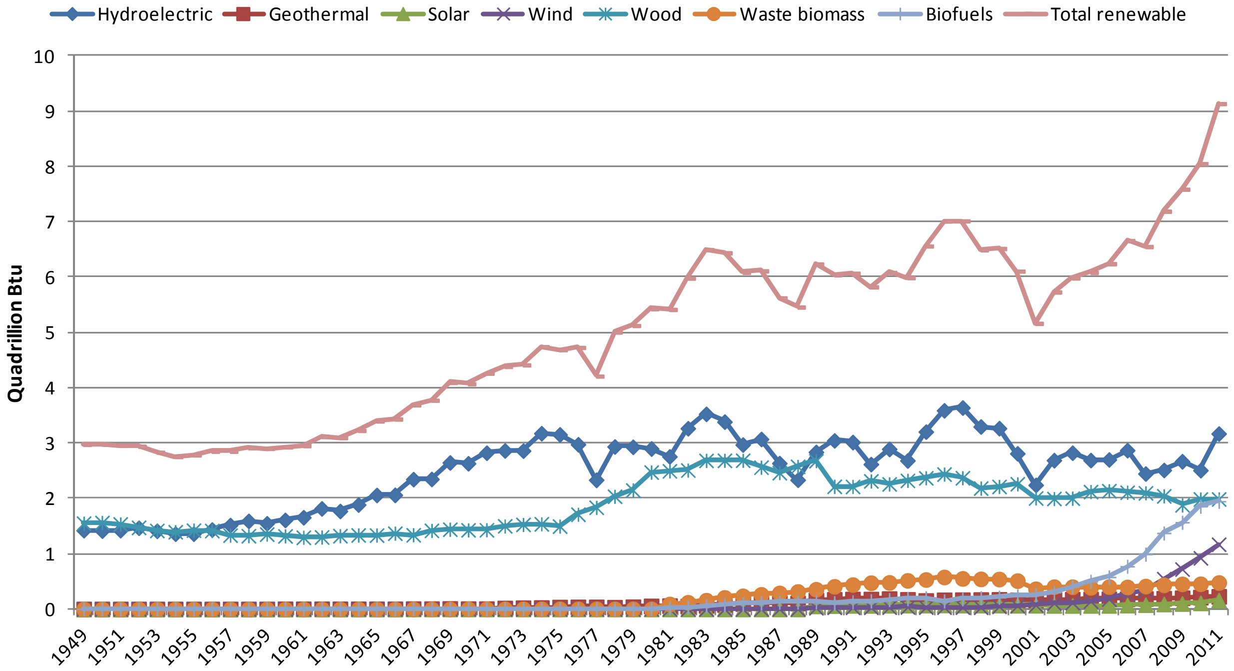


Figure 4-3: U.S. renewable energy consumption 1949-2011 (Source: EIA [9, 10])

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. Livestock manure is in use currently as an energy source with 160 anaerobic digester biogas recovery systems in operation on livestock farms in the U.S. as of the end of 2010. 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 [11].

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 inflow to support anaerobic digesters at the end of 2006, only about 500 of them had digesters installed. 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 [12].

As indicated in previous sections and illustrated in Figure 4-3, 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 4-4 shows the contribution of renewable resources to the total energy consumed in the U.S. in 2010.

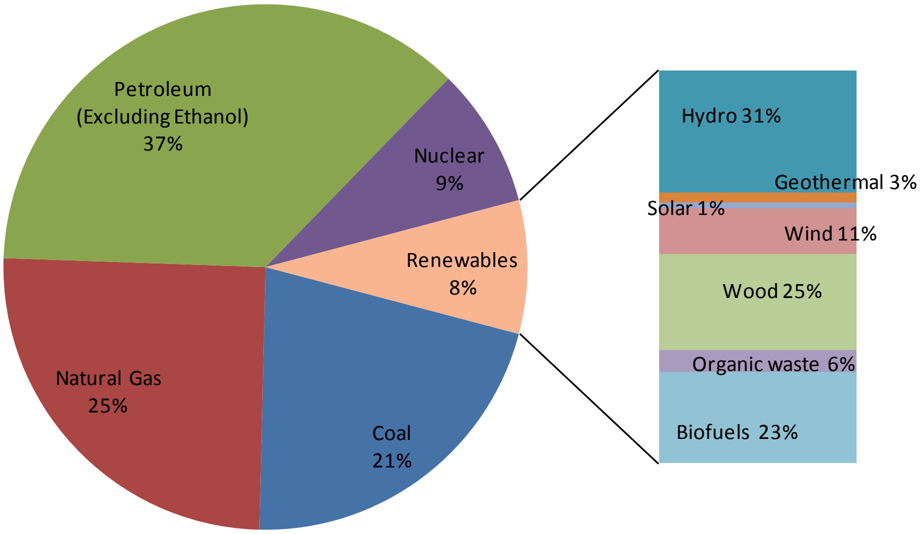


Figure 4-4: Summary of U.S. energy consumption in 2011 (Data source: EIA [9, 13])

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 4-5 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 9 percent of total renewable electricity, followed by municipal solid waste and landfill gas (organic waste in Figure 4-5), which together contributed 4 percent of the renewable electricity.

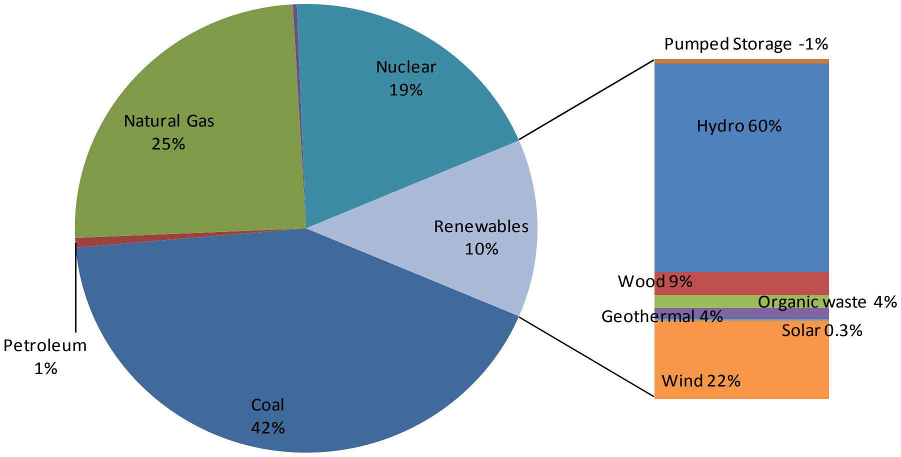


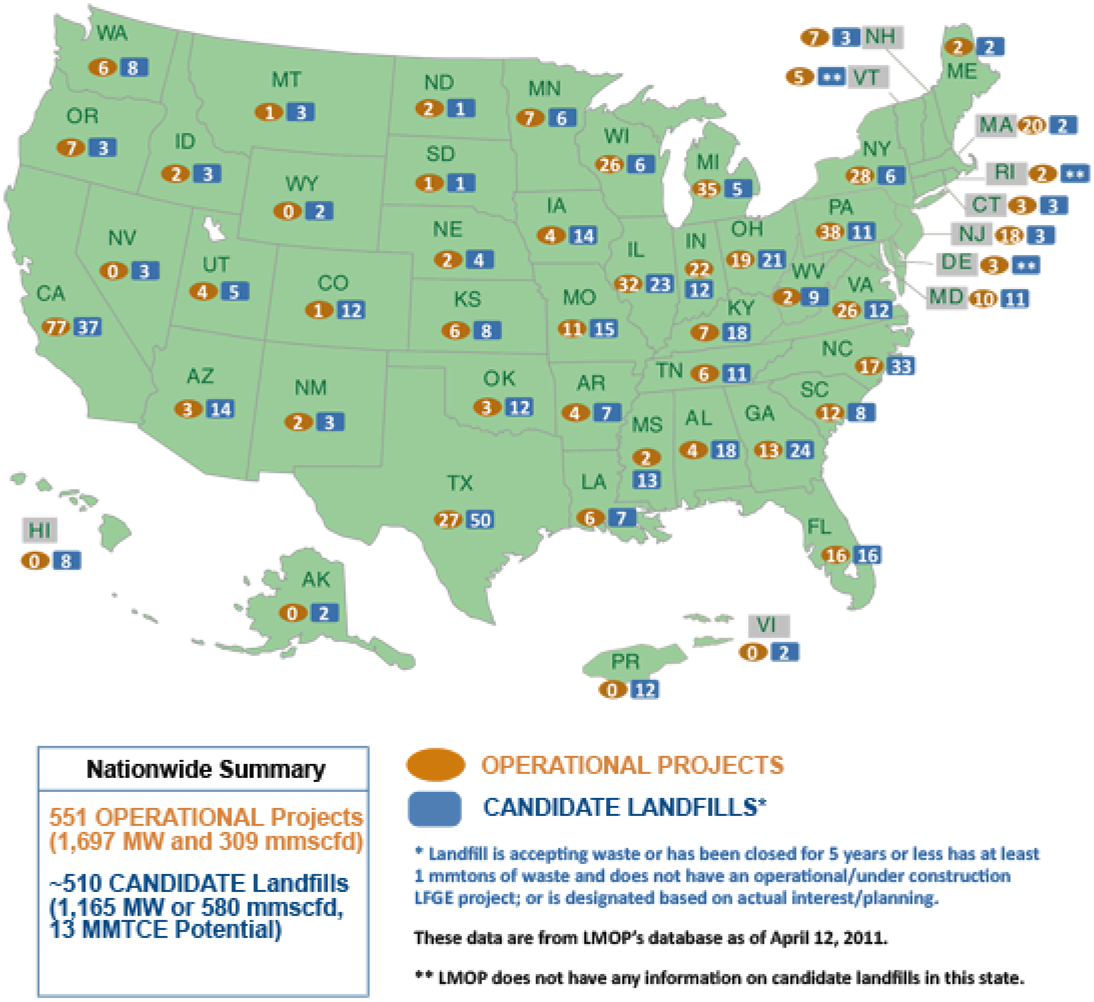
Figure 4-5: Summary of U.S net electricity generation in 2011 (Data source: EIA [14])

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 [15].

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 [15])

Figure 4-6 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 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 510 'candidate' landfills that have the size and other characteristics necessary to support energy projects with a total combined capacity of 1,165 MW of electricity generation and 580 mmscfd of gas for direct use [1].



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 4-6: Landfill gas projects (Source: EPA [1])

Table 4-2 shows the top states with the potential for electricity generation from livestock farms. Biogas is more readily recovered from swine and dairy farms because the manure is handled in the wet slurry state that is hospitable to the waste-digesting microorganisms.

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

Table 4-2: Top ten states for potential electricity generation from swine and dairy farms (Data source: AgStar [11])

According to the EPA Combined Heat and Power Partnership Program there were 76 combined heat and power plants in U.S. wastewater treatment facilities at the end of 2006 with total electricity generating capacity of 220 MW. Table 4-3 shows the location and capacities these plants.

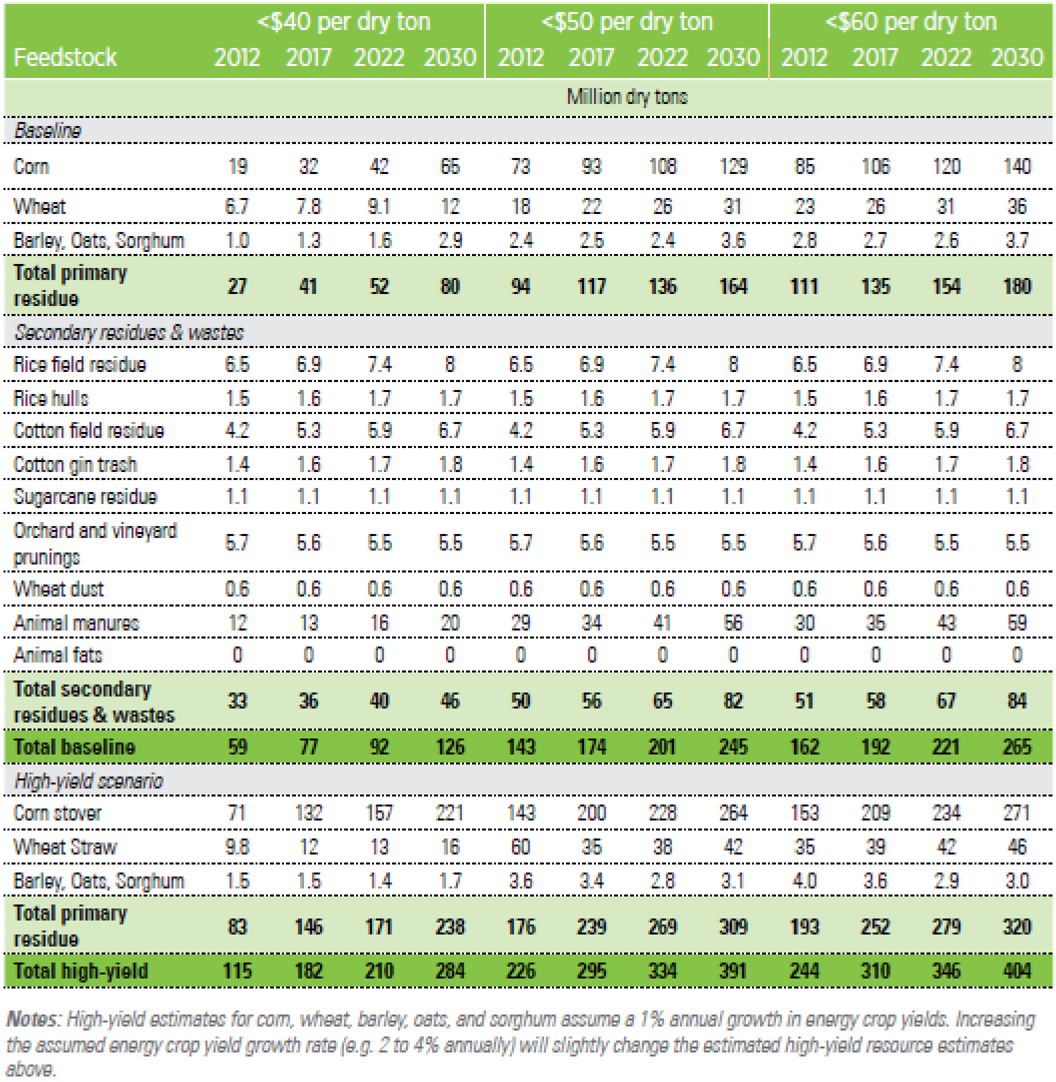
According to the EPA, this capacity could be increased by a further 340 MW if all the wastewater treatment plants that used anaerobic digestion technology to process their waste would capture the biogas and use it to generate electricity and heat. Out of the approximately 500 wastewater treatment facilities that utilized anaerobic digestion technology only 106 of them convert the biogas to energy. In addition to the 76 units listed in Table 4-3 SUFG is aware of electricity generating plants in two locations in Indiana with a total capacity of 195 kW. More information about these plants is given in Section 4.4.

State	**Number of Sites**	**Capacity (MW)**
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. (Data source: EPA [12])

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

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



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

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

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

4.4 Organic waste biomass in Indiana

Organic waste biomass, in particular wood residue and byproducts, has historically been the main source of renewable energy in Indiana. Figure 4-7 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 [16].

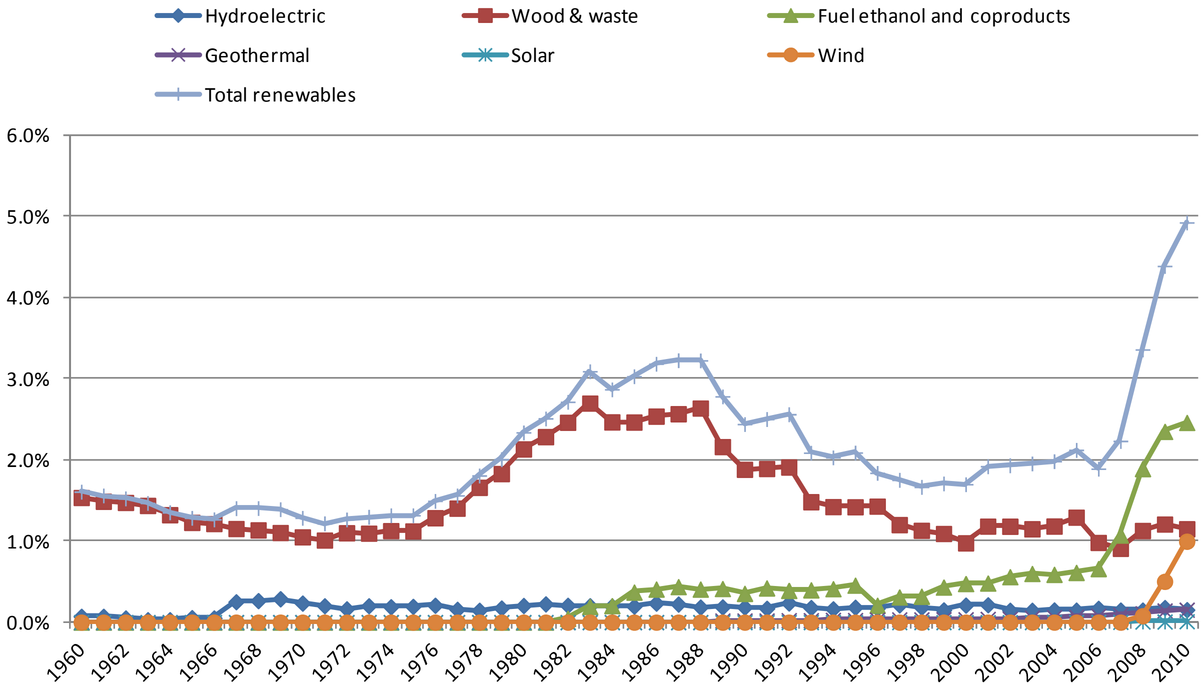


Figure 4-7: Renewables share of Indiana total energy consumption (Source EIA [17])

The other organic waste biomass that is a significant source of energy in Indiana is landfill gas. The most active user of landfill gas is Wabash Valley Power Association which has a total of 42.4 MW of electricity generating capacity from fourteen power plants on 8 landfills. Other major users of landfill energy include Hoosier Energy with 3.5 MW electricity generating capacity in a Clark County landfill and Granger Energy that has several energy conversion projects in the Southside landfill in Indianapolis. The Granger Energy project in the Southside Indianapolis landfill includes 4 MW of electricity generating capacity and supplies landfill gas to various area businesses for heating and steam generation. The total electricity generating capacity installed in Indiana landfills is 53.3 MW. Other operators of landfill electricity generating projects include Energy Systems LLC and the town of Munster [18].

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 [19]. 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 [20]. The potential to expand biogas production from livestock farms is substantial. Indiana is ranked among the top ten with potential for producing 3.5 billion cubic feet of biogas per year from biodigesters fed livestock manure on 296 farms [11].

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 [21].

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

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

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

Two Indiana companies (Algaewheel and Stellarwind Bio Energy) are involved in 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 [22]. 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 [23].

4.5 Incentives for organic waste biomass

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

Federal Incentives

- <u>Renewable Electricity Production Tax Credit (PTC)</u> provides a 2.2 cents/kWh tax credit for closed-loop biomass and 1.1 cents/kWh for open-loop biomass, landfill gas municipal solid waste 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 [24].

- <u>Business Energy Investment Tax Credit (ITC)</u> credits up to 30 percent of expenditures on qualifying renewable energy systems [24].

- <u>Renewable Energy Production Incentive (REPI)</u> 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 2.1 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 2005 through 2026 [24].

- 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 [24].

- 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 [24].

- High Energy Cost Grant Program administered by the USDA is aimed at improving the electricity supply infrastructure in rural areas having home energy costs exceeding 275 percent of the national average. Eligible infrastructure includes renewable resources generation. The USDA has allocated $21 million for the 2011 funding cycle. The individual grants range from $75,000 to $5 million [25]

Indiana Incentives

- Clean Energy Portfolio Goal sets a voluntary goal of obtaining 4 percent between 2013 and 2018, 7 percent between 2019 and 2024, and 10 percent by 2025, of electricity from clean energy sources based on 2010 retail sales. Participation in the goal makes utilities eligible for incentives that can be used to pay for the compliance projects [24].

- 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 15 years. Biomass compensation is $6.18/kW per month plus $0.085/kWh. REP is a pilot rate and no new contracts will be negotiated after March 30, 2013 [24, 26].

- Northern Indiana Public Service Company (NIPSCO) offers feed-in tariff incentive rates for electricity generated from renewable resources for up to 15 years. The payment for biomass facilities is $0.106/kWh. The tariff is an experimental one running until December 31, 2013. The total system-wide renewable capacity allowed under the tariff is 30 MW with 500 kW of the cap reserved for solar projects of capacity less than 10 kW and 500 kW for wind projects of capacity less than 10 kW [24, 27].

- Emissions Credits are received by electricity generators that do not emit NO_x and that displace utility generation. They are eligible to receive NO_x emissions credits under the Indiana Clean Energy Credit Program. These credits can be sold on the national market. [28].

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5. Solar Energy

5.1 Introduction

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

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

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

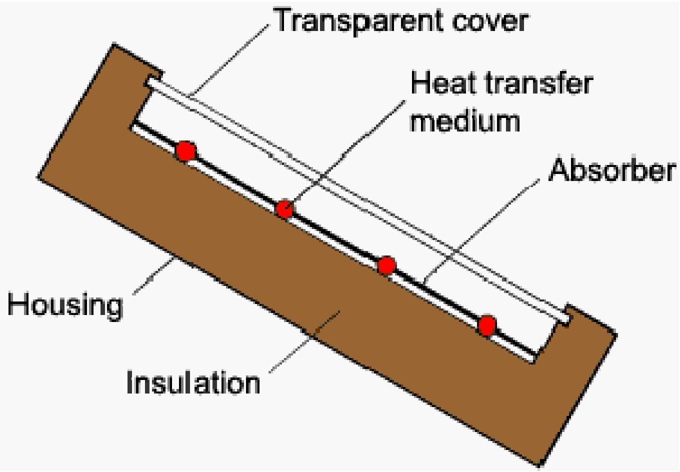

Figure 5-1: Cross-section layout of a flat-plate collector (Source: SolarServer [2])

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

The trough CSP system has trough shaped collectors with a parabolic cross section and a receiver (or absorber) tube located at the focal line of the trough as shown in Figure 5-2. A working fluid is used to transport the heat from the receivers to heat exchangers. Trough CSP systems in use for utility scale electricity generation are typically coupled with a fossil-fuel fired boiler to supplement the supply of heat when the solar energy collected is not adequate. Trough systems can also be coupled with facilities to store the hot working fluid, thereby providing the ability for the plant to be dispatched to match system demand. The parabolic trough system is the most developed and widely used CSP technology in the U.S. and worldwide, with 496 MW out of the total 509 MW of installed CSP capacity in the U.S. being parabolic trough based.

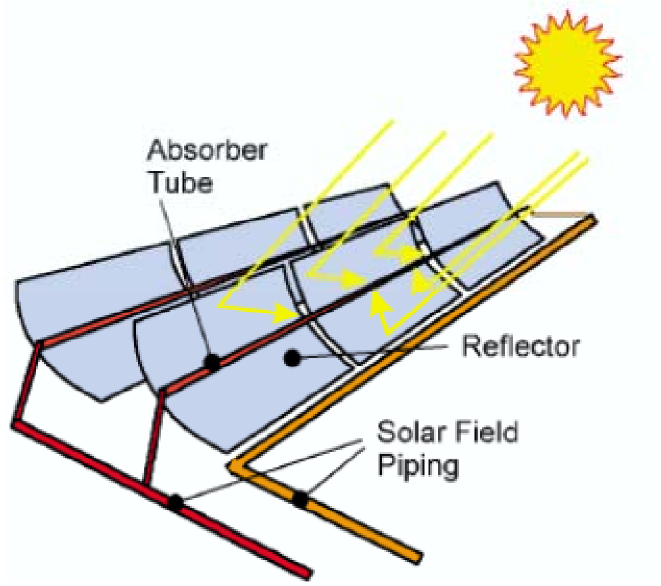

Figure 5-2: A parabolic trough CSP system (Source: NREL [3])

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

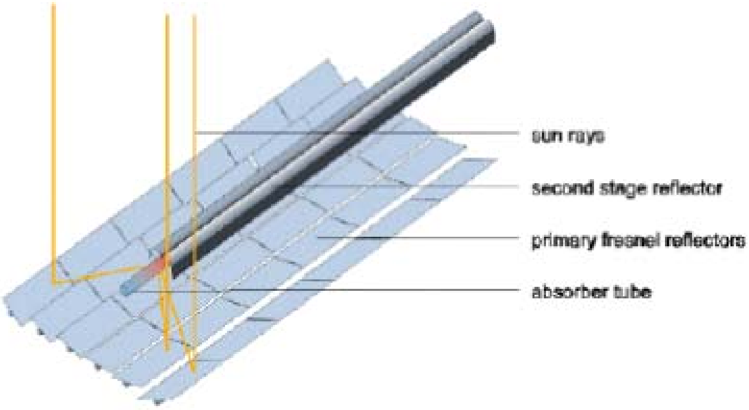

Figure 5-3: A linear Fresnel CSP System (Source: IEA [4])

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

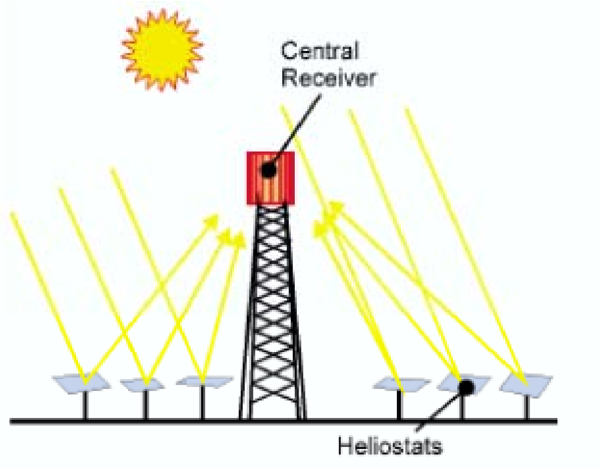

Figure 5-4: A power tower CSP system (Source: NREL [3])

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

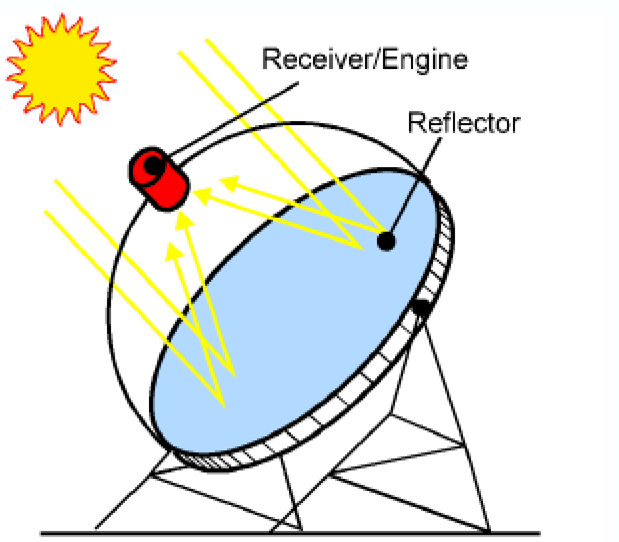

Figure 5-5: A dish/engine CSP system (Source: NREL [3])

5.2 Economics of solar technologies

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

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

power plant. The plant with the highest cost is a power tower CSP plant. The other five plants are parabolic trough based CSP plants with capital costs ranging from 4,000 $/kW to over 7,000 $/kW.

Project Name	Developer, Owner	Location	Capacity (MW)	Technology	Status	Online Date	Total cost (million $)	Capital cost ($/kW)
Colarado Intergated Solar Project (Cameo)	Abengoa, Xcel	Palisades, Colorado	2	Parabolic Trough	Operational	2010	4.5	2,250
NextEra Beacon Solar Energy Project	Nextra	California City, California	250	Parabolic Trough	Under development	2014	1,000	4,000
Nevada Solar One	Acciona	Boulder City, Nevada	64	Parabolic Trough	Operational	2007	266	4,156
Ibersol Ciudad Real	Iberdrola Renewables	Puertollano, Spain	50	Parabolic Trough	Operational	2009	254*	5,080
Shams 1	Abengoa, Masdar, Total	Madinat Zayed, United Arab Emirates	100	Parabolic Trough	Under development	2012	600	6,000
Solana Generating Station	Abengoa	Phoenix, Arizona	280	Parabolic Trough	Under development	2013	2,000	7,143
Gemasolar Thermosolar Plant	Torresol, Masdar, Sener	Andalucía, Spain	20	Power Tower	Operational	2011	292*	14,678

*cost converted from Euros (€) at 1.27 $ per €

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

Figure 5-6 shows the overnight capital cost estimates of utility scale electricity generating technologies given in the November 2010 EIA update of generating plant costs [8]. 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.

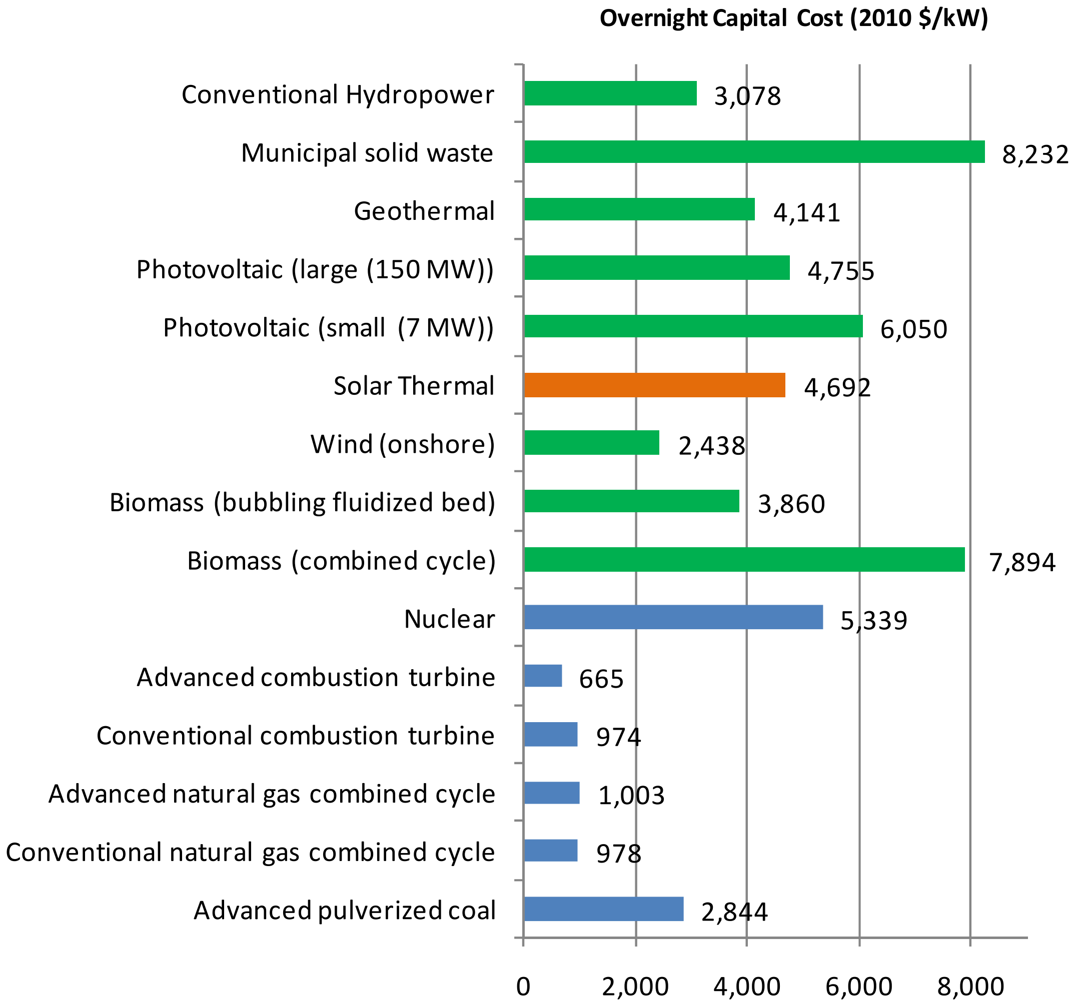


Figure 5-6: Capital cost of generating technologies (Data source: EIA [8])

Figure 5-7 shows the estimate of the fixed and variable operating and maintenance (O&M) costs. As can be seen in Figure 5-7 solar thermal technology has moderate O&M cost, with a zero variable O&M cost and a fixed annual O&M cost of $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.

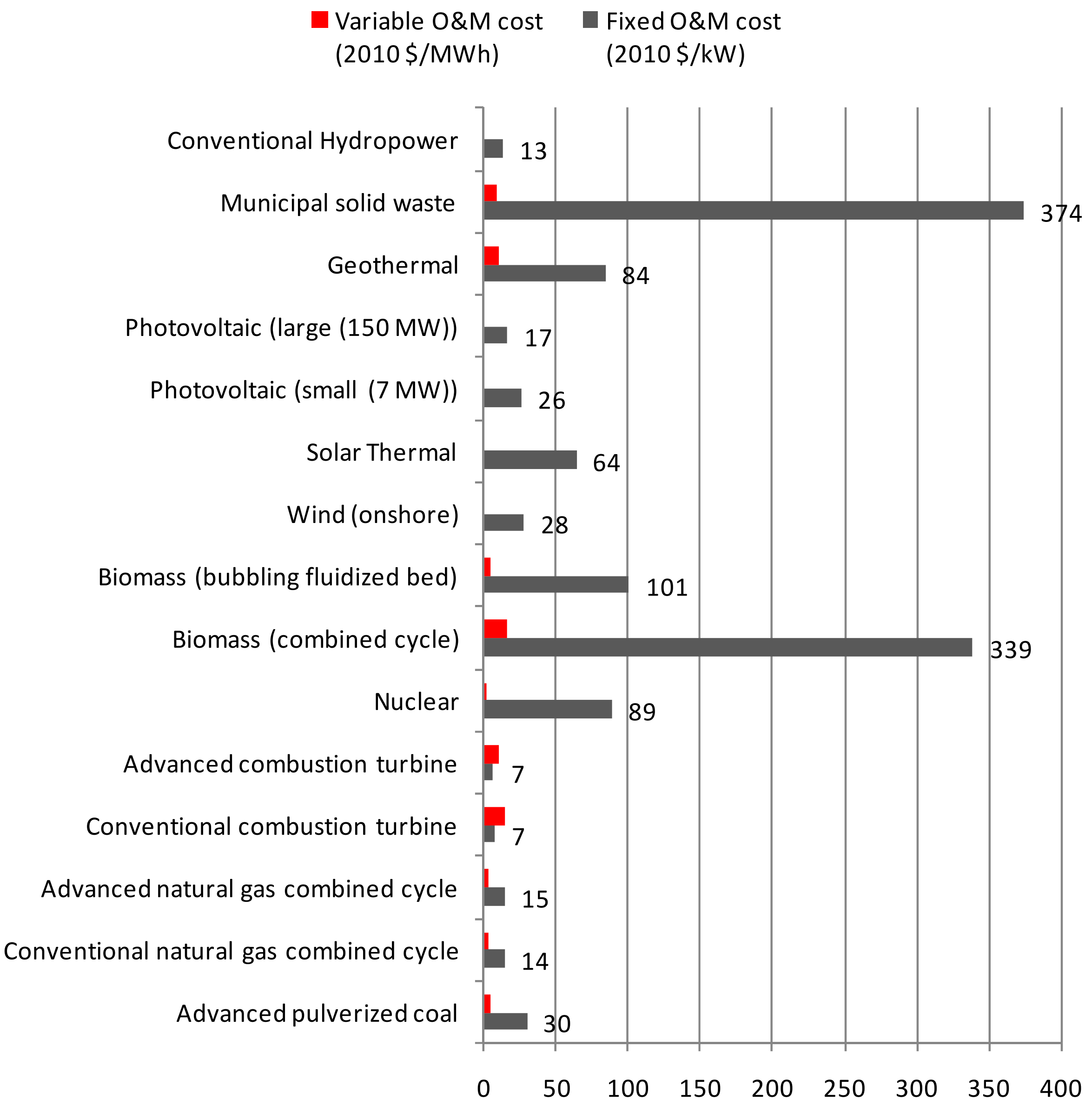


Figure 5-7: Operating and maintenance cost of generating technologies (Data source: EIA [8])

5.3 State of solar energy nationally

As can be seen in Figures 5-8 and 5-9, there are substantial solar resources available in the U.S., especially in the southwestern region. Figure 5-8 shows the solar resources available to a stationary concentrating collector, and Figure 5-9 shows the solar resource available to a concentrating collector that tracks the sun throughout the day.

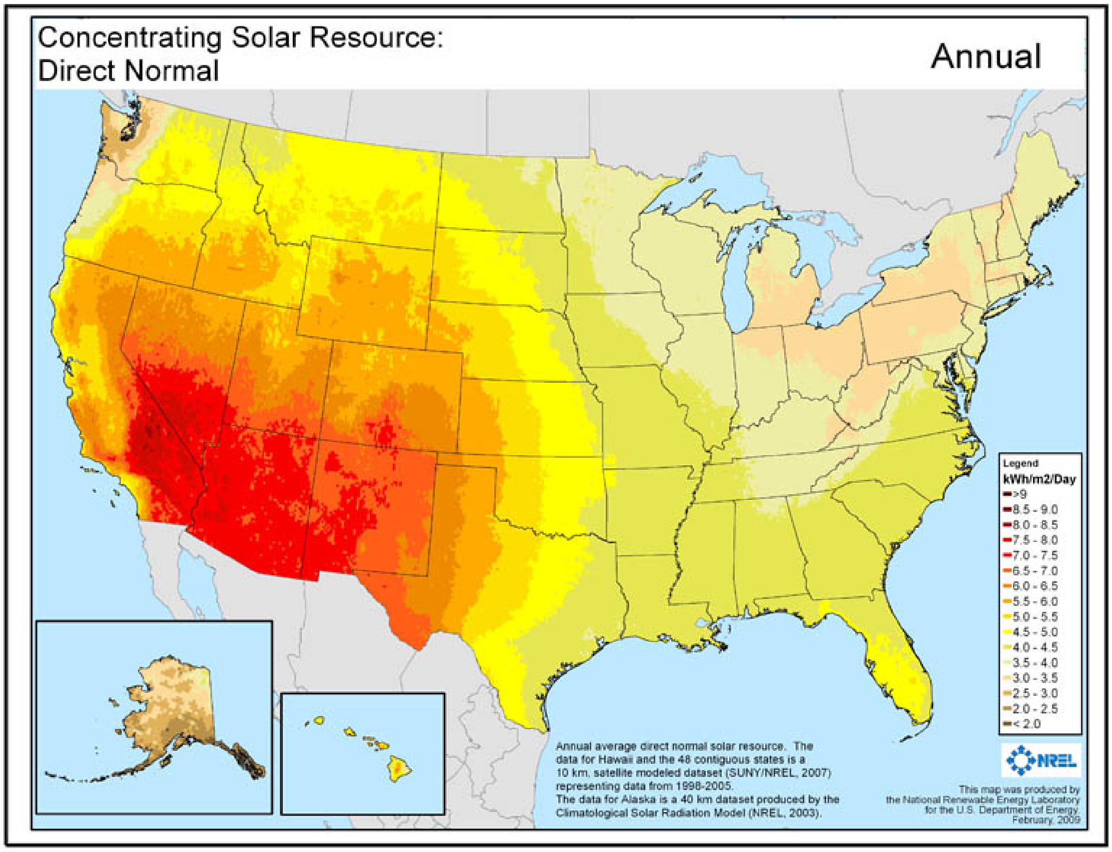


Figure 5-8: Concentrating solar power resource in the U.S. (Source: NREL [9])

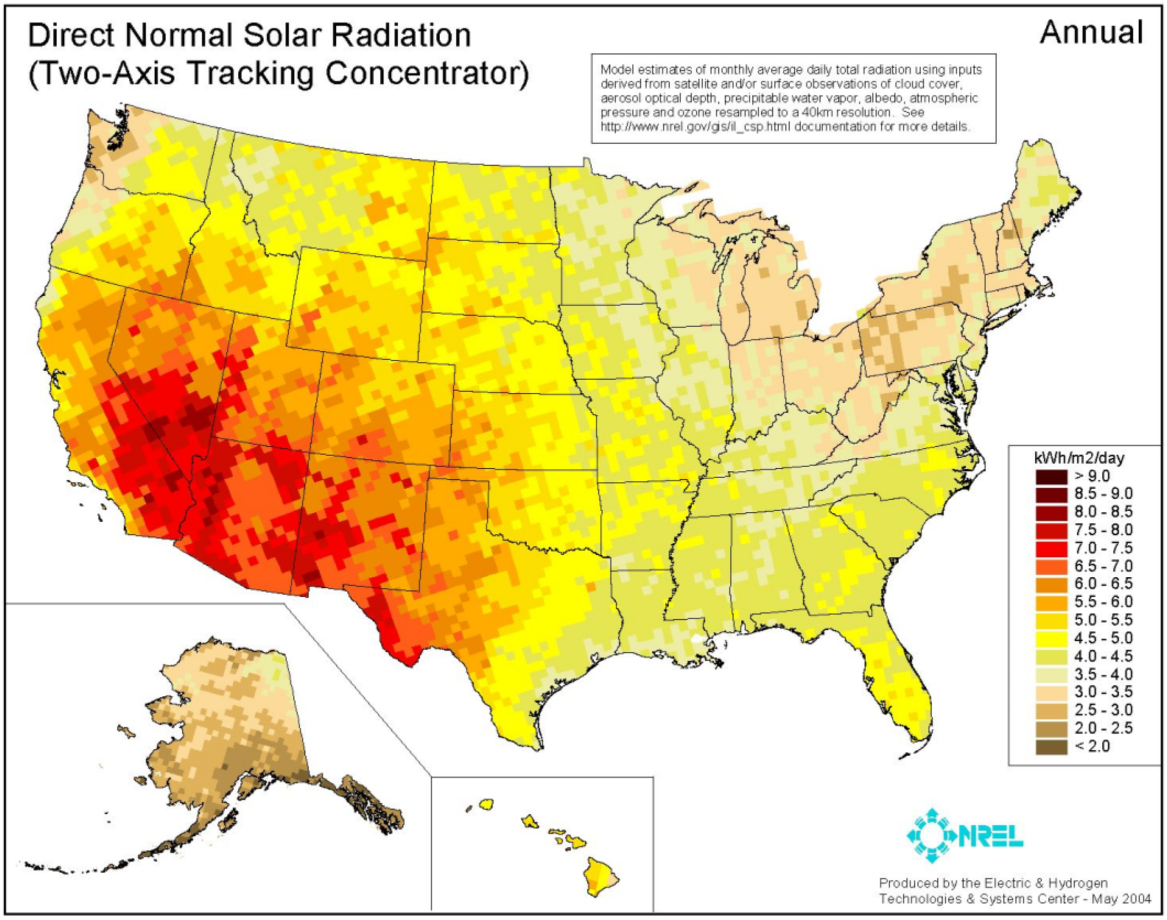


Figure 5-9: Solar resource available to a tracking concentrator (Source: NREL [9])

Like the PV systems presented in Section 6, there has been a surge in the installation of CSP capacity in the U.S. in the last 5 years. After a period of approximately 25 years when no new CSP capacity was built in the U.S. the first major project, the 64 MW Nevada Solar One CSP project in Boulder City, Nevada was commissioned in 2007. The next major project commissioned was the 75 MW Martin Next Generation Solar Project in Martin County, Florida. According to the Solar Energy Association there were over 1,000 MW of CSP capacity under construction at the end of 2011. These include Abengoa Energy's two 280 MW projects in Gila Bend, California and the 392 MW three phase Ivanpah Solar Project in Barstow, California. Figure 5-10 shows the annual net CSP capacity installations in the U.S. up to the end of 2010. The negative 10 MW net capacity addition in 1999 represents the retirement of the DOE funded 10 MW *Solar Two* Power Tower demonstration plant in Barstow, California built in 1996 and retired 1999.

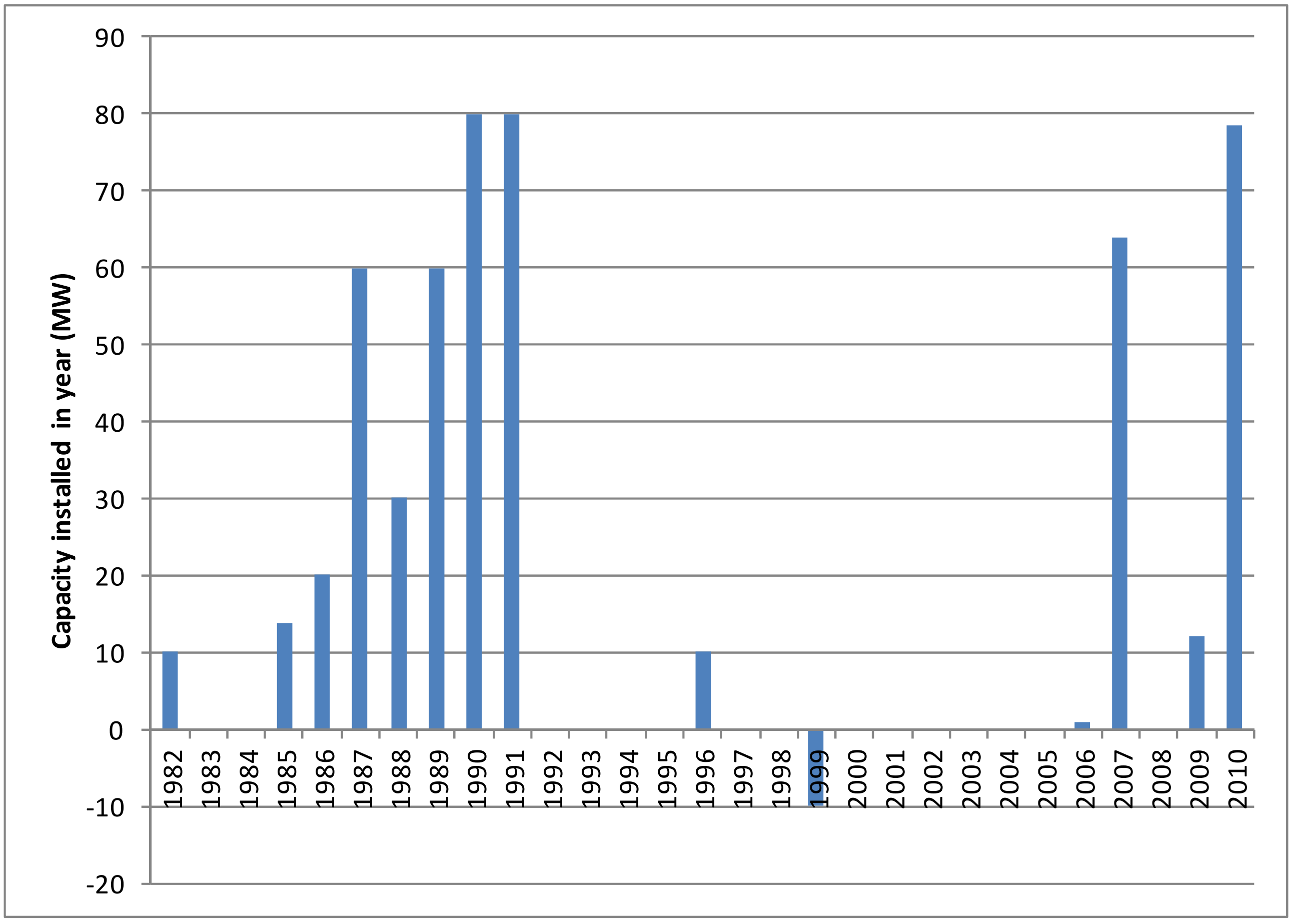


Figure 5-10: U.S. annual net CSP capacity installation (Data source SEIA [10], GoSolar California [11])

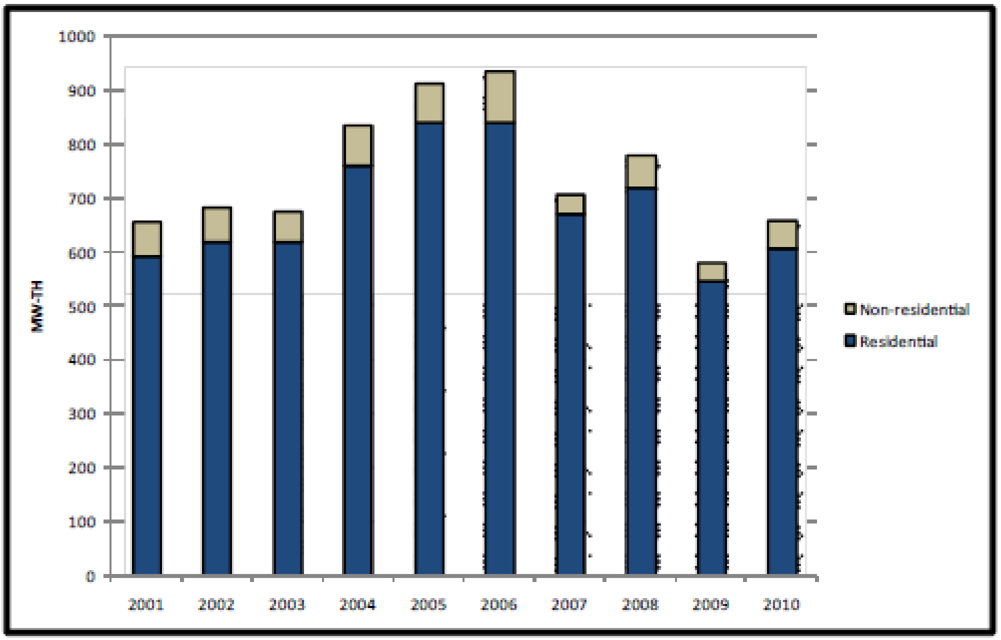
At the end of 2011 there were a total of 509 MW of solar thermal CSP capacity installed in the U.S., compared to 3,959 MW of PV capacity. Table 5-2 is a list of CSP power plants in the U.S. at the end of 2011.

Project Name	**Developer/ Owner**	**City/County**	**State**	**Capacity (MW)**	**Technology**	**Online Date**
Solar Energy Generating System (SEGS) I	Luz/Nextra	Dagett	CA	13.8	Parabolic Trough	1985
SEGS II	Luz/Nextra	Dagett	CA	30	Parabolic Trough	1986
SEGS III	Luz/Nextra	Kramer Junction	CA	30	Parabolic Trough	1987
SEGS IV	Luz/Nextra	Kramer Junction	CA	30	Parabolic Trough	1987
SEGS V	Luz/Nextra	Kramer Junction	CA	30	Parabolic Trough	1988
SEGS VI	Luz/Nextra	Kramer Junction	CA	30	Parabolic Trough	1989
SEGS VII	Luz/Nextra	Kramer Junction	CA	30	Parabolic Trough	1989
SEGS VIII	Luz/Nextra	Harper Lake	CA	80	Parabolic Trough	1990
SEGS IX	Luz	Harper Lake	CA	80	Parabolic Trough	1991
Saguaro Solar Power Plant	Solargenix	Red Rock	AZ	1	Parabolic Trough	2005
Nevada Solar One	Acciona	Boulder City	NV	64	Parabolic Trough	2007
Kimberlina	Ausra	Bakersfield	CA	5	Linear Fresnel	2009
Sierra SunTower	eSolar	Lancaster /Antelope Valley	CA	5	Tower	2009
Holaniku at Keyhole Point	Sopogy	Kona	HI	2	MicroCSP	2009
Martin Next Generation Solar Energy Center	Florida Power & Light	Martin County	FL	75	Parabolic Trough	2010
Maricopa Solar Power Plant	Tessera Solar	Phoenix	AZ	1.5	Dish-engine	2010
Colorado Integrated Solar Project (Cameo)*	Abengoa/Xcel	Palisades	CO	2	Parabolic Trough	2010

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

Table 5-2: CSP plants in the U.S. (Data sources NREL [7], SEIA [12], CSPtoday[13])

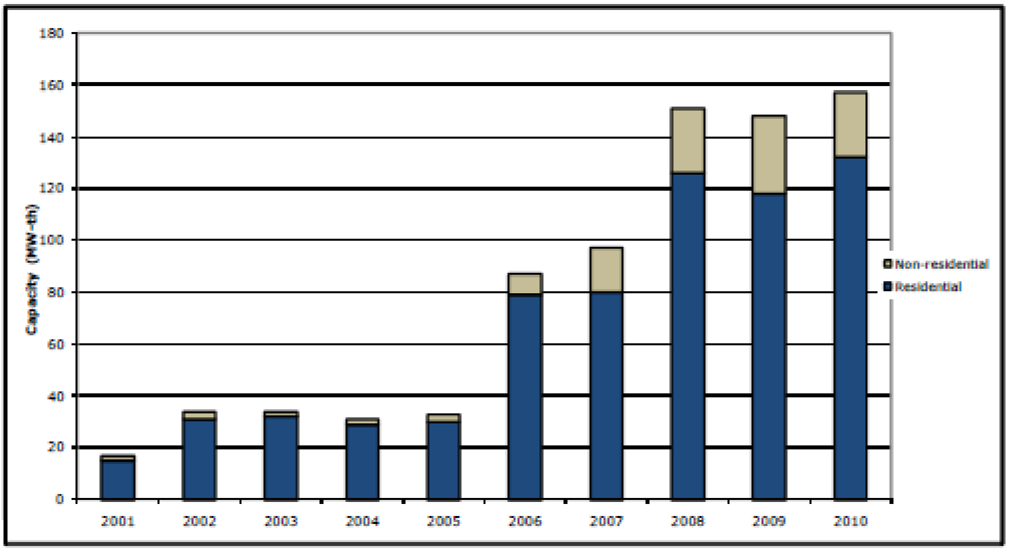
One of the most common applications for solar thermal energy in the U.S. is for heating of swimming pools. These solar pool heating systems can either be standalone units or in parallel with a conventional heater [14]. Figure 5-11 shows the capacity installed annually, in thermal megawatts (MW_{th}), of solar thermal systems used for heating swimming pools.



*Capacity in thermal megawatts (MW_{th})

Figure 5-11: Annual installed U.S. capacity for solar pool heating (2001-2010) (Source: IREC [10])

The other major users of solar thermal energy are water heating and space heating/cooling. Figure 5-12 shows the annual installed capacity of solar thermal systems used for water heating and space heating/cooling from 2002 to 2010.



*Capacity in thermal megawatts (MW_{th})

Figure 5-12: Annual installed U.S. capacity for solar heating and cooling (2002-2010) (Source: IREC [10])

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 unlikely that it would be the location of choice for multi-megawatt electricity generating plants such as the 354 MW SEGS facility in California or the 64 MW Nevada Solar One plant referred to in Section 5.3. However there is some potential for water heating applications of solar thermal technologies. According to the EIA 2011 solar thermal collector manufacturing report, Indiana was the 20th top destination for solar thermal collectors in 2009 [15].

Figure 5-13 shows the solar radiation available to a flat collector facing south in Indiana. Flat plate collectors are typically used for water heating applications. As can be seen in the figure, the southern half of the state has more radiation available.

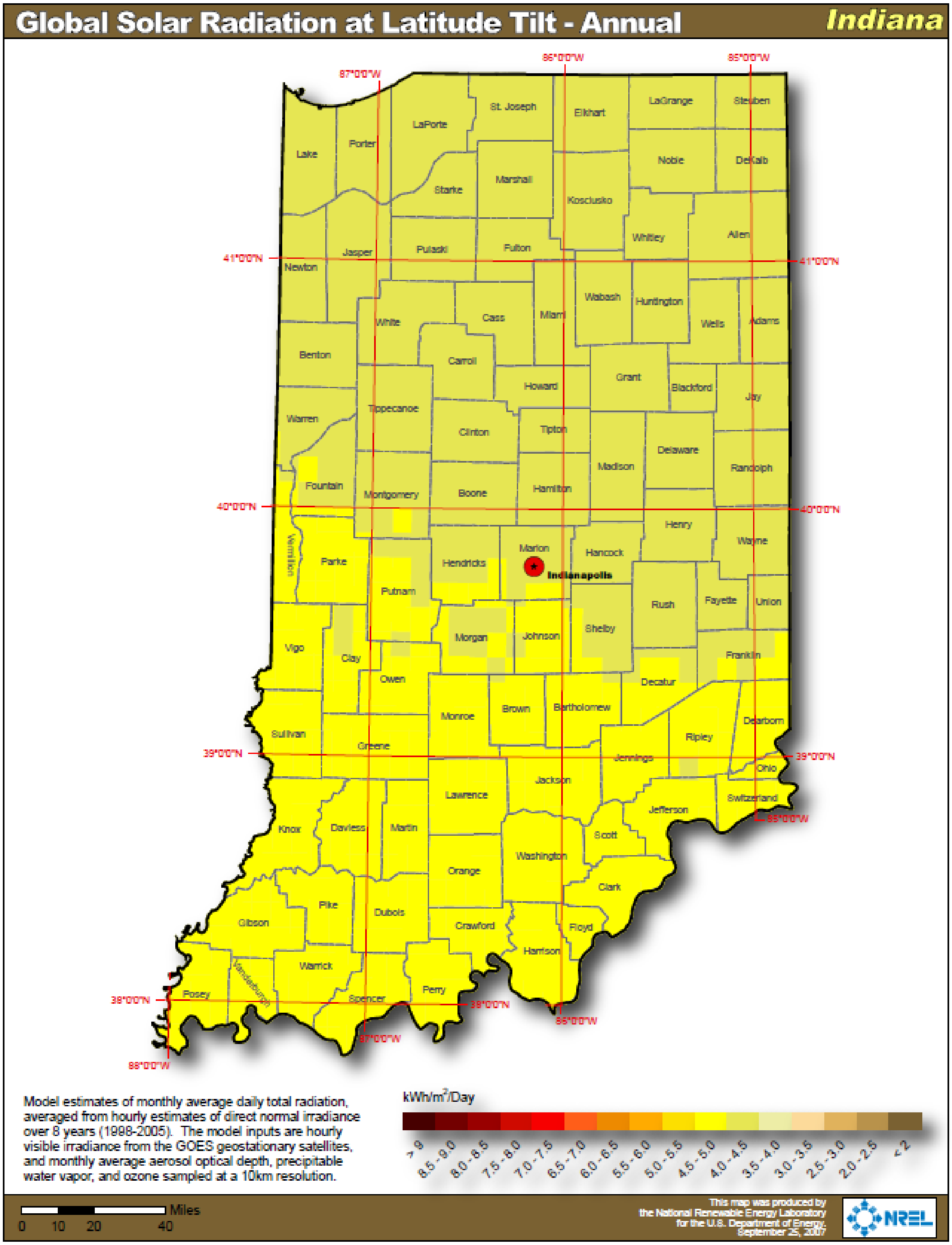


Figure 5-13: Direct normal solar radiation (flat-plate collector) (Source: NREL [16])

5.5 Incentives for solar energy

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

Federal Incentives

- Business Energy Investment Tax Credit (ITC) credits up to 30 percent of expenditures on solar systems. The 2009 American Recovery and Reinvestment Act provided for treasury cash grant in lieu of the ITC [17].

- 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, providing them confidence in lending to customers who would usually have been denied credit [17].

- Modified Accelerated Cost-Recovery System (MACRS) allows businesses to recover investments in qualified 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 [17].

- 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 [17].

- 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 [17].

- 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 [17].

- 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 [17].

- Value-Added Producer Grant Program supports planning activities and provides 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 [18].

- 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 [19].

Indiana Incentives

- Net Metering Rule qualifies renewable resource facilities with a maximum capacity of 1 MW for net metering. The net excess generation is credited to the customer in the next billing cycle [17].

- Renewable Energy Property Tax Exemption provides property tax exemptions for solar thermal, PV, wind, hydroelectric and geothermal systems [17].

- 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 [17].

- Clean Energy Portfolio Goal sets a voluntary goal of obtaining 4 percent between 2013 and 2018, 7 percent between 2019 and 2024, and 10 percent by 2025, of electricity from clean energy sources based on 2010 retail sales. Participation in the goal makes utilities eligible for incentives that can be used to pay for the compliance projects [17].

- Emissions Credits are available by electricity generators that do not emit NO_x and that displace utility generation under the Indiana Clean Energy Credit Program. These credits can be sold on the national market [20].

- Northern Indiana Public Service Company offers feed-in tariff incentive rates for electricity generated from renewable resources for up to 15 years. The payments for solar facilities are $0.30/kW for solar facilities with a capacity below 10 kW and $0.26/kW for facilities up to 2 MW. The tariff is experimental and slated to run until December 31, 2013. The allowable generator generating unit size under the tariff is between 5 and 5,000 kW and the total system-wide capacity allowed is 30 MW. Five hundred kW of the total system-wide cap are reserved for solar projects of capacity less than 10 kW, and 500 kW for wind projects of capacity less than 10 kW [17, 21].

5.6 References

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6. Photovoltaic Cells

6.1 Introduction

Unlike solar thermal systems discussed in Section 5 of this report, photovoltaic (PV) cells convert solar energy directly into electricity without having to first convert it to heat. In addition, since PV cells use both direct and indirect sunlight, their use is more geographically widespread than solar thermal systems that require access to direct solar radiation. Figure 6-1 shows the layout and functioning of a PV cell [1, 2]. 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.

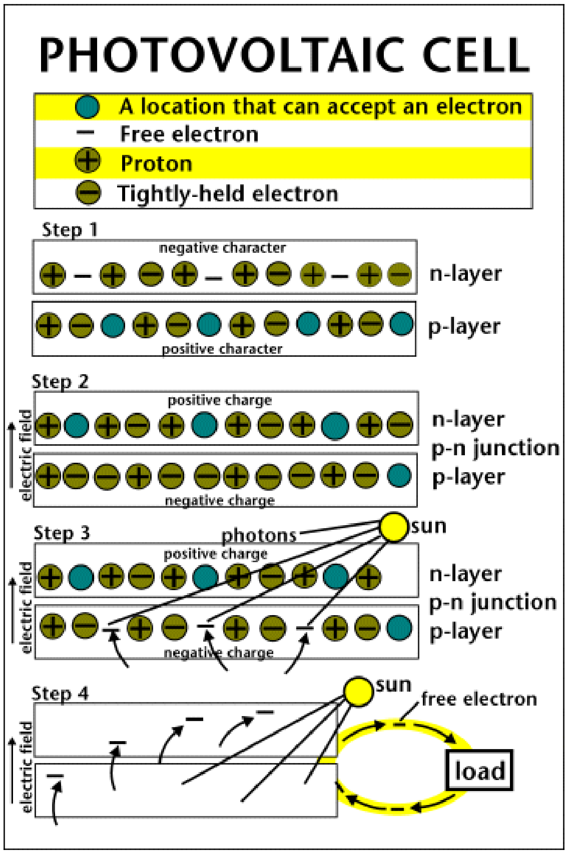


Figure 6-1: Photovoltaic cell operation (Source: EIA [1])

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

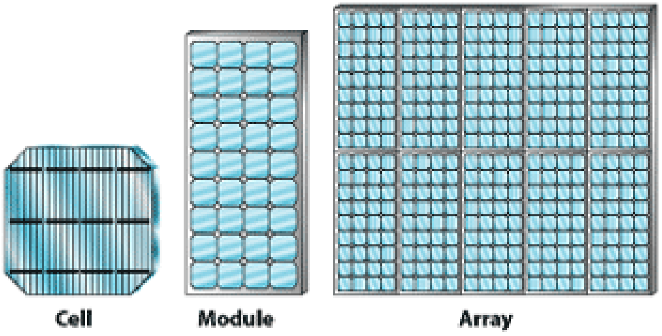


Figure 6-2: Illustration of a cell, module and array of a PV system (Source: EERE [3])

There are currently three main types of PV cell technologies in commercial use: crystalline silicon, thin-film and concentrating PV cells. Other PV silicon cells still in the development phase include advanced thin-films and organic cells. The crystalline silicon cell is the most common PV cell technology and was the first PV technology to be developed. It was developed in the 1950s and was initially used to power satellites and smaller items like watches and electronic calculators. As the prices of PV systems declined their use spread to other areas such as highway signs and other facilities remote from the electricity grid. In more recent years PV power systems have gained more widespread application as grid-connected generating resources with over 3,900 MW of grid-connected PV systems installed in the US since 2000 [4, 5].

Unlike crystalline silicon cells, thin-film cells are made by depositing thin layers of non-crystalline (amorphous) silicon or other photovoltaic material on low-cost substrate material. As a result, thin-film PV cells have a lower cost per unit of area than crystalline silicon cells. However, since they have a lower energy conversion efficiency this cost advantage is reduced by the required larger surface area relative to a crystalline silicon PV system with the same power rating. One of the main advantages of thin-film PV cells is that they can be made into flexible panels that are easily fitted onto building structures such as roofing shingles, facades and glazing on sky lights. Although a much newer technology, thin-film based PV systems have gained widespread use in the U.S. with 170 MW of grid-connected thin-film PV capacity having been installed in the last ten years [4, 5].

The third category of photovoltaic cell technology in commercial use is the concentrating photovoltaic cell (CPV) technology. CPV systems use optical lenses to focus the sun's rays onto small, high efficiency PV cells thus reducing the amount of photovoltaic material needed. Unlike the other photovoltaic technologies, CPV systems require direct sunlight and therefore their viability is restricted to sunny locations. At the writing of this report there were three grid-connected CPV systems with a total capacity of 7 MW in operation in the U.S. [5, 6]. Figure 6-3 shows the layout of a CPV cell.

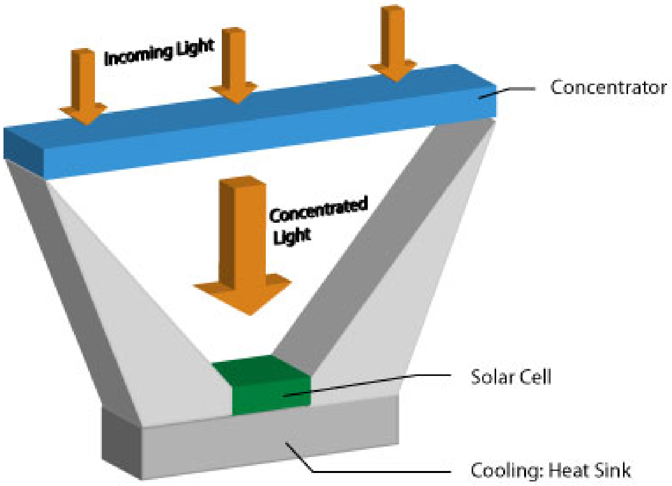
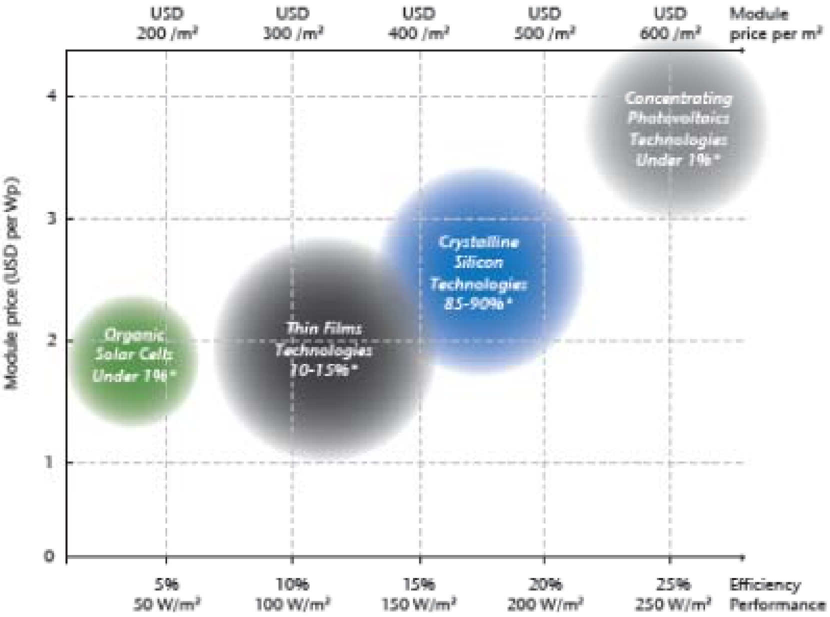


Figure 6-3: Illustration of concentrating photovoltaic cell (Source: Green Rhino Energy [6])

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



*percentage share of 2008 global market

Figure 6-4: Performance and price of different PV technologies (Source IEA [2])

6.2 Economics of PV systems

Figure 6-5 shows EIA's estimates of the overnight capital cost[5] of a utility scale photovoltaic electricity generating plant alongside other utility scale electricity generating technologies. 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, small PV and nuclear, with nuclear power's estimated cost at $5,339 /kW.

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

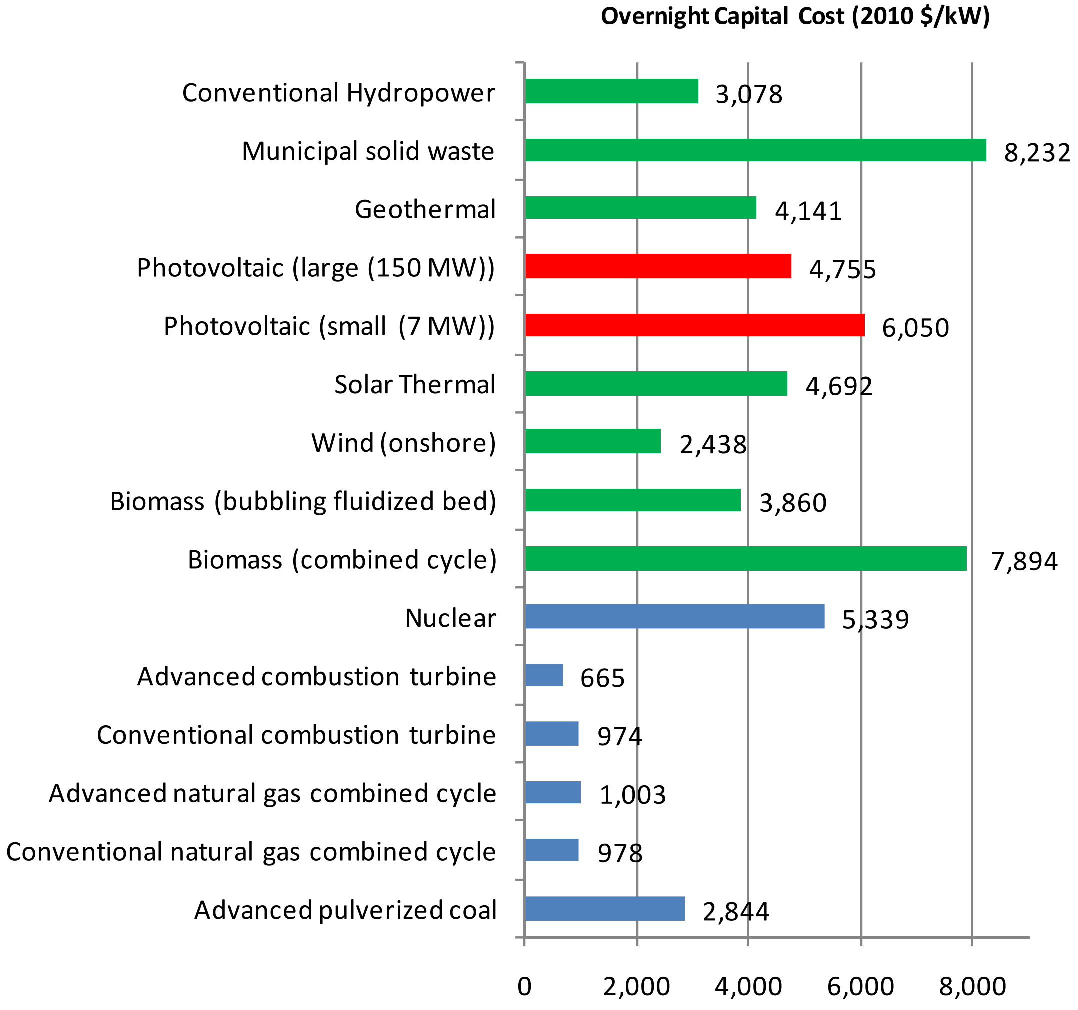

Figure 6-5: Capital cost of generating technologies (Data source: EIA [7])

Figure 6-6 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 [8]. 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 as large as 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 $11.0/W in 1998 to $6.2/W in 2010.

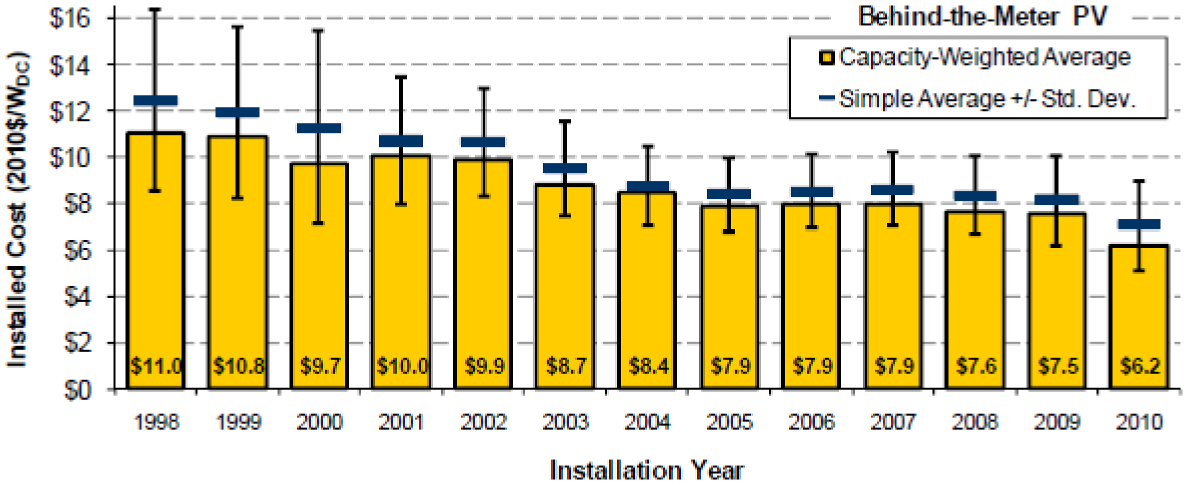

Figure 6-6: Average installed cost trends over time for behind-the-meter PV systems (Source: Berkeley [8])

Figure 6-7 shows the trend in component level cost for those PV systems in the Berkeley sample set that reported costs at the component level. Since component level cost was not reported for the whole Berkeley sample the total costs (capacity-weighted average) in Figure 6-7 differ slightly from those in Figure 6-6. Between 2007 and 2010 the system installation cost expressed in 2010 dollars dropped 21 percent from 8 $/W in 2007 to 6.3 $/W in 2010. 76 percent of this 1.7 $/W reduction was in the PV module cost while 24 percent was from the other non-module, non-inverter cost. The cost of the inverter remained flat.

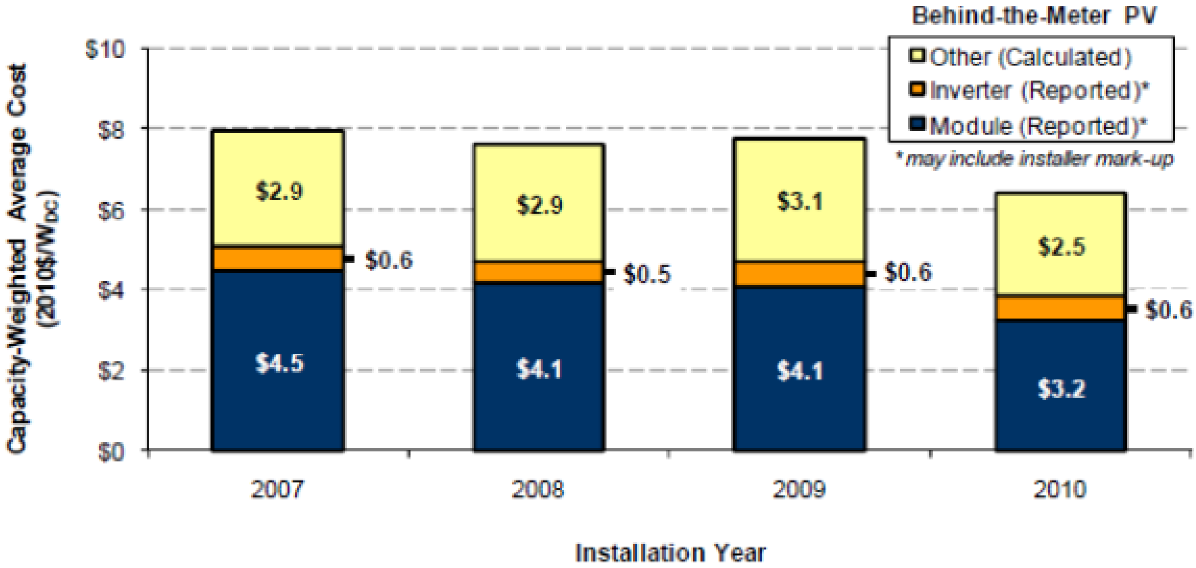

Figure 6-7: Installer-reported component costs over time for behind-the-meter PV **(**Source: Berkeley [8])

6.3 State of PV systems nationally

PV installed capacity in the U.S. has been increasing rapidly in the last decade growing from a mere 4 MW in 2000 to over 3,900 MW at the end of 2011. Figure 6-8 shows the annual and the cumulative installed capacity of grid-connected PV in the U.S.

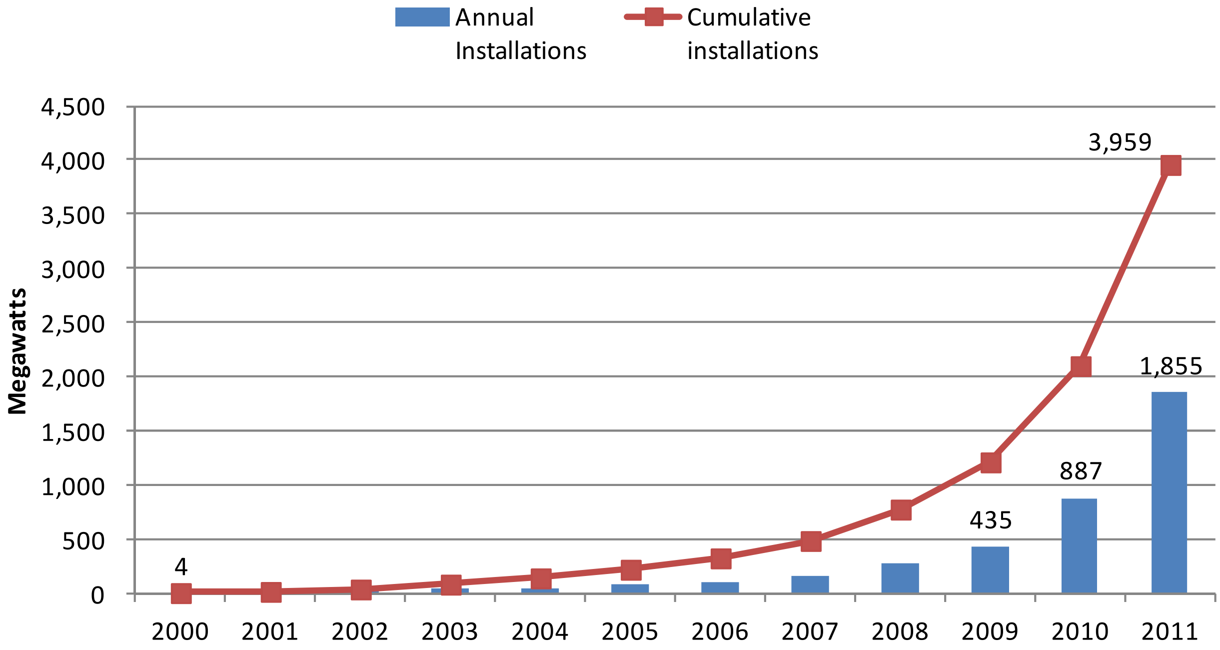

Figure 6-8: Grid-connected U.S. PV installed 2000 to 2011 (Data source SEIA [9, 10, 11])

The main factors behind this rapid expansion have been state and federal financial incentives and state renewable portfolio standards (RPS) with specific provision for solar technologies. At the state level, sixteen states and the District of Columbia (DC) have a RPS with specific quota for solar or for customer-side distributed generation. PV systems are the most common renewable energy technologies in use for residential customer-side distributed generation. Figure 6-9 shows the various forms of solar provisions in state RPSs. Fourteen states and the District of Columbia offer rebates for PV projects and all but 4 states offer some form of financial incentive for PV projects. Figure 6-10 shows the various types of financial incentives offered by states for solar projects [9, 12, 13].

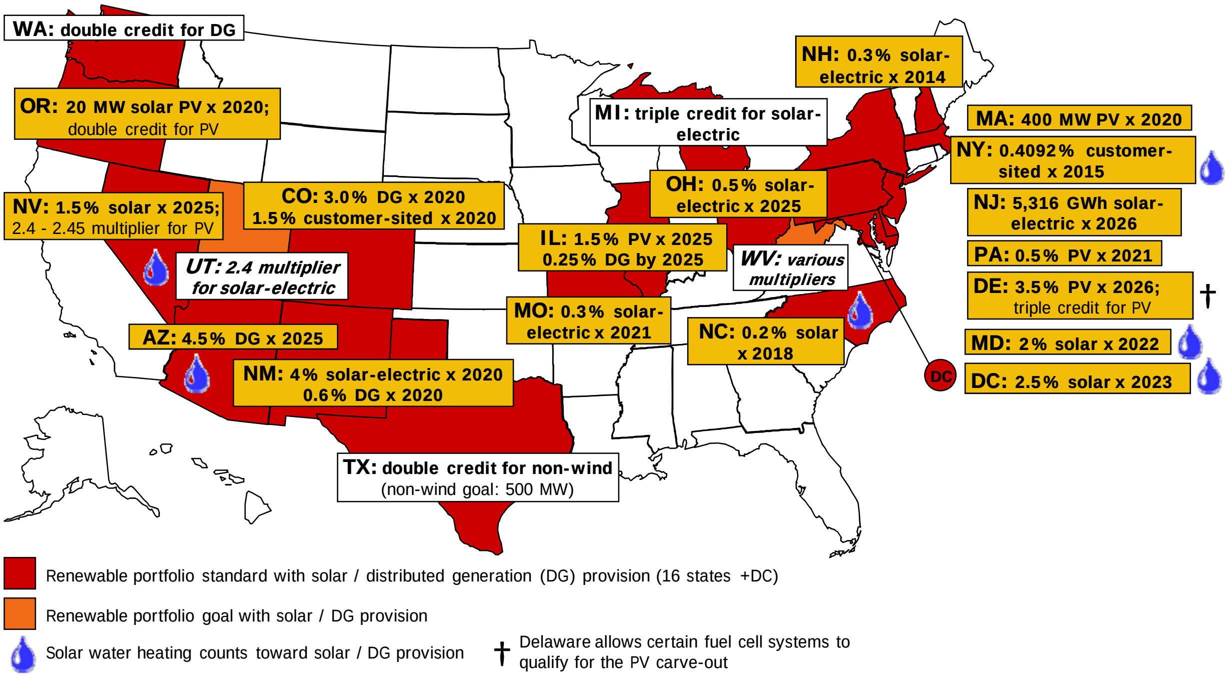

Figure 6-9: Renewable portfolio standards with solar carve-outs (Source DSIRE [13])

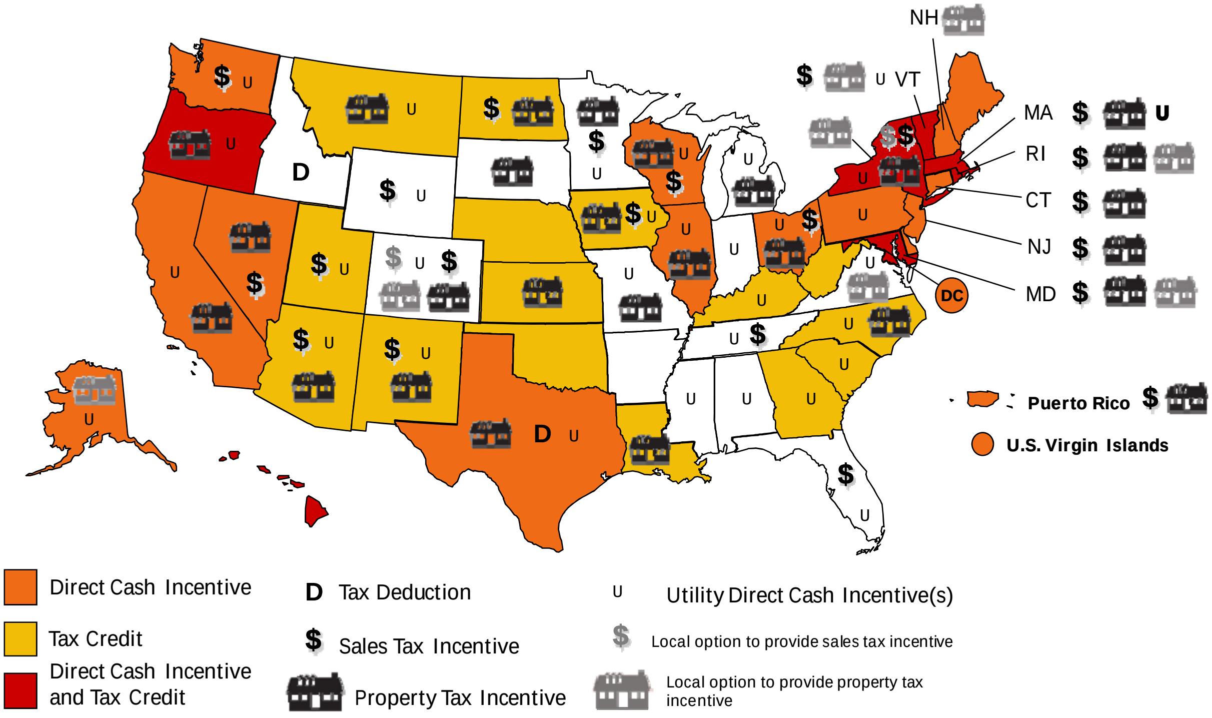

Figure 6-10: Financial incentives for solar-photovoltaic systems (Source DSIRE [13])

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

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

These federal incentives are credited with the rapid rise in multi-megawatt utility scale projects that have been constructed since then. Table 6-1 lists PV projects in the U.S. having a capacity of 10 MW and above, all of which have been constructed since 2009. The two federal programs enacted under ARRA, the loan guarantee and the 30 percent cash grant program, expired in September of 2011 and December 2011, respectively.

Project Name	Developer	Capacity (MW)	Online Date	Electricity Purchaser	State
Copper Mountain Solar	First Solar/Sempra	55	2010	Pacific Gas & Electric	NV
Mesquite Solar Phase 1	Sempra Generation	43	2011	Pacific Gas & Electric	AZ
Long Island Solar Farm	BP Solar	38	2011	Long Island Power Authority	NY
Austin Energy PV Project	SunEdison	34	2011	Austin Energy	TX
Cimarron I Solar Project	First Solar	30	2010	Tri-State G&T Cooperative	NM
San Luis Valley Solar Ranch	SunPower/Iberdrola	30	2011	Xcel Energy	CO
DeSoto Solar Energy Center	SunPower	25	2009	Florida Power & Light	FL
Stroud Solar Station	Cupertino Electric	25	2011	Pacific Gas & Electric	CA
Sun City Project	Eurus	23	2011	Pacific Gas & Electric	CA
Copper Crossing	SunPower/Iberdrola	23	2011	Salt River Project	AZ
Sand Drag Solar Project	Eurus	22	2011	Pacific Gas & Electric	CA
FSE Blythe	First Solar	21	2009	Southern California Edison	CA
	ConEdison/Panda	20	2010	Atlantic City Electric	NJ
Westside Solar Station	Cupertino Electric	20	2011	Pacific Gas & Electric	CA
Greater Sandhill Solar Plant	SunPower	19	2011	Xcel Energy	CO
Kammerer	Recurrent Energy	19	2012	Sacramento Municipal Utility	CA
Bruceville	Recurrent Energy	18	2011	Sacramento Municipal Utility	CA
Cotton Center	Solon	17	2011	Arizona Public Service	AZ
Davidson County Solar	SunEdison	17	2011	Duke Energy	NC
Paloma Solar Plant	First Solar	17	2011	Arizona Public Service	AZ
Blue Wing Solar Project	juwi Solar Inc.	16	2010	CPS Energy	TX
Jacksonville Solar	juwi Solar Inc.	15	2010	Jacksonville Electric Auth.	FL
Bagdad Solar Project	Recurrent Energy	15	2011	Arizona Public Service	AZ
Five Points Solar Station	Solon	15	2011	Pacific Gas & Electric	CA
Nellis Airforce Base	SunPower/MMA Renewable Ventures	14	2007	Nellis Airforce Base	NV
McGraw-Hill Solar Farm	NJR Clean Energy Ventures	14	2011	McGraw-Hill	NJ
Wyandot Solar facility	juwi Solar Inc.	12	2010	American Electric Power	OH
Dillard	Recurrent Energy	12	2012	Sacramento Municipal Utility	CA
Hyder Solar Plant Phase 1	SunEdison	11	2011	Arizona Public Service	AZ
Space Coast Solar Center	SunPower	10	2010	Florida Power & Light	FL
West Pullman Industrial Redevelopment Area	SunPower	10	2010	Exelon Generation LLC	IL
Rinehart Solar Farm Ph1	BlueChip Energy	10	2011	Progress Energy Florida	FL
NJ Oak Solar Farm	Lincoln Renewable Energy	10	2011	Atlantic City Electric	NJ
Prescott	SunEdison	10	2011	Arizona Public Service	AZ
SunEdison NM Solar 5	SunEdison	10	2011	Southwestern Public Service	NM
SunEdison NM Solar 4	SunEdison	10	2011	Southwestern Public Service	NM
SunEdison NM Solar 1	SunEdison	10	2011	Southwestern Public Service	NM
SunEdison NM Solar 2	SunEdison	10	2011	Southwestern Public Service	NM
SunEdison NM Solar 3	SunEdison	10	2011	Southwestern Public Service	NM
Dover SUN Park	SunPower/LS Power	10	2011	Delmarva Power	DE

Table 6-1: PV systems of 10 MW and above installed in the U.S. (Data source: SEIA [5])

6.4 PV systems in Indiana

Similar to the nation, Indiana has seen a rapid growth in the amount of PV capacity installed. According to the *Open PV Project* database maintained by the National Renewable Energy Laboratory (NREL) [14], there were 188 PV installations in Indiana totaling 3,530 kW at the time this report was written. Nearly 80 percent of that capacity was installed in 2011. Figure 6-11 shows the annual and cumulative PV capacity installations as reported to the NREL *Open PV Project* database.

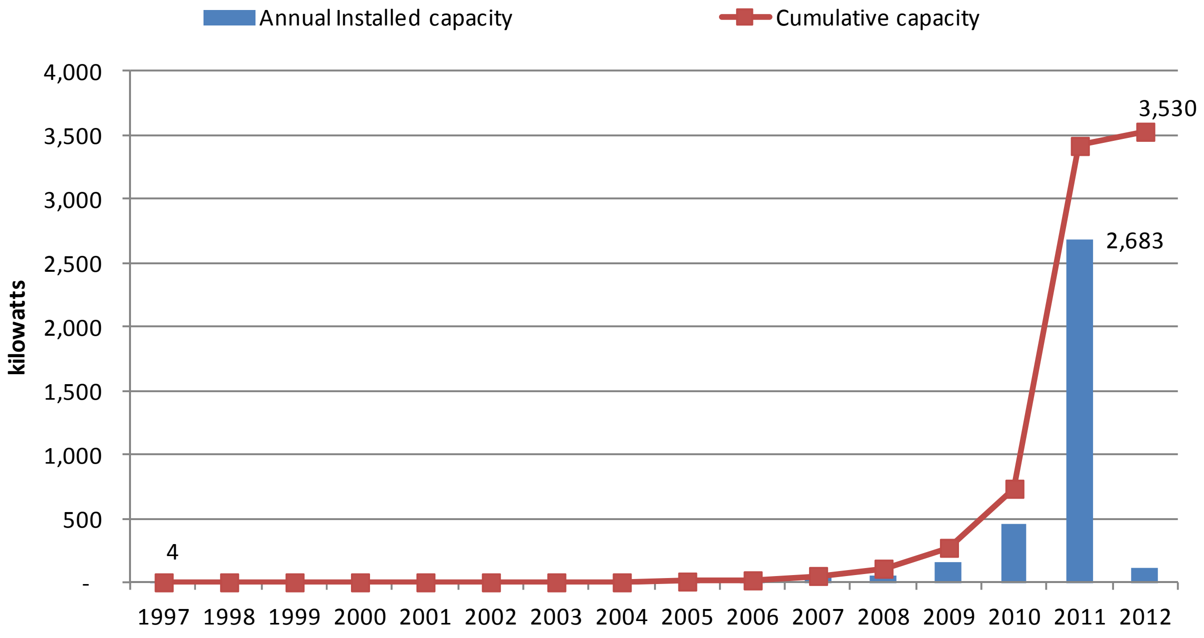

Figure 6-11: Indiana installed PV capacity in NREL *Open PV Project* database (Data source NREL [14]

The largest PV installation is the 2,010 kW project at the Fort Harrison Federal Compound in Indianapolis. This single project constitutes nearly 60 percent of Indiana's total installed capacity. The second largest PV installation in Indiana is a 186 kW project at the Metal Pro Roofing Corporation of Franklin City in Johnson County, followed by a 100 kW installation at the Johnson Melloh renewable energy demonstration laboratory in Indianapolis. A proposed 10 MW PV project at the Indianapolis airport will increase Indiana's PV capacity fourfold when it is completed. Table 6-2 lists the 30 PV installations with a capacity of 10 kW and above.

Owner /Developer	Rated Capacity (kW)	Location	Date Installed	Cost ($/Watt)
US General Services Administration	2010	Fort Benjamin Harrison, Indianapolis	2011	3.94
Metal Pro Roofing	186	Franklin, Johnson County	2011	n/a
Johnson Melloh Solutions Demonstration Lab	100	Indianapolis	2011	n/a
Transpo Bus Station	93	South Bend	2010	n/a
Lakestation Indiana City Hall	73	Lakestation, Lake County	2011	
Indianapolis Housing Authority	60	Laurelwood Apartments Indianapolis	2011	n/a
Laurelwood Apartments	59	Indianapolis	4/2012	5.93
Telamon Corporation, Carmel	50	Carmel	2/2012	n/a
University of Notre Dame	50	Stinson-Remick Hall, Notre Dame	2010	10.00
Goshen Family Physicians	19	Goshen, Elkhart County	2011	n/a
Residential	19	Mentone, Kosciusko County	2010	n/a
Residential	17	Marklevilley, Hancock County	2011	n/a
Cool Creek Park	16	Carmel, Hamilton County	2010	8.35
Nusun Solar	15	Columbus, Bartholomew County	2011	4.50
IBEW Local Union 725	14	Terre Haute	2010	6.04
Commercial Establishment	14	Connersville, Fayette County	2007	14.25
Residential	13	Terre Haute	2009	7.76
McCormick Motors	13	Nappanee, Elkhart County	2011	n/a
Hope Builders	13	Elkhart	2010	n/a
Residential	11	Memphis, Clark County	2011	n/a
Merry Lea Learning Center Goshen College	11	Albion, Noble County	2011	n/a
Educational	11	Newburgh, Warrick County	2007	10.00
Educational	11	Evansville	2010	7.94
Educational	11	Evansville	2010	7.94
Commercial	11	Kokomo	2009	7.93
Residential	11	Angola, Steuben County	2009	5.32
Big Fish'n Campground	10	Lafayette	2011	n/a
University of Notre Dame	10	Fitzpatrick Hall , Notre Dame	2011	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 [14])

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.

6.5 Incentives for PV systems

Federal Incentives

- Business Energy Investment Tax Credit (ITC) credits up to 30 percent of expenditures on solar systems. The 2009 American Recovery and Reinvestment Act provided for treasury cash grants in lieu of the ITC [13].

- 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 [13].

- Modified Accelerated Cost-Recovery System (MACRS) allows businesses to recover investments in qualified 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 [13].

- 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 [13].

- 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 [13].

- 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 [10].

- 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 [13].

- Value-Added Producer Grant Program supports planning activities and provides 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. The maximum award per grant is $300,000 [15].

- High Energy Cost Grant Program administered by USDA is aimed at improving the electricity supply infrastructure in rural areas having home energy costs exceeding 275 percent of the national average. Eligible infrastructure includes renewable resources generation. USDA has allocated $21 million for the 2011 funding cycle [16].

Indiana Incentives

- Emissions Credits are available to electricity generators that do not emit NO_x and that displace utility generation under the Indiana Clean Energy Credit Program. These credits can be sold on the national market [17]

- Net Metering Rule qualifies renewable resources with a maximum capacity of 1 MW for net metering in Indiana. The net excess generation is credited to the customer in the next billing cycle [13].

- Renewable Energy Systems Property Tax Exemption provides property tax exemptions for the entire renewable energy device and affiliated equipment. In March 2012 solar PV was added to the list of technologies eligible for property tax exemption. The exemption applies to both real property and mobile homes equipped with renewable energy systems and may only be claimed by property owners [13].

- Solar Access Laws prevent planning and zoning authorities from prohibiting or unreasonably restricting the use of solar energy. Indiana's solar-easement provisions do not create an automatic right to sunlight, though they allow parties to voluntarily enter into solar-easement contracts which are enforceable by law [13].

- Clean Energy Portfolio Goal sets a voluntary goal of obtaining 4 percent between 2013 and 2018, 7 percent between 2019 and 2024, and 10 percent by 2025, of electricity from clean energy sources based on 2010 retail sales. Participation in the goal makes utilities eligible for incentives that can be used to pay for the compliance projects [13].

- 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 15 years. Solar compensation is $0.24/kWh for systems between 20 and 100 kW and $0.20/kWh for systems greater than 100 kW up to 10 MW. This rate expires in March 2013 after which no new contracts will be negotiated [13, 18].

- 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 [13, 19].

- Northern Indiana Public Service Company offers feed-in tariff incentive rates for electricity generated from renewable resources for up to 15 years. The payments for solar facilities are $0.30/kW for solar facilities with a capacity below 10 kW and $0.26/kW for facilities up to 2 MW. The tariff is experimental and slated to run until December 31, 2013. The maximum allowed generating unit size is 5 MW and the total system-wide capacity allowed under the tariff is 30 MW. Five hundred kW of the system-wide cap are reserved for solar projects of capacity less than 10 kW, and 500 kW for wind projects of capacity less than 10 kW [13, 20].

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7. Hydropower

7.1 Introduction

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

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

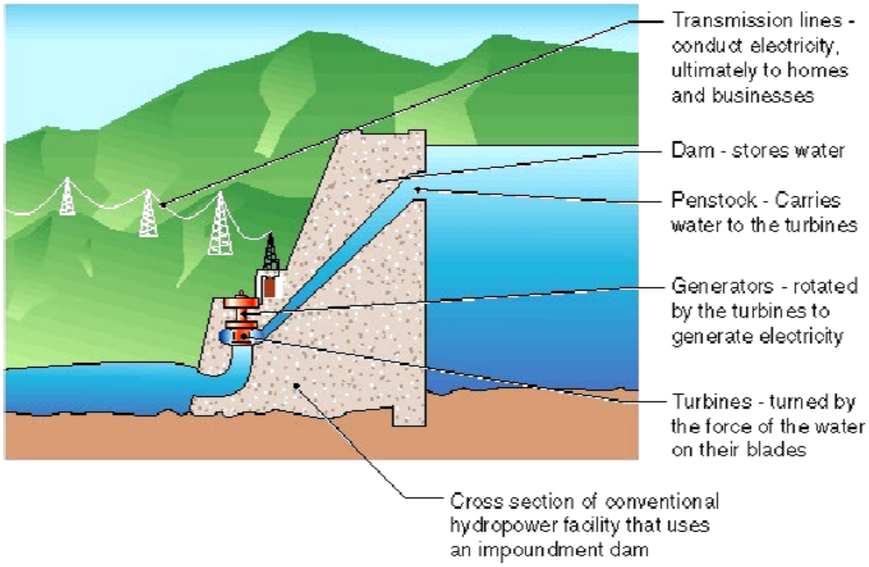

Figure 7-1: Schematic of impoundment hydropower facility (Source: INL [1])

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

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

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

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

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

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

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

Other factors may also act as deterrents to potential hydropower projects, including the increasingly costly and uncertain process of licensing or relicensing. About 300 hydroelectric facilities will have to be relicensed through 2017 [6]. Though the Energy Policy Act of 2005 helped reform the licensing procedure, many still consider the process to be burdensome and complicated [7]. Obtaining a license for a new facility, or renewing the license of an older facility, can take 8-10 years or longer [6].

7.2 Economics of hydropower

Hydropower projects are very capital intensive and the cost is very site specific. Table 7-1 shows the capital costs estimates from various sources. The capital cost estimates range from as low as $1,700/kW in 1996 dollars done by Idaho National Laboratory (INL) to nearly $14,000/kW cost estimate 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	6,226
	Meldahl	2010	4,504
	Willow Island	2011	7,889
	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: [8-13])

According to the EIA November 2010 updated plant costs [10], hydroelectric plants have one of the lowest O&M costs among electricity generating technologies. Figure 7-2 shows the variable and fixed O&M costs of various generating technologies. As can be seen in the Figure 7-2, hydroelectricity's variable O&M costs are estimated at zero and the fixed O&M cost of $13/kW is the second lowest after natural gas combustion turbines.

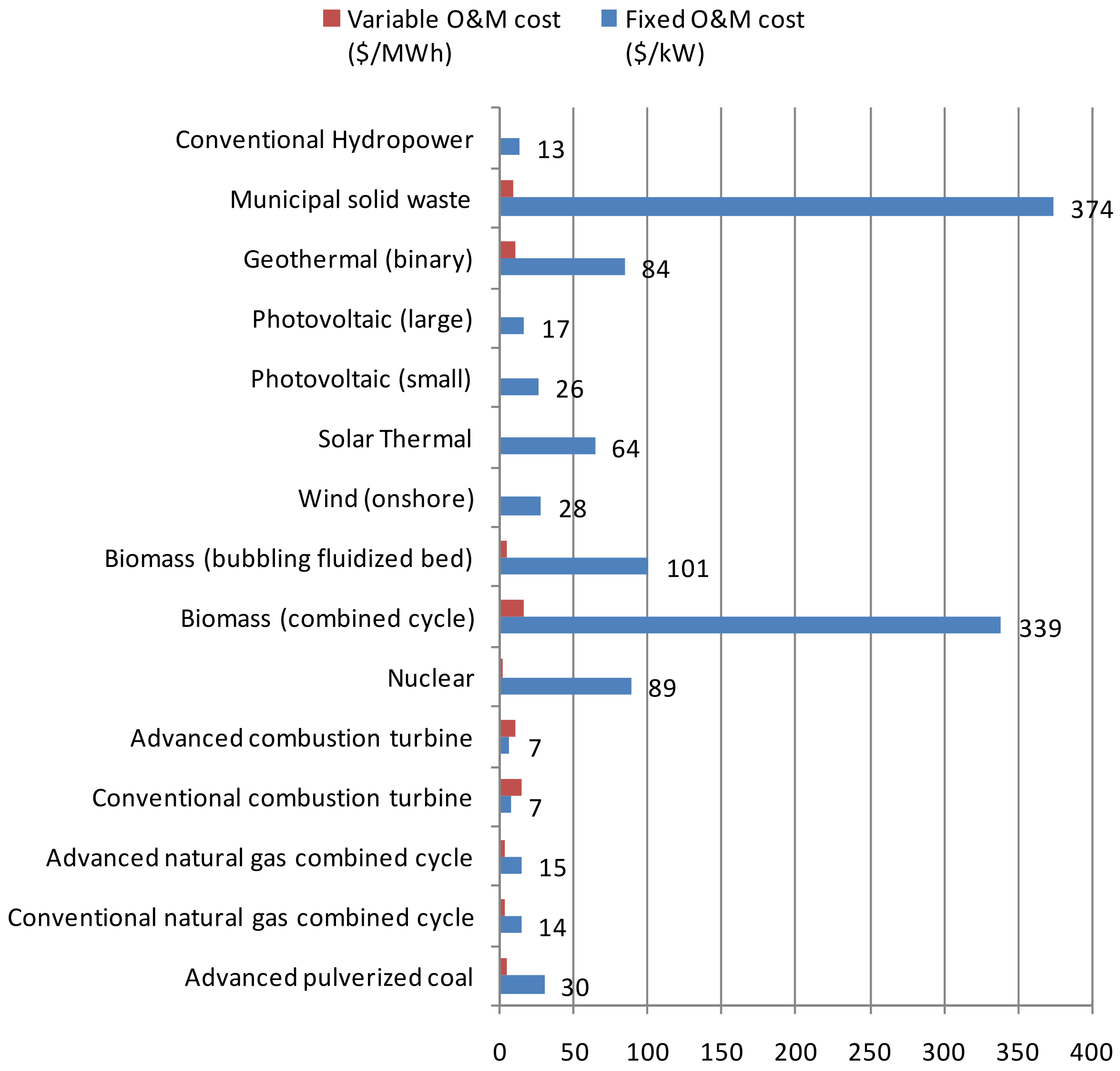

Figure 7-2: Variable and fixed O&M costs of generating technologies (Data source: EIA [10])

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 [14].

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 [14])

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 [15]. The breakdown of the state-by-state contribution to the total 30 GW identified is shown in Figure 7-3 [16].

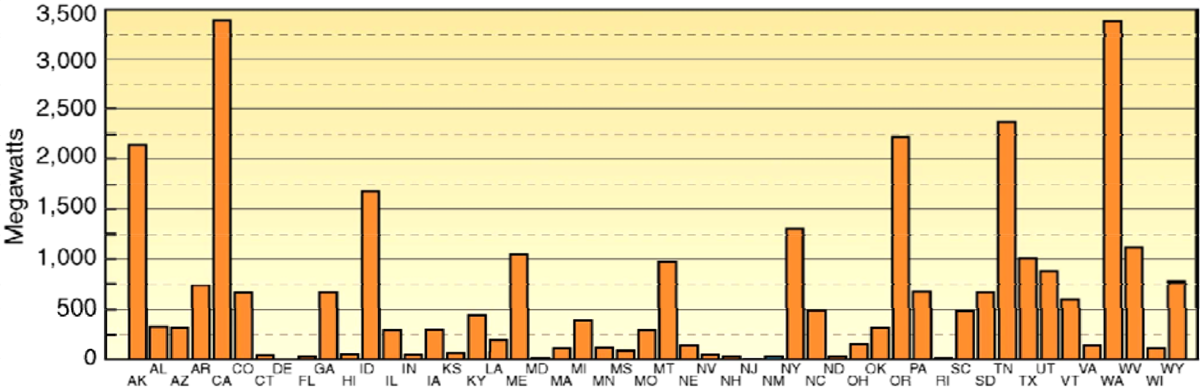

Figure 7-3: State breakdown of potential hydropower capacity (Source: INL [16])

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 [17]. Oak Ridge National Laboratory (ORNL) is updating hydropower potential assessments based on INL's study. ORNL's assessment 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 [18]. Figure 7-4 shows the distribution of non-powered dams in the U.S.

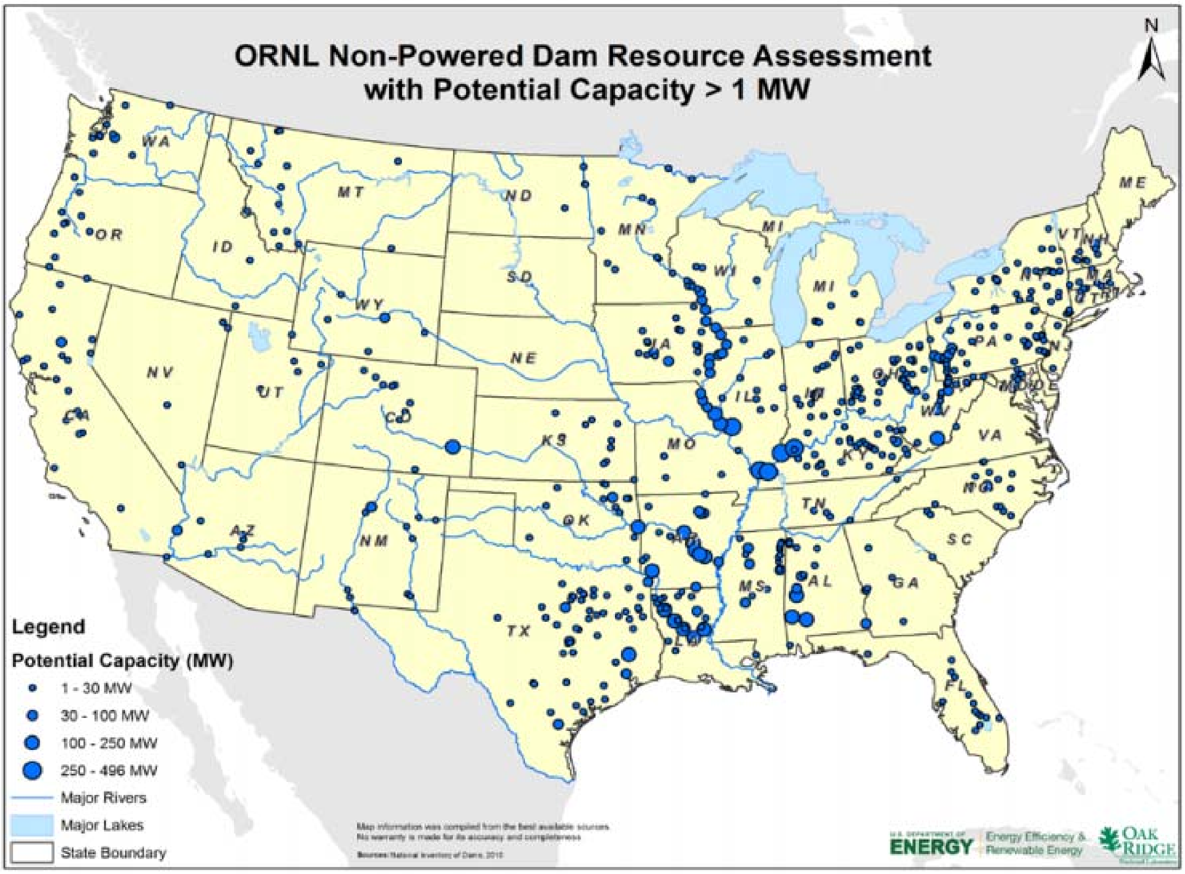

Figure 7-4: Non-powered dams with potential capacity over 1 MW (Source: ORNL [18])

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 [5]. 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 [19]. In April 2011, DOE and U.S. Department of the Interior (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 [20].

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 over 1,340 MW of installed wind capacity compared to 73 MW of hydroelectricity in Indiana, wind is now the dominant source of renewable electricity. This is a significant change from the situation in 2008 when only 20 kW of grid-connected wind capacity was in operation in Indiana.

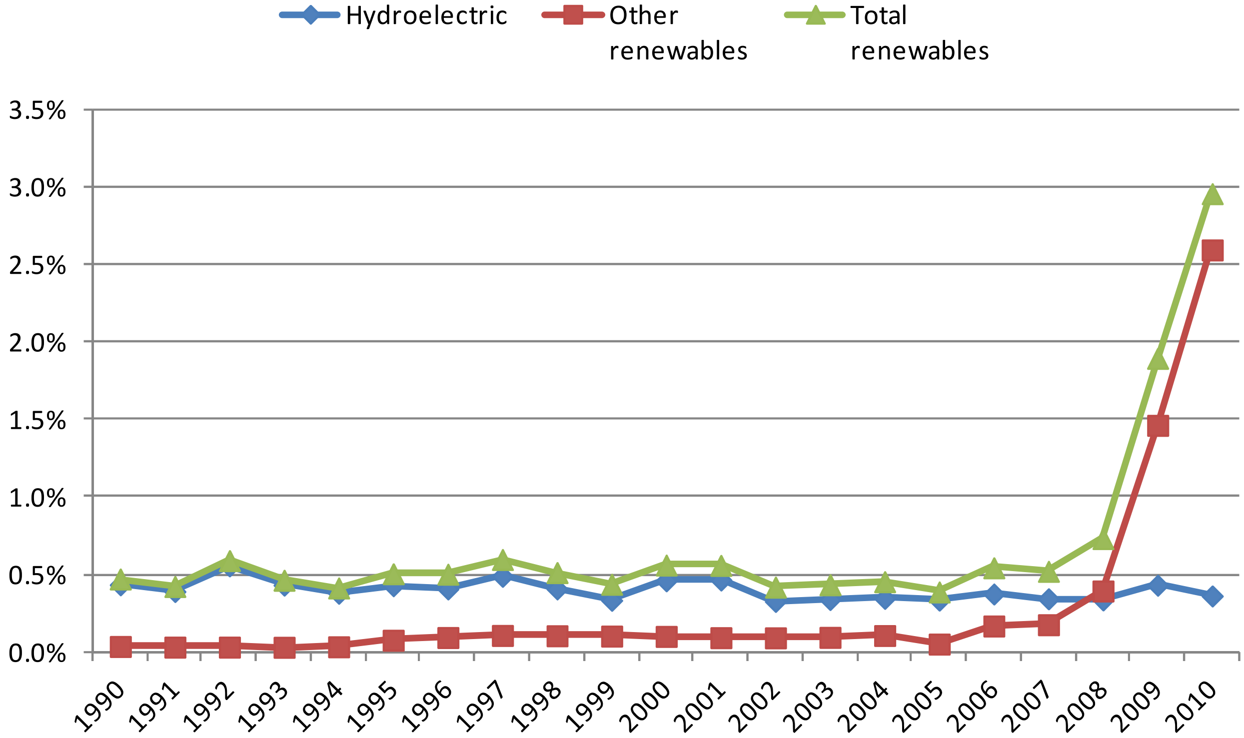

Figure 7-5: Renewables share of Indiana net electricity generation (1990-2009) (Data source: EIA [21])

However when one considers total Indiana energy consumption, wood and more recently ethanol dominate as sources of renewable energy consumed in Indiana as shown in Figure 7-6.

Hydroelectricity comes in third contributing less 0.2 percent of the total energy consumed in Indiana.

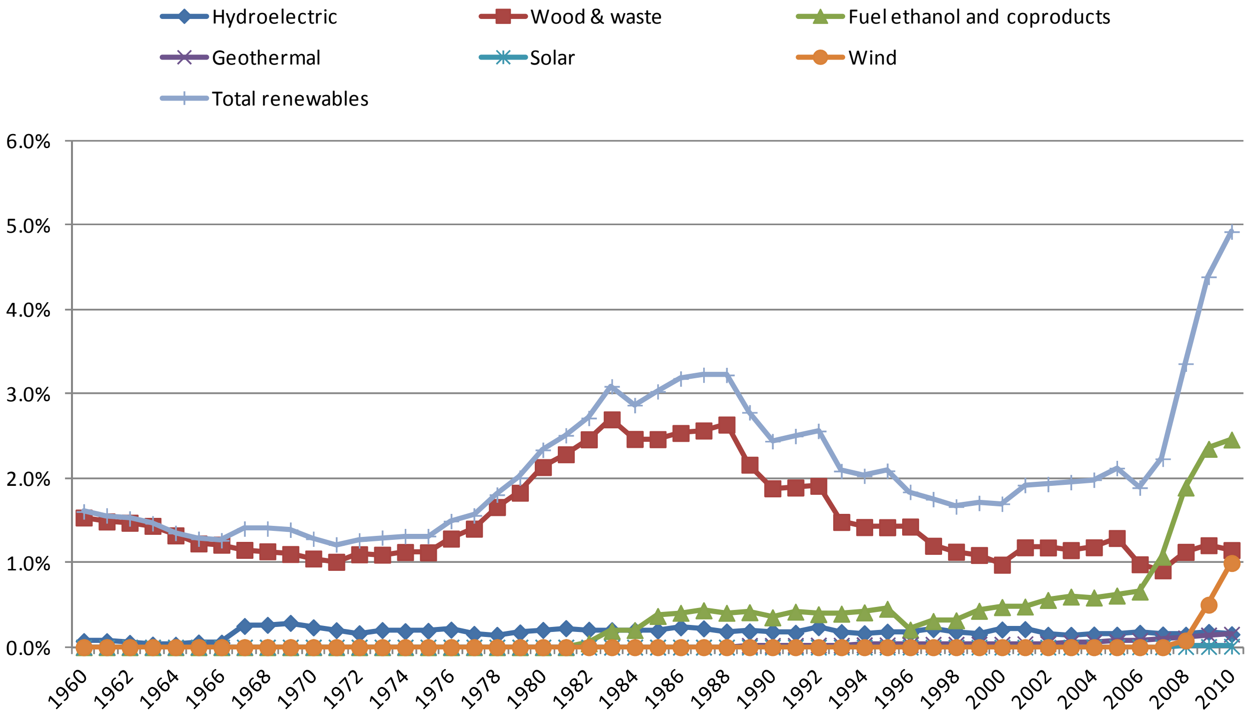

Figure 7-6: Renewables share of Indiana total energy consumption (1960-2010) (Data source: EIA [22])

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 [23].

	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: INL [23])

The 43 MW shown in Table 7-3 is the net capacity that could be 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, a wholesale electricity supplier to municipal utilities in Ohio, Pennsylvania, Michigan, Virginia, Kentucky and West Virginia is in the process of developing six run-of-the-river hydroelectric projects on existing dams along the Ohio River. Four of these projects – Cannelton, Melhahl, Smithland and Willow Island are already under construction while two projects, Robert Byrd and Pike Island, are undergoing the licensing process at the Federal Energy Regulatory Commission (FERC). One of the projects under construction, the 84 MW Cannelton project, is in the Indiana/Kentucky section of the river. Table 7-4 shows the estimated capital cost and expected commissioning dates of the projects.

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

Table 7-4: AMP hydropower projects along Ohio River (Source: AMP [12, 13, 24])

7.5 Incentives for hydropower

Federal Incentives

- Renewable Electricity Production Tax Credit (PTC) provides a 1.1 cents/kWh tax credit for qualified small hydroelectric and marine energy technologies. As part of the February 2009 American Recovery and Reinvestment Act the PTC was modified to provide the option for qualified producers to take the federal business energy investment credit (ITC) or an equivalent cash grant from the U.S. Department of Treasury. The PTC for hydroelectric facilities expires in December 2012 [25].

- 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 [25].

- 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 [26].

Indiana Incentives

- Net Metering Rule qualifies renewable resource facilities with a maximum capacity of 1 MW for net metering. The net excess generation is credited to the customer in the next billing cycle [25].

- Renewable Energy Property Tax Exemption provides property tax exemptions for solar, wind, hydroelectric and geothermal systems [25].

- Clean Energy Portfolio Goal sets a voluntary goal of obtaining 4 percent between 2013 and 2018, 7 percent between 2019 and 2024, and 10 percent by 2025, of electricity from clean energy sources based on 2010 retail sales. Participation in the goal makes utilities eligible for incentives that can be used to pay for the compliance projects [25].

- Emissions Credits are earmarked for electricity generators that do not emit NO_x and that displace utility generation. Qualified generators are eligible to receive NO_x emissions credits under the Indiana Clean Energy Credit Program. These credits can be sold on the national market [27].

- Northern Indiana Public Service Company offers feed-in tariff incentive rates for electricity generated from renewable resources for up to 10 years. The payment for hydroelectric facilities is $0.12/kWh for new hydroelectric facilities with a capacity no more than 1 MW. The tariff is experimental and slated to run until December 31, 2013. The total system-wide renewable capacity allowed under the tariff is 30 MW with 500 kW of the cap reserved for solar projects of capacity less than 10 kW, and 500 kW reserved for wind projects of capacity less than 10 kW [25, 28].

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