Economic Impact of Renewable Energy in Pennsylvania

Final Report

March 2004

Prepared for

THE HEINZ ENDOWMENTS
HOWARD HEINZ ENDOWMENT AND VIRA I. HEINZ ENDOWMENT

COMMUNITY FOUNDATION FOR THE ALLEGHENIES

Black & Veatch Project 135401

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BLACK & VEATCH

11401 Lamar
Overland Park, Kansas 66211

Tel: (913) 458-2000

Black & Veatch Corporation

Community Foundation for the Alleghenies
Economic Impact of Renewable Energy in Pennsylvania

B&V Project 135401
05 March 2004

Michael Kane
Community Foundation for the Alleghenies
216 Franklin Street, Suite 606
Johnstown, PA 15901

Subject: Final Report Submital

Attention: Michael Kane
Executive Director

Gentlemen:

Black & Veatch is pleased to submit this Final Report to Community Foundation for the Alleghenies and Heinz Endowments for the Economic Impact of Renewable Energy in Pennsylvania.

We trust that this submittal meets your expecations and needs. Should you have any comments, please feel free to contact me at (913) 458-8222.

Very truly yours,

BLACK & VEATCH

Ryan Pletka
Project Manager

RJP
Enclosure[s]

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Community Foundation for the Alleghenies
Michael Kane, Executive Director

Black & Veatch Principal Investigators:
Ryan Pletka, Project Manager
John Wynne, Chief Economist
Jason Abiecunas
Sam Scupham
Nate Lindstrom
Ryan Jacobson
Bill Stevens

About Black & Veatch*:* Black & Veatch is a large consulting, engineering, and construction firm with over 7,000 employees and offices in more than 90 cities around the world (including two in Pennsylvania). The company primarily serves the energy, water, and information technology sectors. Within the energy field, the firm has been involved in the execution of over 80,000 MW of power projects over the past decade

Black & Veatch's energy experience covers all major energy sources including natural gas, coal, nuclear, oil, hydro, biomass, solar, wind, and geothermal. Approximately 40 people work in Black & Veatch's Global Renewable Energy Group, which provides renewable energy services from strategic consulting to project design and construction.

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E. Economic Impacts Assessment

Glossary of Terms[1]

Ancillary Services: Services in addition to electrical energy required by the grid system operator to maintain proper functioning and reliability of the grid. Services include

Availability Factor: A percentage representing the number of hours a generating unit is available to produce power (regardless of the amount of power) in a given period, compared to the number of hours in the period.

Avoided Cost: The cost a utility would incur to supply additional electricity were it not for the existence of an independent power source. Avoided cost rates have been used to establish the power purchase price utilities offered to independent suppliers (see Qualifying Facility).

Baseload Unit: A power generating facility that is intended to run at near full-load capacity levels, as much of the time as possible. Typically these are the lowest cost generators, such as large coal and nuclear plants.

Biomass: Any material of recent biological origin.

British thermal unit (Btu): The standard unit for measuring quantity of heat energy, such as the heat content of fuel. It is the amount of heat energy necessary to raise the temperature of one pound of water one degree Fahrenheit.

Busbar: In electric utility operations, a busbar is a conductor that serves as a common connection for two or more circuits. It may be in the form of metal bars or high-tension cables. The busbar cost is often given as a standard cost of generating power at the interconnection point with the main electric grid.

Capacity: The load for which a generating unit, generating station, or other electrical apparatus is rated either by the user or by the manufacturer.

Capacity charge: The payment made to offset all costs associated with the total capital cost of a plant including equipment costs and other capitalized costs such as interest during construction.

Capacity Factor: The ratio of the electrical energy produced by a generating unit for the period of time considered to the electrical energy that could have been produced at continuous full-power operation during the same period.

Capital Cost: The cost of field development and plant construction and the equipment required for the generation of electricity.

Cogeneration: The production of electrical energy and another form of useful energy (such as heat or steam) through the sequential use of energy.

Combined cycle: A combustion turbine installation using waste heat boilers to capture exhaust energy for steam generation.

Commercial operation date: The date at which a plant is substantially completed, has passed any required testing and is otherwise declared ready to delivery capacity and energy to the grid.

Concentrator: A reflective or refractive device that focuses incident insolation onto an area smaller than the reflective or refractive surface, resulting in increased insolation at the point of focus.

Debt service reserve fund: An amount of money required to be set aside in a reserve account to cover debt payments in the event that the project and other revenues are insufficient to make debt payments.

Demand: The rate at which electric energy is delivered to or by a system, part of a system, or a piece of equipment. It is expressed in kilowatts, kilovoltamperes or other suitable unit at a given instant or averaged over any designated period of time. The primary source of "Demand" is the power-consuming equipment of the customers.

[1] Glossary sources: (A) EIA, "Energy Consumption and Renewable Energy Development Potential on Indian Lands", April 2000. (B) California Energy Commission, www.energy.ca.gov/glossary. (C) Black & Veatch, "Power Plant Engineering", Fifth Printing, 2001. (D) Edison Electric Institute, "Glossary of Electric Utility Terms", December 1997.

Demand Charge: The sum to be paid by a large electricity consumer for its peak usage level.

Deregulation: See Electric Utility Restructuring.

Direct Access: The ability of customers to purchase electricity from wholesale providers other than their default utility.

Dispatch: Direction for the plant to commence, continue, increase, decrease or cease the delivery of electricity supplied to the interconnection point.

Dispatchable generation: A generation source that is controlled by a system operator or dispatcher who can increase or decrease the amount of power from that source as the system requirements change.

Distributed Generation: A distributed generation system involves small amounts of generation located on a utility's distribution system for the purpose of meeting local (substation level) peak loads and/or displacing the need to build additional (or upgrade) local distribution lines.

Distribution System: The substations, transformers and lines that convey electricity from high-power transmission lines to ultimate consumers. See Grid.

Electric Utility Restructuring: With some notable exceptions, the electric power industry historically has been composed primarily of investor-owned utilities. These utilities have been predominantly vertically integrated monopolies (combining electricity generation, transmission, and distribution), whose prices have been regulated by State and Federal government agencies. Restructuring the industry entails the introduction of competition into at least the generation phase of electricity production, with a corresponding decrease in regulatory control. Restructuring may also modify or eliminate other traditional aspects of investor-owned utilities, including their exclusive franchise to serve a given geographical area, assured rates of return, and vertical integration of the production process.

Energy Charge: The amount of money owed by an electric customer for kilowatt-hours consumed.

Escalation: the rate of growth applied to a present value cost to determine the future cost of the item. It is equal to the expected inflation rate times any real price effects.

Federal Energy Regulatory Commission (FERC): An independent regulatory commission within the U.S. Department of Energy that has jurisdiction over energy producers that sell or transport fuels for resale in interstate commerce; the authority to set oil and gas pipeline transportation rates and to set the value of oil and gas pipelines for ratemaking purposes; and regulates wholesale electric rates and hydroelectric plant licenses.

Firm Energy: Power supplies that are guaranteed to be delivered under terms defined by contract.

Fixed O&M: Operating and maintenance costs associated with a generating facility that do not vary with the output of the facility. Such costs typically include staffing, insurance, rents, etc. For comparison purposes, these costs are often expressed as an annual expenditure per unit of capacity ($/yr-kW).

Fluidized Bed Combustion: A process for burning powdered coal (or other fuels) that is poured in a liquid-like stream with air or gases. The process reduces sulfur dioxide emissions from coal combustion.

Fossil Fuel: Oil, coal, natural gas or their by-products. Fuel that was formed in the earth in prehistoric times from remains of living-cell organisms.

Fuel Cells: One or more cells capable of generating an electrical current by converting the chemical energy of a fuel directly into electrical energy. Fuel cells differ from conventional electrical cells in that the active materials such as fuel and oxygen are not contained within the cell but are supplied from outside.

Generation: The total amount of electric energy produced by the generating units in a generating station or stations measured at the generator terminals, usually expressed in terms of kilowatt-hours.

Geothermal Energy: As used at electric utilities, hot water or steam extracted from geothermal reservoirs in the Earth's crust that is supplied to steam turbines at electric utilities that drive generators to produce electricity.

Giga: One billion.

Green Pricing: In the case of renewable electricity, green pricing represents a market solution to the various problems associated with regulatory valuation of the nonmarket benefits of renewables. Green pricing programs allow electricity customers to express their willingness to pay for renewable energy development through direct payments on their monthly utility bills.

Greenfield: Undeveloped land.

Grid: The layout of an electrical distribution system.

Gross Plant Output: The instantaneous electrical output of an electricity generating plant (e.g., electricity used to power pumps, fans, etc. needed to run the facility). Typically measured in kilowatts or megawatts.

Heat rate: A measure of generating station thermal efficiency, generally expressed in Btu per net kilowatt-hour. It is computed by dividing the total Btu content of fuel burned for electric generation by the resulting net kilowatt-hour generation.

Heating value: The amount of heat produced by the complete combustion of a given amount of fuel. Can be expressed as higher heating value (HHV) or lower heating value (LHV).

Horsepower (HP): A unit for measuring the rate of doing work. One horsepower equals about three-fourths of a kilowatt (745.7 watts).

Hot Start: A plant startup which occurs when the facility has been off-line less than 4 hours and is given a dispatch instruction to start up.

Hub Height: In a horizontal-axis wind turbine, the distance from the turbine platform to the rotor shaft.

Independent Power Producer (IPP): A wholesale electricity producer (other than a qualifying facility under the Public Utility Regulatory Policies Act of 1978), that is unaffiliated with franchised utilities in the area in which the IPP is selling power and that lacks significant marketing power. Unlike traditional utilities, IPPs do not possess transmission facilities that are essential to their customers and do not sell power in any retail service territory where they have a franchise.

Interconnection: A connection between two electric systems permitting the transfer of electric energy in either direction

Levelized cost: The present value of the total cost of building and operating a generating plant over its economic life, converted to equal annual payments. Costs are levelized in real dollars (i.e., adjusted to remove the impact of inflation).

Internal Combustion Engine: An engine in which fuel is burned inside the engine. A car's gasoline engine or rotary engine is an example of a internal combustion engine. It differs from engines having an external furnace, such as a steam engine.

Investor Owned Utility (IOU): A company, owned by stockholders for profit, that provides utility services. A designation used to differentiate a utility owned and operated for the benefit of shareholders from municipally owned and operated utilities and rural electric cooperatives.

Kilovolt (kV): One-thousand volts (1,000). Distribution lines in residential areas usually are 12 kV (12,000 volts).

Kilowatt (kW): One thousand watts of electricity (See Watt).

Kilowatt-hour (kWh): One thousand watt-hours (see Watt-hour).

Landfill Gas: Gas generated by the natural degrading and decomposition of municipal solid waste by anaerobic microorganisms in sanitary landfills. The gases produced, carbon dioxide and methane, can be collected by a series of low-level pressure wells and can be processed into a medium Btu gas that can be burned to generate steam or electricity.

Load Factor: A percent indicating the difference between the electrical energy a consumer used during a given time span and the amount that would have been used if the usage had stayed at the peak demand level the whole time. The term also is used to mean the percentage of capacity of an energy facility (such as power plant or gas pipeline) that is utilized in a given period of time.

Marginal Cost: The change in cost associated with a unit change in quantity supplied or produced.

Marketer: An agent for generation projects who markets power on behalf of the generator. The marketer may also arrange transmission, firming or other ancillary services as needed. Though a marketer may perform many of the same functions as a broker, the difference is that a marketer represents the generator while a broker acts as a middleman.

Market Clearing Price: The price at which supply equals demand.

Megawatt (MW): One million watts of electricity (See Watt).

Megawatt-hour (MWH): One million watt-hours of electricity (See Watt-hour).

Merchant Facilities: High-risk, high-profit facilities that operate, at least partially, at the whims of the market, as opposed to those facilities that are constructed with close cooperation of municipalities and have significant amounts of waste supply guaranteed.

Microturbine: A miniature combustion turbine, similar in concept to the larger gas turbines used in conventional utility power plants. Whereas large gas turbines rang from 20,000 to over 200,000 kW, microturbines range from 25 to 400 kW.

Municipal Solid Waste: Locally collected garbage, which can be processed and burned to produce energy.

Municipal Utility: A provider of utility services owned and operated by a municipal government.

Net Plant Capacity: The instantaneous peak dependable output of an electricity generating plant minus any internal electricity consumption (e.g., electricity used to power pumps, fans, etc. needed to run the facility). Typically measured in kilowatts or megawatts.

Net Plant Heat Rate: See Heat Rate. A measure of the fuel efficiency of a power generation station based on the Net Plant Capacity.

Nitrogen oxides (NO_x):- Gases formed in great part from atmospheric nitrogen and oxygen when combustion takes place under conditions of high temperature and high pressure; considered a major air pollutant.

Non-Firm Energy: Electricity that is not required to be delivered or to be taken under the terms of an electric purchase contract.

Nonutility Generation: Electric generation by nonutility power producers to supply electric power for industrial, commercial, and military operations, or sales to electric utilities. See Nonutility Power Producer.

Nonutility Power Producer: A corporation, person, agency, authority, or other legal entity or instrument that owns electric generating capacity and is not an electric utility. Nonutility power producers include qualifying cogenerators, qualifying small power producers, and other nonutility generators (including independent power producers) without a designated, franchised service area that do not file forms listed in the Code of Federal Regulations, Title 18, Part 141.

Operation and Maintenance (O&M) Cost: Operating expenses are associated with operating a facility (i.e., supervising and engineering expenses). Maintenance expenses are that portion of expenses consisting of labor, materials, and other direct and indirect expenses incurred for preserving the operating efficiency or physical condition of utility plants that are used for power production, transmission, and distribution of energy.

Parabolic Dish: A high-temperature (above 180 degrees Fahrenheit) solar thermal concentrator, generally bowl-shaped, with two-axis tracking.

Parabolic Trough: A high-temperature (above 180 degrees Fahrenheit) solar thermal concentrator with the capacity for tracking the sun using one axis of rotation.

Passive Solar: A system in which solar energy alone is used for the transfer of thermal energy. Pumps, blowers, or other heat transfer devices that use energy other than solar are not used.

Peak demand: The greatest demand which occurred during a specified period of time.

Peaking Unit: A power generating facility that is intended to run during high electricity demand periods. Typically these are the highest cost generators, such as simple cycle combustion turbines and inefficient fossil plants.

Photovoltaic Cell: An electronic device consisting of layers of semiconductor materials fabricated to form a junction (adjacent layers of materials with different electronic characteristics) and electrical contacts and being capable of converting incident light directly into electricity (direct current).

Photovoltaic Module: An integrated assembly of interconnected photovoltaic cells designed to deliver a selected level of working voltage and current at its output terminals, packaged for protection against environment degradation, and suited for incorporation in photovoltaic power systems.

Power Pool: Two or more interconnected utilities that plan and operate to supply electricity in the most reliable, economical way to meet their combined load.

Public Utility Holding Company Act (PUHCA): 1935. This act prohibits acquisition of any wholesale or retail electric business through a holding company unless that business forms part of an integrated public utility system when combined with the utility's other electric business. The legislation also restricts ownership of an electric business by non-utility corporations.

Public Utility Regulatory Policies Act of 1978 (PURPA): One part of the National Energy Act, PURPA contains measures designed to encourage the conservation of energy, more efficient use of resources, and equitable rates. Principal among these were suggested retail rate reforms and new incentives for production of electricity by cogenerators and users of renewable resources.

Pulverized coal: A finely ground form of coal used in many boiler applications. There are various pulverizer technologies that can be used.

Qualifying Facility (QF): A cogeneration or small power production facility that meets certain ownership, operating, and efficiency criteria established by the Federal Energy Regulatory Commission (FERC) pursuant to the Public Utility Regulatory Policies Act of 1978 (PURPA). (See the Code of Federal Regulations, Title 18, Part 292.)

Rankine Cycle: The steam-Rankine cycle employing steam turbines has been the mainstay of utility thermal electric power generation for many years. The cycle, as developed over the years uses superheat, reheat and regeneration. Modern steam Rankine systems operate at a cycle top temperature of about 1,073 degrees Celsius with efficiencies of about 40 percent.

Refuse-Derived Fuel (RDF): Fuel processed from municipal solid waste that can be in shredded, fluff, or densified pellet forms.

Reliability: The guarantee of system performance at all times and under all reasonable conditions to assure constancy, quality, adequacy and economy of electricity. It is also the assurance of a continuous supply of electricity for customers at the proper voltage and frequency.

Renewable Energy Source: An energy source that is regenerative or virtually inexhaustible. Typical examples are wind, geothermal, and water power.

Reserve Margin: The differences between the dependable capacity of a utility's system and the anticipated peak load for a specified period.

Self-Generation: A generation facility dedicated to serving a particular retail customer, usually located on the customer's premises. The facility may either be owned directly by the retail customer or owned by a third party with a contractual arrangement to provide electricity to meet some or all of the customer's load.

Simple Cycle: An electric generating technology in which electricity is produced from one or more gas (combustion) turbines with no waste heat recovery.

Silicon: A semiconductor material made from silica, purified for photovoltaic applications.

Solar Energy: The radiant energy of the sun, which can be converted into other forms of energy, such as heat or electricity.

Stirling Engine: An external combustion engine that converts heat into useable mechanical energy (shaft work) by the heating (expanding) and cooling (contracting) of a captive gas such as helium or hydrogen.

Subbituminous: A dull black coal ranking between lignite and bituminous, it is mined chiefly in Montana and Wyoming.

Subcritical: A steam cycle that is designed with a main steam pressure lower than critical pressure.

Substation: An assemblage of equipment for the purposes of switching and/or changing or regulating the voltage of electricity.

Sulfur oxides (SO_x):- Pungent, colorless gases formed primarily by the combustion of fossil fuels; considered major air pollutants; sulfur oxides may damage the human respiratory tract as well as vegetation.

Sunk Cost: In economics, a sunk cost is a cost that has already been incurred, and therefore cannot be avoided by any strategy going forward.

Supercritical: A steam cycle that is designed with a main steam pressure higher than critical pressure.

Tariff: A document, approved by the responsible regulatory agency, listing the terms and conditions, including a schedule of prices, under which utility services will be provided.

Time-Of-Use Rates: Electricity prices that vary depending on the time periods in which the energy is consumed. In a time-of- use rate structure, higher prices are charged during utility peak-load times. Such rates can provide an incentive for consumers to curb power use during peak times.

Tipping Fee: Price charged to deliver municipal solid waste to a landfill, waste-to-energy facility, or recycling facility.

Transmission losses - The general term applied to energy (kilowatt-hours) and power (kilowatts) lost in the operation of an electric system. Losses occur principally as energy transformations from kilowatt hours to waste heat in electrical conductors and apparatus.

Transmission System (Electric): An interconnected group of electric transmission lines and associated equipment for moving or transferring electric energy in bulk between points of supply and points at which it is transformed for delivery over the distribution system lines to consumers, or is delivered to other electric systems.

Turbine: A machine for generating rotary mechanical power from the energy of a stream of fluid (such as water, steam, or hot gas). Turbines convert the kinetic energy of fluids to mechanical energy through the principles of impulse and reaction, or a mixture of the two.

Unbundling: Disaggregating electric utility service into its basic components and offering each component separately for sale with separate rates for each component. For example, generation, transmission and distribution could be unbundled and offered as discrete services.

Variable O&M: Those operating and maintenance costs that vary according to the of plant output, such as lubricating oils, limestone and water.

Volt: The unit of electromotive force or electric pressure analogous to water pressure in pounds per square inch. It is the electromotive force which, if steadily applied to a circuit having a resistance of one ohm, will produce a current of one ampere

Watt: The electrical unit of real power or rate of doing work. The rate of energy transfer equivalent to one ampere flowing due to an electrical pressure of one volt at unity power factor. One watt is equivalent to approximately 1/746 horsepower, or one joule per second.

Watt-hour: The total amount of energy used in one hour by a device that requires one watt of power for continuous operation. Electric energy is commonly sold by the kilowatt-hour

Wheeling: The use of the transmission facilities of one system to transmit power and energy by agreement of and for, another system with a corresponding wheeling charge (e.g., the transmission of electricity for compensation over a system that is received from one system and delivered to another system).

List of Abbreviations

$/kW........Dollar per kilowatt
$/MBtu.....Dollar per million British thermal units
$/MWh.....Dollar per megawatt hour
°F ....degree Fahrenheit
ACFB........atmospheric circulating fluidized bed
AQC.........air quality control
AWEA.......American Wind Energy Association
BAU ....business as usual
Btu...........British thermal unit
CPWC.......cumulative present worth cost
DG...........distributed generation
DOE.........Department of Energy
EA............environmental assessment
EIA ....Energy Information Administration, US DOE
EPA..........Environmental Protection Agency
EPC..........engineer, procure and construct
FCR..........fixed charge rate
FERC........Federal Energy Regulatory Commission
FGD ....flue gas desulfurization
FOM.........fixed O&M
GIS ....geographic information system
gpm ....gallons per minute
GW ....gigawatt
GWh ....gigawatt hour
HHV.........higher heating value
HP ....horsepower
IDC..........interest during construction
INEEL.......Idaho National Engineering and Environmental Laboratory
IOU..........Investor Owned Utility
IPP ....Independent Power Producer
kV............kilovolt
kW...........kilowatt
kWh.........kilowatt-hour
LFCR........levelized fixed charge rate
LHV..........lower heating value
LMOP.......Landfill Methane Outreach Program
m.............meter
m/s..........meter per second
MACRS.....Modified Accelerated Cost Recovery System
MBtu........million Btu
mgd ....million gallons per day
MW..........megawatt
MWh........megawatt-hour
NASS........National Agricultural Statistics Services
NEPA........National Environmental Policy Act
NO_x..........nitrogen oxide
NPDES .....National Pollutant Discharge Elimination System
NPHR ....Net plant heat rate
NREL........National Renewable Energy Laboratory
NYSERDA .New York State Energy Research and Development Authority
O&M ....operations and maintenance
ORNL ....Oak Ridge National Laboratories
PC............pulverized coal
PM ....particulate matter
psig..........pounds per square inch (gage)
PTC..........production tax credit
PUHCA .....Public Utility Holding Company Act
PURPA......Public Utility Regulatory Policies Act of 1978
PV............photovoltaic
QF ....qualifying facility
RDF ....refuse derived fuel
RPS..........Renewable Portfolio Standard
SO_x ....sulfur oxides
USDA ....US Department of Agriculture
VOM.........variable O&M
W/m^2 ....watt per square meter

Economic Impact of Renewable Energy in Pennsylvania

A. EXECUTIVE SUMMARY

5 March 2004

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Abstract

Black & Veatch analyzed the potential economic impacts of renewable energy development in Pennsylvania spurred by a Renewable Portfolio Standard (RPS). The study was performed for the Community Foundation for the Alleghenies with funding from the Heinz Endowments. The study found that the proposed RPS would result in a slight electricity cost increase but would provide a windfall of economic benefits to Pennsylvania.

Renewable technologies have been developed to harvest energy from wind, solar radiation, biomass, water, and the earth's thermal energy. Although the potential resources are huge, non-hydro renewable energy currently supplies only 2 percent of the electricity demand in the United States. However, state governments have begun to take an interest in renewable energy. To date, 12 states have implemented RPS policies mandating that a portion of power supplied to retail customers come from renewable energy sources.

Currently, over 90 percent of the electricity generated in Pennsylvania comes from coal and nuclear energy. The balance is made up with petroleum/natural gas, hydroelectric, and a small percentage of renewable energy (1.4 percent). Although Pennsylvania has adopted some incentives for renewable energy development, these have had limited success as only a small amount of new renewable energy has been developed. In fact, in a recent study performed by the Union of Concerned Scientists that ranked states' support of renewable energy ***Pennsylvania received a grade of "D"*** due to the limited success of the renewable energy policies and the low amount of installed renewable energy. Clearly a shift in policy is required if more renewable energy generation is desired. While the amount of renewable energy generation in Pennsylvania is still small, a thriving renewable energy industry exists with over 200 active companies. This strong industrial base complements the abundant renewable energy resource potential.

The most abundant renewable energy resources include wind, solar, biomass, landfill gas, and hydro sources. ***The technical potential of these resources is capable of supplying more than the current Pennsylvania demand for electricity.*** The study developed a hypothetical least-cost portfolio of renewable energy technologies that would likely be developed to meet the RPS requiring 10 percent of energy be supplied from new renewable energy by 2015. Wind energy and biomass were estimated to contribute over 80 percent of the energy. The remainder is made up of hydro, digester gas and landfill gas generation projects, and a small amount of solar photovoltaic generation.

The economic impacts of the RPS portfolio were compared to a "business as usual" (BAU) case of building all fossil fuel resources. The analysis revealed that over 20 years the RPS portfolio would cost $1.23 billion greater than the BAU case on a present value basis. Relatively speaking, this cost is minimal. When spread over all retail electric customers, this increase in cost would result in an ***increase in electric rates of only 0.036 cents/kWh***, or about 29 cents per month for the average residential customer. However, the RPS portfolio would result in ***$10.1 billion more in gross state output over 20 years*** than the BAU portfolio. In addition, the RPS portfolio would provide a ***$2.8 billion advantage in earnings*** and generate about ***85,000 more job-years over 20 years*** than the BAU portfolio. In addition, a review of recent studies revealed that there is strong evidence for fossil fuel price and consumption decreases as a result of renewable energy development. This analysis revealed that even a 1 percent reduction in fossil fuel prices would lead to a $140 million reduction in annual fossil fuel expenditures for power generation, or 50 percent of the RPS cost premium in 2015.

1. INTRODUCTION

Black & Veatch Corporation has prepared this report for the Community Foundation for the Alleghenies to assess the economic impacts of renewable energy development in Pennsylvania. Funding for the project has been provided by the Heinz Endowments.

Pennsylvania has long been blessed with tremendous energy resources that have served as the backbone for a diverse and robust economy. However, the exploitation of the state's fossil fuel resources has left the state with a legacy of environmental concerns. There is significant interest in the state to address these issues by instigating a shift from fossil fuels to sustainable renewable energy resources.

In response to increasing public interest in clean energy sources, concerns about energy security, and environmental impacts of fossil fuels the Pennsylvania legislature is contemplating a renewable portfolio standard (RPS). RPS policies have been a popular mechanism used by other states and countries to mandate a certain percentage of electricity be generated from renewable energy resources.

The Community Foundation for the Alleghenies retained Black & Veatch to determine the technical potential and economic impacts of renewable energy development in Pennsylvania. The study included a review of the current status of renewable energy, characterization of renewable power generation technologies, assessment of Pennsylvania renewable resources, and evaluation of economic impacts of implementing a 10 percent new RPS.

Approach

A resource assessment was performed to quantify the technical and near-term potential of wind, solar, biomass, biogas, hydroelectric, and geothermal resources. In addition, assessments were made of demand side reduction options including distributed generation and ground source heat pumps. The assessment included detailed GIS analysis based on the latest available renewable energy resource data to determine the geographic distribution, size of the resources, and technical feasibility of utilization.

Resource estimates were combined with technology characteristics to develop a set of economic supply curves showing the amount of renewable energy available (MWh) at varying levelized costs ($/MWh). The supply curves for the individual renewable energy technologies were then combined to generate a statewide renewable energy supply curve. This curve revealed the least-cost renewable energy generation portfolio to meet an RPS mandating 10 percent new renewable energy by 2016.

This report answers the following questions:

- What is the current status of renewable energy development in the United States and Pennsylvania?
- What technologies are available for generating power from renewable resources and what are their characteristics?
- What is the technical and near-term potential for development of renewable resources in Pennsylvania?
- What are the most cost effective resources, and what is the likely mix of technologies that would be built in response to a 10 percent RPS?
- How will development of renewable resources impact the cost of electricity in Pennsylvania?
- What economic benefits or costs will the state experience by adopting an RPS policy?

The study examines economic development impacts resulting from renewable energy development including job creation, earnings, cost of electricity, natural gas costs, and state economic output.

The estimated economic impacts were compared with a "Business as Usual" scenario, in which the majority of generation expansion is met with conventional natural gas and coal technologies.

This report is based on hundreds of assumptions related to resource availability, costs, economic impacts and other factors. These assumptions have been developed based on Black & Veatch experience, industry inquiries, and review of literature in the field. Careful analysis of similar recent studies aided in the development of appropriate assumptions, and it is felt that the assumptions made in the report are generally conservative in nature.

There are numerous market dynamics in the energy business that could dramatically alter these results. These include new federal policies and legislation, development or importation of substantial natural gas resources, and technology advancements. The specific laws and rules implementing the RPS are also very important. For example, this study included cofiring biomass with coal and new low impact hydro as qualifying resources in the RPS. If these resources are excluded it will raise the cost of achieving the renewable development goals.

The model used for this report was a relatively simple linear model. The renewable energy supply curves were developed based largely on best available public information and they represent a snapshot of what could be developed in the near term without consideration of significant future technology advancements. While it is recognized that there are several shortcomings to this approach it is felt that the modeling approach is appropriate given the constraints of time and budget allocated for this project.

Finally, environmental "externalities" were not considered in this analysis. An RPS will provide value to the citizens of Pennsylvania in terms of improved environmental, health, and safety aspects. However, no effort is made to quantify these benefits in this study.

Report Organization

This Executive Summary reviews the findings of the main report sections. These are:

- A. Executive Summary
- B. Current Status of Renewable Energy
- C. Renewable Technologies Assessment
- D. Renewable Resources Assessment
- E. Economic Impacts Assessment

2. CURRENT STATUS OF RENEWABLE ENERGY

The objective of this section was to provide an overview of renewable energy and describe the current status of renewable energy development in Pennsylvania and other states. The section also addressed policy developments including, most importantly, a potential Renewable Portfolio Standard (RPS) in Pennsylvania.

Renewable energy sources are practically inexhaustible in that most ultimately derive their energy from the sun. Technologies to harness renewable energy are diverse and include wind, solar, biomass, biogas, geothermal, hydroelectric, and ocean energy. Renewable energy is often thought of as intermittent and unreliable. While wind and solar are intermittent resources, biomass, geothermal, and most hydroelectric sources can be dispatched as base-load resources. Renewable energy is also typically thought of as more expensive than conventional power sources. However, costs have decreased in the past 20 years and there are numerous options for low cost generation from new renewable energy projects.

Although renewables, excluding hydro, only supply about 2 percent of the United States current electrical energy needs, there has been strong growth in recent years. Of all renewable technologies wind is growing the fastest, with growth rates over 30 percent sustained for the past several years.

Several differing policy approaches have been adopted to support new renewable energy generation. One of the most popular approaches is the Renewable Portfolio Standard (RPS), which mandates that a certain percentage of electricity provided to consumers must come from renewable resources. Another popular method of support for renewable energy development is the Public Benefits Fund (PBF), alternatively known as the Public Benefits Charge, in which a fee is levied on electricity sales. These fees are then used to support renewables. To support renewables, Pennsylvania has initiated a PBF program and is participating in the Million Solar Roofs program. Recent efforts have begun to establish a more aggressive RPS to replace some current ineffective policies.

Pennsylvania's current support of renewable energy is behind other states in the region. The Union of Concerned Scientists recently conducted a study of each state's support of renewable energy development. Pennsylvania received a grade of "D" based upon the limited success current renewable energy policies and the low level of installed renewable energy generation. Clearly, a policy shift in Pennsylvania is needed if more renewable energy development is desired.

Within Pennsylvania, coal and nuclear energy currently supply the vast majority of electricity. The state has extensive coal reserves and currently accounts for about 7 percent of total national coal production. Renewable energy sources accounted for about 1.4 percent of total generation. Biomass leads the installed non-hydro renewable capacity followed by wind, which has nearly 300 MW of new capacity complete or planned for near term installation. Despite the relatively small installed renewable capacity, the Pennsylvania renewable industry is robust, with over 200 companies providing manufacturing, engineering, consulting or operating services.

3. RENEWABLE TECHNOLOGY ASSESSMENT

The objective of this section was to characterize the various renewable energy technologies suitable for application in Pennsylvania. These technologies include the following:

- Wind
- Solar
- Geothermal
- Biomass
- Biogas
- Hydroelectric

Advances in equipment and operating experience spurred by government incentives have lead to many mature renewable technologies. The technical feasibility and cost of energy from nearly every form of renewable energy have improved since the early 1980s. In particular, wind energy generation (with the federal production tax credit) can now deliver power at prices competitive with new natural gas-fired combined cycle plants. Biomass cofiring with coal can also result in low cost renewable energy generation.

Although significant progress has been made, most renewable energy technologies struggle to compete economically with conventional fossil fuel technologies, and in most areas the renewable fraction of total electricity generation remains small. This is true despite a huge resource base that has potential to provide many multiples of current electricity demand. Nevertheless, the field is rapidly expanding from niche markets to making meaningful contributions to the world's electricity supply.

Table A-1 compares the most promising renewable technologies for application in Pennsylvania. The characteristics of each technology are also summarized. Estimates for costs and performance parameters are based on Black & Veatch project experience, vendor inquiries, and a literature review.

Table A-1. Comparison of Renewable Electric Generation Technologies (Excluding Incentives).

Technology	2002 Installed Capacity (MWe)		Capacity Factor (percent)	Capital Cost (US$/kW)	Levelized Cost of Energy (US$/MWh)	Pennsylvania Potential
	US	PA				
Wind (Utility Scale)	5,326	34	26–40	1,000–1,800	40–110	Good
Solar Photovoltaic	212	<1	13–15	7,100–9,000	490–680	Niche Markets
Biomass – Direct	4,425*	33*	70–90	2,000–2,500	44–100**	Moderate
Biomass – Cofiring	2,100*	50*	70–90	100–700	0–65**	Excellent
Biogas (Landfill gas)	1,100	70	70–90	1,300–2,700	40–70	Good
Biogas (Digestion)	<50	<1	70–90	2,300–3,800	80–120	Good
Hydro (New)	79,842	736	40–60	2,500–4,500	90–160	Moderate
Hydro (Incremental)	NA	NA	40–60	6,00–3,000	25–110	Good

Sources: Black & Veatch. Energy Information Agency, *Renewable Energy Annual 2002*. "PV market update", *Renewable Energy World*. EPA Landfill Methane Outreach Program.

Notes:

* Black & Veatch estimate. Actual capacity unknown as cofiring rates can vary significantly.

** Levelized cost for biomass ranging from $0–2/MBtu fuel cost.

Wind

- Fastest growing energy source (30 percent average annual growth in last five years)
- Areas with greatest wind potential often distant from load centers
- Advantages: relatively inexpensive, quick construction, favorable regulatory environment
- Disadvantages: intermittent, visual disruption, potential avian impacts if improperly sited
- Pennsylvania potential: *Good* for properly sited farms or small clusters of turbines

Solar

- Two types: solar photovoltaic (PV) and solar thermal
- Total PV panel shipments in 2003 topped 562 MW; current installed grid connected solar thermal is 350 MW
- For economic reasons, two-thirds of PV applications are off-grid
- Growth rates for PV exceeding 20 percent annually
- Advantages: PV is very low maintenance, modular, easy to install
- Disadvantages: intermittent, expensive
- Pennsylvania potential: *Poor* for solar PV except for niche applications. Solar thermal electricity generation is not practical in the near-term in Pennsylvania, but there are a few opportunities for solar water heating.

Biomass

- Biomass is material of recent biological origin; includes agricultural residues, sewage sludge, wood chips, energy crops, etc.
- Conversion methods: solid fuel combustion in power plants (including cofiring), gasification, pyrolysis, etc.
- Advantages: dispatchable, beneficial use of waste streams, familiar technology, cofiring is inexpensive, can be used for combined heat and power
- Disadvantages: poor (if any) public perception, still releases some pollution
- Pennsylvania potential: *Very good*, especially for cofiring at existing coal plants

Biogas

- Biogas is produced from decay of waste in landfills and anaerobic digestion of sewage, animal manure, or other wastes
- Most technologies designed to burn natural gas can burn biogas
- Advantages: baseload resource, some low cost cases, addresses other environmental issues
- Disadvantages: Limited resource potential
- Pennsylvania potential: *Good*, although best opportunities already taken

Geothermal

- Geothermal plants use heat from the earth to generate steam and drive turbine-generators
- Geothermal fluids usually reinjected; minimal environmental impact
- Advantages: dispatchable, relatively low cost, mature technology
- Disadvantages: wells can be depleted, significant development risk in drilling wells, limited resource
- Pennsylvania potential: *Limited* to ground source heat pumps

Hydro

- Most mature and widespread renewable energy technology
- Some opposition to large projects because of environmental and socioeconomic concerns
- Small, "low-impact" projects (< 50 MW) may be considered renewable
- Other developmental water technologies: wave, tidal, ocean thermal, tidal stream
- Advantages: dispatchable, mature, low cost
- Disadvantages: long development times, environmental concerns for large projects
- Pennsylvania potential: *Moderate* potential for new low-impact hydro schemes; *good* potential for incremental hydro at existing sites

4. RENEWABLE RESOURCES ASSESSMENT

The objective of this section was to assess the renewable energy resources of Pennsylvania. The total technical and near-term potential for each resource were quantified, levelized generation costs were calculated, and a set of supply curves were developed. Results are presented for two general classes of resources:

- Relatively large scale generating technologies built to meet a 10 percent RPS.
- Distributed renewable resources adopted by the market for "behind the meter" applications.

The end result of this section is a projection of the portfolio of technologies that will be built to satisfy the Pennsylvania renewable energy market.

The resource potential for utility-scale power generation and utilization of distributed resources was estimated by the following general methodology:

- **Resource characterization** – publicly available resource data from government agencies and research institutes was obtained and analyzed to determine the amount and quality of resources that could be developed.
- **Technology selection** – technologies that are fully commercial, economically competitive, and applicable to the available renewable energy resources in Pennsylvania were selected including wind, biomass cofiring, internal combustion engines for landfill gas and digester gas, hydroelectric turbines, and solar photovoltaic panels.
- **Definition of assumptions** – conservative technical and economic assumptions were selected for each technology.
- **Technical and near-term potential estimation** – technical and near-term estimates were made of the energy potential for each resource. Technical potential is the practical upper limit for electric generation considering the strength of the resource, land use, and other factors. The near-term potential is the market development potential, or near-term estimate (10-15 years) for feasible development of each resource.
- **Levelized generation cost estimation** – the levelized cost of generating electricity was calculated for each technology.
- **Supply curve generation** – resource supply curves were constructed from the levelized cost estimates for the classifications within each technology. The supply curves were aggregated to form a comprehensive supply curve of renewable energy in Pennsylvania.

Table A-2 shows the results of the estimate of technical and near term potential for each renewable energy technology.

Table A-2. Pennsylvania Renewable Energy Potential.

Capacity	Technical, MW	Near-Term, MW
Biogas	223	89
Biomass Cofiring	4,361	1,023
Biomass Direct*	1,072*	—
Hydro	2,142	561
Solar	114,000	4
Wind	14,777	3,531
Total	**136,575**	**5,208**
Energy	**Technical, GWh**	**Near-Term, GWh**
Biogas	1,563	624
Biomass Cofiring	24,305	5,900
Biomass Direct*	7,512	—
Hydro	9,194	2,408
Solar	137,812	4.8
Wind	43,651	8,696
Total	**224,037**	**17,633**

* It is assumed that available biomass will be used in cofiring applications before direct use.

The analysis shows that Pennsylvania has enough long term renewable energy potential to satisfy its entire electrical power needs. According to the EIA, in 2002, the total electrical consumption in Pennsylvania was 139,960 GWh. This study identified 224,037 GWh of long term renewable energy technical potential, or 160% of the 2002 consumption. Most of this potential energy is from relatively high cost solar. In the near-term, it appears feasible and economically viable to develop over 5,200 MW of renewable energy capacity in Pennsylvania, enough to generate over 17,600 GWh of electricity. This is 12.6 percent of the 2002 energy consumption and is projected to be enough to meet the 2015 10 percent RPS requirement without relying on electricity imports from other states.

The comprehensive supply curve for renewable energy in Pennsylvania is shown in Figure A-1. The vertical line represents the projected electric generation required to meet the RPS by 2015. The colored bars to the left of the "RPS Requirement" line show the cost and quantity of renewable energy generation to meet the RPS. This curve shows which products can be brought to market at the lowest cost (resources on the left side). Incremental hydro (upgrades at existing stations) and biomass cofiring are the lowest cost resources.

In addition to the RPS technologies shown in the chart below, the potential for utilization of distributed resources was estimated by assessing the market for each technology. Plausible assumptions about the rate of adoption by homeowners and commercial enterprises were made to estimate the potential conventional energy savings from adoption of distributed technologies.

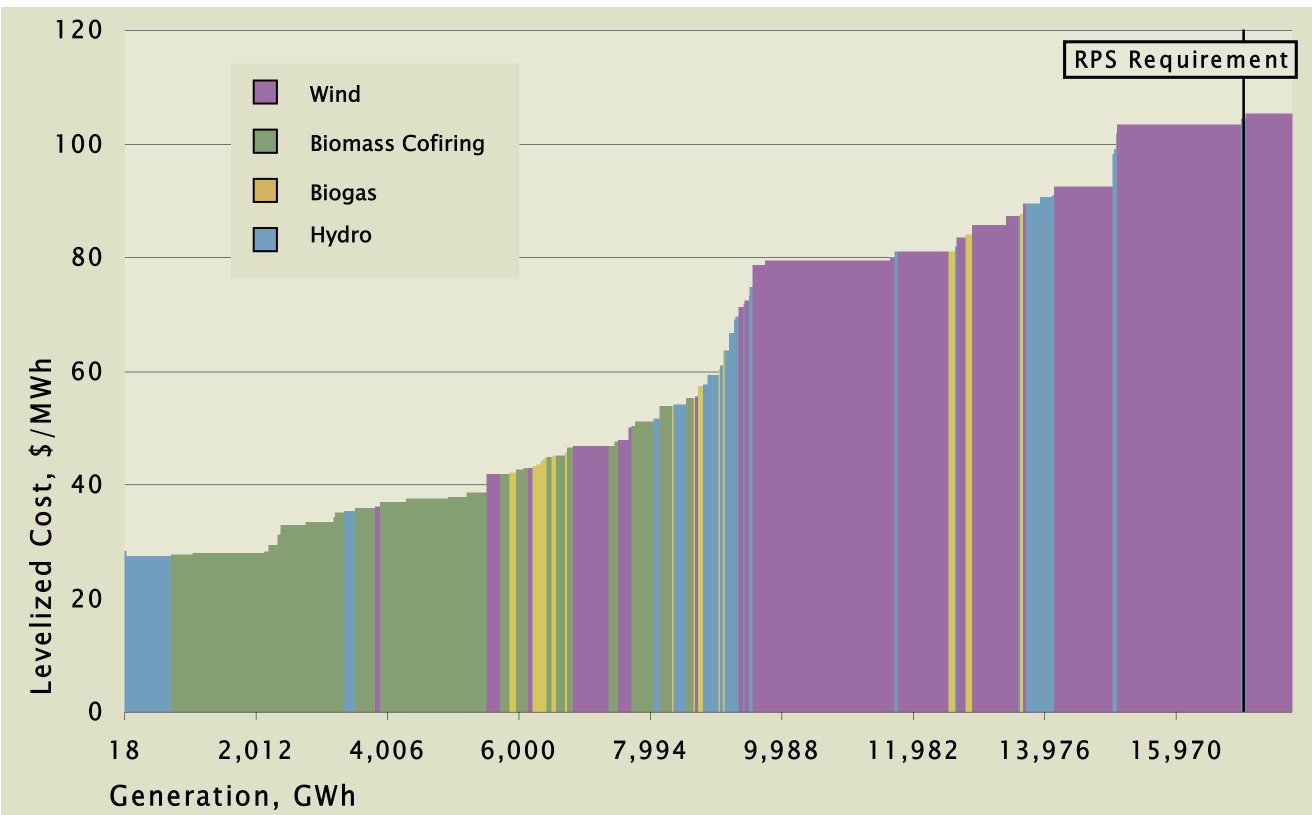

Figure A-1. Near-Term Potential Renewable Energy Generation Supply Curve.

Based on the resource assessment, wind, biomass cofiring, biogas and hydro electric generation technologies appear to be the most likely technologies to be developed under an RPS, with wind and biomass co-firing accounting for around 80 percent of the total required renewable. In addition, despite its high cost, a small level of solar photovoltaic energy is assumed to contribute to the RPS. This generation mix represents an estimate of just one generation scenario capable of meeting the requirements of the RPS.

Table A-3 shows the cost and generation contributed by each technology towards the RPS. This table presents the weighted average technical and economic values for all resources that make up the supply mix.

The analysis of the potential for distributed resources found that considerable conventional energy savings could be realized if these technologies were adopted on a large scale, 30 percent of homeowners in Pennsylvania. Fuel cell and microturbine technology have the potential to generate power from renewable fuels efficiently; however, these technologies are not yet commercial and are not expected to have an impact within the term of the RPS. Small wind turbines have the potential to provide power to rural communities and farms. Solar photovoltaic technology has the potential to supply all of the electricity needs for the state; however, near-term potential is only a fraction of total demand. Large-scale adoption of solar thermal and geothermal heat pump technologies could reduce the residential consumption of fossil fuels for space and water heating by 40 percent.

Table A-3. RPS Renewable Energy Portfolio (Weighted Average Values).

Technology	Wind*		Biomass	Landfill	Digester	Hydro	Solar
	Low	High	Cofiring	Gas	Gas		
Share of RPS Mix (energy), %	23	23	34.6	3.7	1.5	14.2	0.0
Generation, GWh	3,901	3,914	5,900	625	258	2,424	4.84
Capacity, MW	1616	1,529	1,023	89	37	554	4
Capacity Factor,	27.6	29.2	65.8	80.0	80.0	49.9	13.8
Capital Cost, $/kW	1,293	1,823	346	1,590	2,510	1,502	7,245
Variable O&M, $/MWh	7.0	7.4	0.0	15.0	15.0	2.7	0.0
Fixed O&M, $/kW/yr	20.5	20.5	12.1	0.0	0.0	10.3	0.0
Fuel Cost, $/MBtu	–	–	2.05	–	–	–	–
Heat Rate, Btu/kWh	–	–	11,146	–	–	–	–
Levelized Cost Range, $/MWh	33–81	66–103	28–55	42–68	81–88	27–104	488–681
Average Levelized Cost, $/MWh	70	95	36.58	48.20	83.72	57.62	551.42

*Note: In addition to cost differences for transmission distance and wind class, two general cost categories were modeled for wind for this study: "inexpensive" and "expensive". Inexpensive, low cost projects will be the first to be developed, while expensive sites are remote, have difficult construction access, high land cost, etc. This study conservatively assumed that approximately 50 percent of Pennsylvania wind sites are classified as expensive.

5. ECONOMIC IMPACTS ASSESSMENT

The objective of this portion of the analysis was to determine the relative economic impacts of renewable energy development in Pennsylvania compared to the "business as usual" (BAU) development of fossil fuel resources.

The evaluation of the economics of renewable energy development included the estimation of the resulting economic costs and benefits to the state including: (1) cost of electricity; (2) direct and indirect impacts on jobs, income, and economic output; and (3) fossil fuel price impacts, as introduced below:

1. **Cost of electricity –** the direct added electricity costs or savings which result from mandating an RPS and which are paid or realized by electricity consumers.
2. **Jobs, income, gross state output–** the socioeconomic impacts on the local economy arising from providing power through renewable resources instead of conventional generation technologies. These impacts include direct and indirect differences in the jobs, income, and gross state output.
3. **Fossil fuel prices** – the potential for reduced costs of fuel and conservation of scarce fuel resources which could arise if the RPS results in significant reductions in fuel usage.

In addition to these economic benefits, development of renewable resources will have environmental, health, safety and other benefits. Many studies have tried to value these "externalities" and are the subject of much uncertainty and considerable controversy. No effort is made to quantify these benefits in this study.

The economic impact analysis relied directly on the renewable energy technology and resource characteristics developed in the previous sections. Assumptions were also developed to characterize the BAU case. Based on these inputs, various estimates were made of economic impacts.

Cost of Electricity

To estimate the direct impact that an RPS would have on electricity costs, an economic model was used to measure the 20-year (2006-2025) costs of meeting 10 percent of electricity consumption with renewable energy. This cost was compared to the cost of providing the same energy from a mix of coal and natural gas resources (BAU scenario).

Annual cost estimates were calculated and compared for the two portfolio mixes. The RPS portfolio cost of $4.68 billion is nearly $1.23 billion, or 36 percent higher than the $3.44 billion BAU case (20-year cumulative present value basis).

Taken in context, the RPS premium is small. By comparison, one advocacy group estimated consumer savings from the start of deregulation in 1999 to 2001 totaled $4 billion.[2] Further, on a statewide energy consumption basis, $1.23 billion equates to a premium of only 0.036 cents/kWh or a 0.46 percent increase over the average 2001 Pennsylvania electricity price (7.86 cents/kWh). Based on an average household monthly electricity consumption of 800 kWh, the RPS would increase electricity costs per household by about 29 cents per month versus the BAU scenario.

Jobs, Income, and Economic Output

There are significant socioeconomic impacts associated with the investment in a new power plant, including increases in employment, output, and income in the local and regional economy.

[2] J. Hanger, "2003 Mid-Course Review", Citizens for Pennsylvania's Future, available at www.eere.energy.gov/pro/pdfs/john_hanger.pdf.

Increases in these categories occur as labor is directly employed in the construction and operation of a power plant, as local goods and services are purchased and utilized. The "multiplier" effect occurs when those directly realizing added income from the project spend a portion of that income in the local economy. The multiplier impacts for this study were analyzed by using the Bureau of Economic Analysis Regional Input-Output Modeling System (RIMS II model).

The impacts from the construction and operation of the renewable energy and BAU portfolios were summarized to calculate the total impact to Pennsylvania. The impacts are proportional to the percent of project expenditures (e.g., equipment purchases) made in Pennsylvania. For example, there is currently little wind turbine manufacturing capacity in Pennsylvania, so multiplier impacts associated with new wind farms are relatively modest. On the other hand, the presence of American Hydro and other Pennsylvania companies indicates strong industrial capability for hydro, resulting in higher projected multiplier impacts.

The cumulative impacts over the 20 year planning period are estimated by combining the impacts estimated on a unit basis with the total MW of capacity installed. Table A-4 compares the total impacts associated with the RPS and BAU portfolios. Figure A-2 shows the total estimated employment impact for each of the technologies.

Table A-4. Cumulative Impacts For Construction and Operation Periods, RPS Versus BAU Portfolios.

	Output Impact	Earnings Impact	Employment Impact
RPS Portfolio	$15,468,918,425	$4,736,305,108	129,439
BAU Portfolio	$5,391,459,876	$1,897,570,828	44,272
Difference	$10,077,458,549	$2,838,734,279	85,167

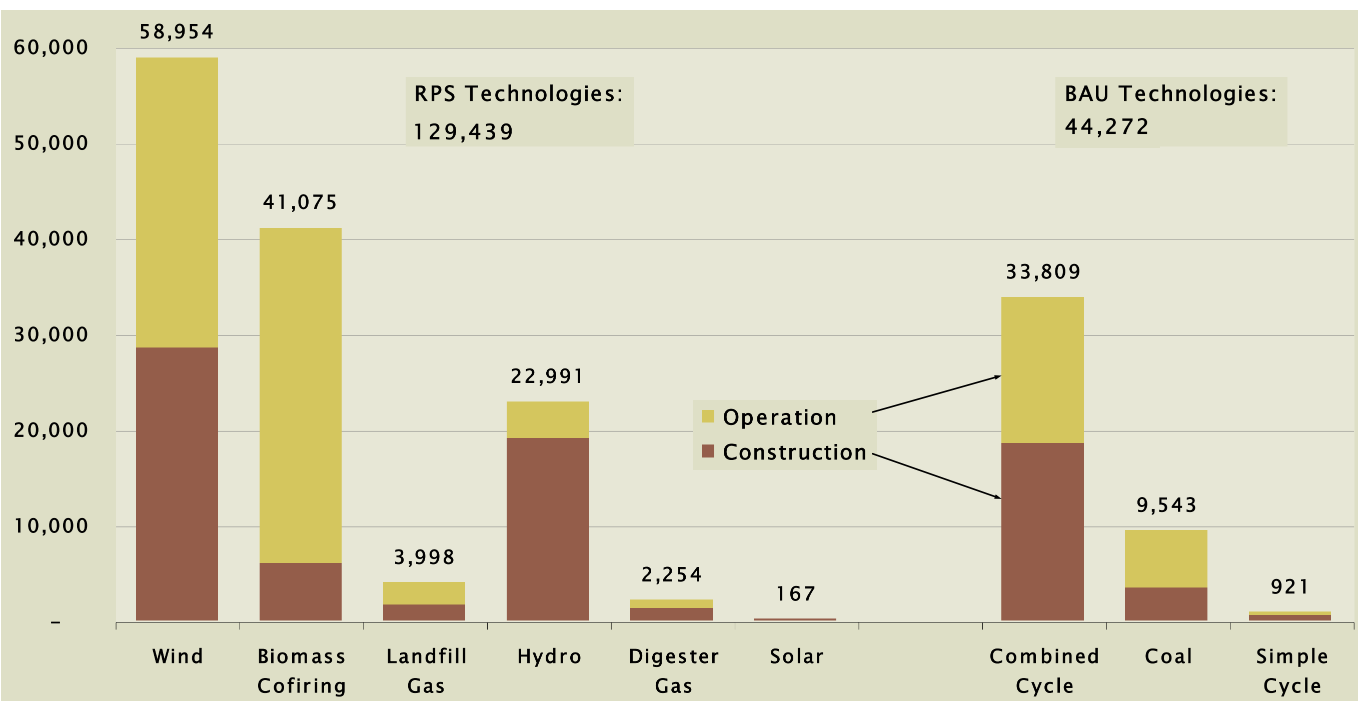

Figure A-2. Cumulative Employment Impacts for Construction and Operation Periods.

The results of the analysis indicated that the RPS portfolio has a significantly larger impact than does the BAU scenario. This includes an approximate $10.1 billion advantage in output, a $2.8 billion advantage in earnings, and approximately 85,000 more job-years over the 20 year planning period. It is also useful to note that the RPS portfolio's added earnings multiplier impacts of approximately $2.8 billion would more than offset the BAU's cumulative present value direct electricity cost advantage of approximately $1.2 billion.

Fossil Fuel Prices

Black & Veatch analyzed the potential impacts to fossil fuel prices and consumption as a result of the RPS in Pennsylvania by consulting four recent national and regional studies. The studies present strong evidence that suggest that natural gas prices will decrease as a result of the adoption of policies encouraging renewable energy development. If the relationship between renewable energy and natural gas prices assumed by these studies holds true, a decrease in natural gas prices of up to perhaps 3 percent could be experienced in Pennsylvania. However, because the share of natural gas fueled power generation in Pennsylvania is relatively small (3 percent), the results of the analyses on these states are difficult to generally apply to Pennsylvania. Further, it is difficult to assert that relatively small changes in consumption by Pennsylvania would have significant impacts on the regional or national gas market.

Table A-5 shows the potential savings by assuming 1, 2, and 3 percent reductions in gas and coal prices. For example, if the RPS policy resulted in a reduction of 3 percent for natural gas and coal 2002 prices, the combined impact would be annual savings in excess of $400 million. By comparison, the expected cost premium in 2015 for the RPS portfolio over the BAU portfolio is only $295 million. Even a 1 percent reduction would result in annual fuel savings of almost $140 million based on 2002 prices, roughly 50 percent of the projected 2015 RPS premium.

Table A-5. Potential Fossil Fuel Price Savings.

	Total Expenditures, $000s	Savings, $000s
2002 Natural Gas	12,191,026	
1% Price Reduction	12,069,116	121,910
2% Price Reduction	11,947,205	243,820
3% Price Reduction	11,825,295	365,730
2002 Coal	1,697,213	
1% Price Reduction	1,680,241	16,972
2% Price Reduction	1,663,269	33,944
3% Price Reduction	1,646,296	50,916

Major Economic Analysis Findings:

- **Electricity Costs** – the 20-year projected RPS portfolio electricity cost of $4.68 billion is nearly $1.23 billion, or 36 percent higher than the $3.44 billion estimate for the BAU scenario.
- **Electricity Costs –** the $1.22 billion higher cost equates to a premium of 0.036 cents/kWh over all electricity sold in the state. This is a 0.46 percent increase over the average 2001 Pennsylvania retail electricity price of 7.86 cents/kWh.
- **Electricity Costs** – Based on an average household monthly electricity consumption of 800 kWh, the RPS would increase electricity costs per household by about 29 cents per month versus the BAU scenario.
- **Economic Impacts:** the RPS portfolio has a significantly better economic impact than does the BAU scenario including an approximate $10.1 billion advantage in output, a $2.8 billion advantage in earnings, and approximately 85,000 more job-years over the 20 year planning period.
- **Fuel Savings –** Although not directly modeled in this study, other studies indicate that establishment of an RPS would result in gas and coal cost savings due to decreased demand. A 1 percent reduction in prices would result in annual fuel savings of almost $140 million based on 2002 prices, roughly 50 percent of the projected 2015 RPS premium.

Economic Impact of Renewable Energy in Pennsylvania

B. CURRENT STATUS OF RENEWABLE ENERGY

5 March 2004

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1. SUMMARY AND INTRODUCTION

The objective of this section is to provide an overview of renewable energy and describe the current status of renewable energy development in Pennsylvania and other states. The section also addresses policy developments including, most importantly, a potential Renewable Portfolio Standard (RPS) in Pennsylvania.

Renewable energy sources are practically inexhaustible in that most ultimately derive their energy from the sun. Technologies to harness renewable energy are diverse and include wind, solar, biomass, biogas, geothermal, hydroelectric, and ocean energy. Renewable energy technologies are generally thought of as being intermittent resources, or not dispatchable to the same degree as conventional technologies. While wind and solar are intermittent resources, biomass, geothermal, and most hydroelectric sources can be dispatched as base-load resources. Renewable energy is also typically thought of as more expensive than conventional power sources. However, costs have decreased in the past 20 years and there are numerous options for low cost generation from new renewable energy projects.

Although renewables, excluding hydro, only supply about 2 percent of the United States' current electrical energy needs, there has been growth in recent years. Of all renewable technologies wind is growing the fastest, with growth rates over 30 percent sustained for the past several years.

Several differing policy approaches have been adopted to support new renewable energy generation. One of the most popular approaches is the Renewable Portfolio Standard (RPS), which mandates that a certain percentage of electricity provided to consumers must come from renewable resources. Another popular method of support for renewable energy development is the Public Benefits Fund (PBF), alternatively known as the Public Benefits Charge, in which a fee is levied on every kWh of power sold. These fees are then used to support renewables.

The Union of Concerned Scientists recently conducted a study of each state's support of renewable energy development. Pennsylvania received a grade of "D" based upon the limited success of the RPS currently in place, and the low level of installed renewable energy generation. Clearly, a policy shift in Pennsylvania is needed if more renewable energy development is desired. States that have had notable success implementing RPS policies include Arizona, California, Nevada, Illinois and Texas.

Table B-1 shows the installed electric generating capacity in Pennsylvania by fuel type. Pennsylvania has traditionally relied on coal for power generation. The state has extensive coal reserves and currently accounts for about 7 percent of total national coal production.

Table B-1. Installed PA Generation Capacity

Source	Capacity, MW	Percent
Coal	18,580	51%
Petroleum	3,290	9%
Gas	2,502	7%
Petroleum / Gas Combined	750	2%
Nuclear	9,146	25%
Hydroelectric	2,055	6%
Other	303	1%
Total	**36,626**	**100%**

Source: Energy Information Administration

Renewable energy sources accounted for about 1.4 percent of total generation. Biomass leads the installed renewable capacity followed by wind, which has nearly 300 MW of new capacity nearly complete or planned for near term installation. The Pennsylvania renewable industry is robust, with over 200 companies providing manufacturing, engineering, consulting or operating services.

To support renewables, Pennsylvania has initiated a PBF program and is participating in the Million Solar Roofs program. Recent efforts have begun to establish an RPS. This study will analyze the economic impacts of a Pennsylvania RPS.

2. INTRODUCTION TO RENEWABLE ENERGY

Renewable energy generation technologies are based on energy sources that are practically inexhaustible in that most are solar derivatives; Renewable energy options include wind, solar, biomass, biogas, geothermal, hydroelectric, and ocean energy. Table B-2 shows the power conversion technologies that have been developed to harness each of these energy sources.

Table B-2. Renewable Energy Technologies.

Renewable Energy Source	Generation Technology
Solar	Photovoltaic Thermal Energy Capture
Wind	Wind Turbines
Water	Hydroelectric Turbines
Ocean	Wave Energy Devices Tidal/Current Energy Turbines Thermal Energy Conversion
Geothermal	Steam Turbines Direct Use Geothermal Heat Pumps
Biomass	Combustion (direct fired, co-firing with coal) Gasification / Pyrolysis
Biogas	Engine generators Combustion turbines Microturbines Fuel cells

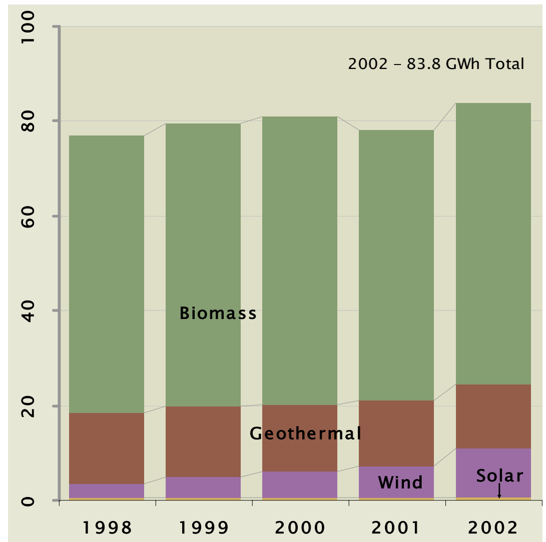

Figure B-1. US Net Renewable Electricity Generation, GWh. (EIA 2002)

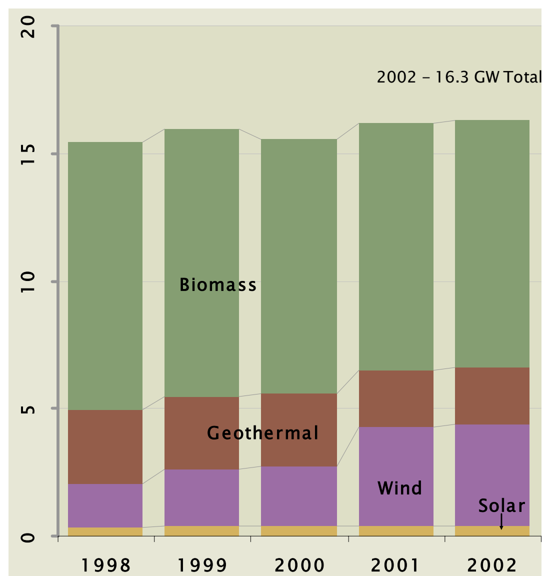

Figure B-2. US Net Renewable Electrical Capacity, GW. (EIA 2002)

Excluding hydro, renewables only supply about 2 percent of the United States' current electrical energy needs. However, the field is rapidly expanding. The following figures demonstrate the current trends for renewable energy in the United States. Perhaps more telling, more wind capacity has been installed in Europe in the last two years than any other energy generation technology. Further, worldwide wind energy additions have outpaced nuclear power additions for the past four years.

Figure B-3 shows the non-hydro installed capacity of renewable energy generation in each state. After hydro, biomass is currently the largest source of renewable electricity in the US. At the start of 2003 there was nearly 10,000 MW of biomass and waste power capacity installed compared to almost 80,000

MW of hydro. However, with growth rates of up to 30 percent annually, wind is quickly catching up. At the start of 2003 there was about 4,000 MW of wind installed; it is expected that this number will exceed 6,000 MW soon. The other renewable resources have smaller shares.

Renewable energy technologies are often favored by the public over conventional fossil fuel technologies because of the perception that renewable technologies are more environmentally benign. The international community has embraced this opinion in recent years as there has been growing concern over the potential effects of greenhouse gas emissions and global warming. With the adoption of the Kyoto Protocol in most of the industrialized world, nations have sought alternative ways to generate electricity in more environmentally benign ways, while decreasing or stabilizing carbon emissions.

Although the US federal government has not committed to the Kyoto Protocol, state and local governments have seen the value of generating power from clean and sustainable sources of energy, and have begun to support and advocate renewable energy generation development.

Renewable energy technologies are generally thought of as being intermittent resources. However, biomass, geothermal, and most hydroelectric sources can be dispatched as base-load resources. Wind and solar are intermittent resources. Both are somewhat predictable, and solar is generally coincident with demand patterns. In general, it does not make economic sense to provide specific backup generation or energy storage for renewables unless they are serving an isolated or remote load.

Renewable energy is typically thought of as more expensive than conventional power sources. Renewables have traditionally been relegated to niche markets, such as the use of biomass in the pulp and paper industry and off-grid solar electrification. However, costs have decreased in the past 20 years and there are numerous options for low cost generation from new renewable energy projects. Low cost sources include landfill and digester gas, addition of hydro turbines in existing conduits or canals, co-firing biomass or waste fuels in coal fired power plants, and new wind projects.

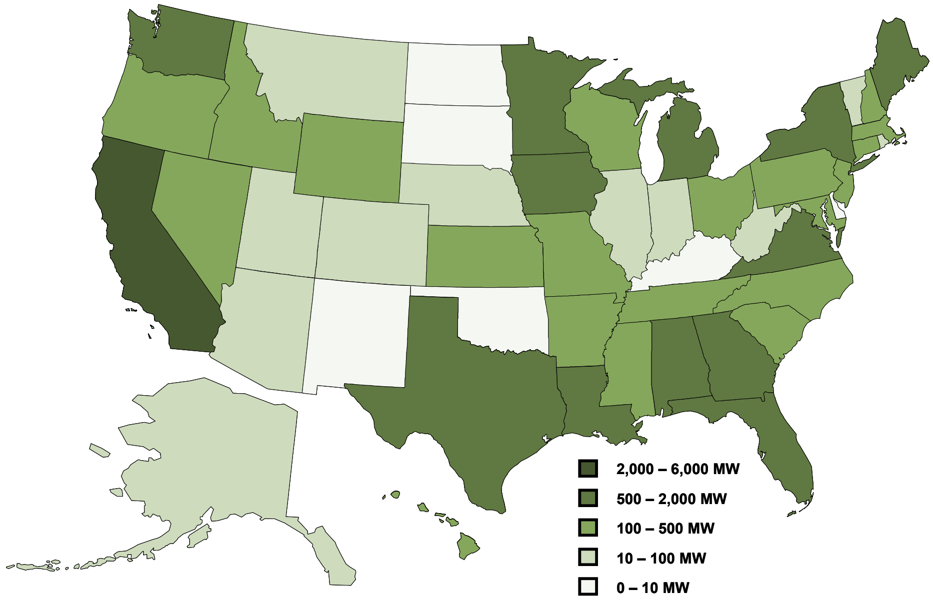

Figure B-3. Total Installed Non-Hydro Renewable Energy Capacity by State. (EIA 2002)

3. OVERVIEW OF STATE DEVELOPMENT

A number of factors have influenced state governments to adopt policies to support the development of renewable energy resources. The general public and legislators have increasingly become aware of the environmental, health, and security impacts of burning fossil fuels, particularly since September 11.

Several differing policy approaches have been adopted to support new renewable energy generation. One of the most popular approaches is the Renewable Portfolio Standard (RPS), which mandates that a certain percentage of electricity provided to consumers comes from renewable resources. Figure B-4 shows the states that have implemented an RPS, and the renewable generation goal for each state as a percentage of total energy supplied to consumers. Another popular method of support for renewable energy development is the Public Benefits Fund (PBF), alternatively known as the Public Benefits Charge, in which a fee is levied on every kWh of power sold. The funds are collected and distributed to support utility scale projects, residential renewable energy and energy efficiency projects, and low-income assistance. A total of 14 states have implemented SBF policies, collectively identifying billions of dollars in potential funding assistance. (Database of State Incentives for Renewable Energy, 2003)

The Union of Concerned Scientists recently conducted a study of each state's support of renewable energy development. Each state was evaluated based on the projected results of RPS programs, renewable energy funds, and the current level of renewable energy generation. Figure B-5 shows the grades assessed to each state by this study. California and Nevada were the only states receiving a grade of "A-", with their RPS programs mandating a growth of renewable energy generation by over 1 percent per year. Pennsylvania received a grade of "D" in this study based upon the limited success of the RPS currently in place, and the low level of installed renewable energy generation. Clearly a policy shift in Pennsylvania is needed if more renewable energy development is desired.

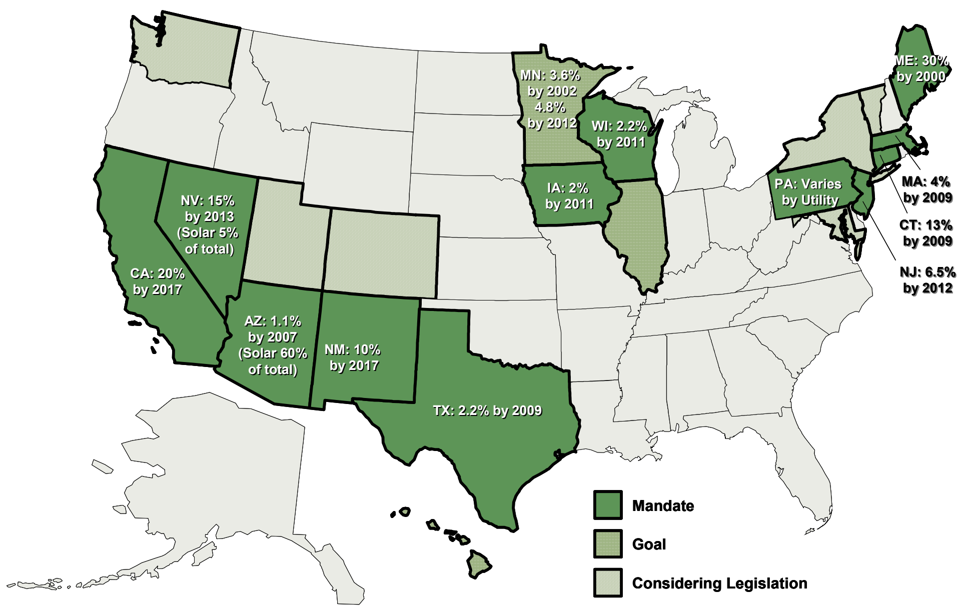

Figure B-4. State Renewable Energy Portfolio Standard Legislation.

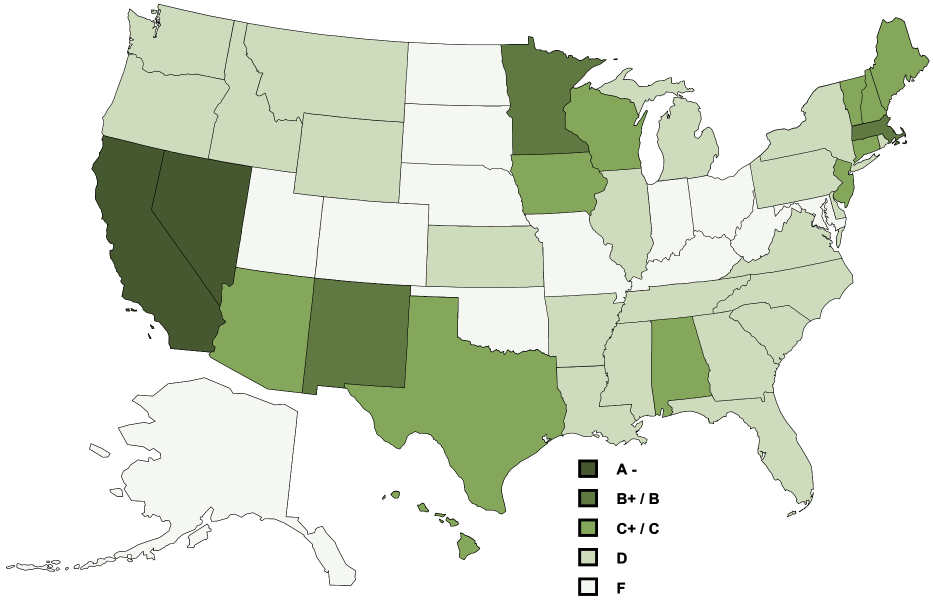

Figure B-5. Union of Concerned Scientists (2003) Renewable Energy Policy Grades.

4. STATE CASE STUDIES

This section presents case studies of states that have implemented successful renewable energy policies. These states have been selected because of either the novel approach of the RPS, relative success of the RPS, or the availability of existing analysis performed on the state's RPS program. Information regarding other states that have implemented RPS programs is presented in Appendix A.

Arizona

Arizona enacted an Environmental Portfolio Standard (EPS) in March of 2001.

- The EPS requires that investor owned utilities provide 1.1 percent of power from renewables by 2007.
- The standard begins with a requirement of 0.2 percent in 2002, increasing by 0.2 percent annually.
- Solar electric must make up 50 percent of the standard in 2001, increasing to 60 percent for 2004 through 2012.
- Applicable technologies include solar electric, solar water heating, solar air conditioning, landfill gas, wind, and biomass.
- Credit trading is allowed under the RPS, but the program is in very early stages.
- A Cost Evaluation Working Group (CEWG) was formed to evaluate the program performance and cost of compliance.
- If, in 2004, the cost of solar electricity has not declined to a Commission approved cost/benefit point, the EPS will not increase for the remaining years of the EPS.

Since the inception of the RPS, nearly 6 MW of new solar photovoltaic, 5 MW of landfill gas generation, and 200 kW of peak demand displacement from solar thermal have been installed.

The CEWG released an evaluation of the program in June 2003. The review concluded that the added cost of the program was $0.114/kWh. The Renewable Energy Policy Project (REPP) performed an independent evaluation with modified assumptions and reached an added cost of $0.002/kWh. Although a net added cost was reached in the analysis, the Arizona Corporation Commission has not set a benchmark for the cost/benefit analysis, so the future of the RPS remains in doubt. Further, the majority of new renewable energy additions were solar photovoltaic, one of the most expensive renewable energy sources.

Figure B-6. 3.8 MW Springerville Solar Plant (source: First Solar).

Table B-3 details the current number and capacity of renewable energy projects in Arizona.

Table B-3. Arizona Renewable Capacity.

Technology	Number of Units	Capacity, MW
Biomass	3	9.3
Geothermal	–	–
Hydro	45	3,000
Photovoltaic	307	5.8
Solar Thermal	3	0.075
Wind	–	–
Total	**358**	**3,008**

Source: NREL REPIS Database

California

California virtually started the renewable energy industry in the early 1980's. A combination of fuel supply and price concerns following the oil embargo and a favorable regulatory environment spurred rapid growth in wind, solar, biomass, and geothermal power generation. The industry has been continually supported by a number of policies, including a new state RPS and other state-run renewable energy support mechanisms.

California passed the highest penetration state RPS in September 2002. It stipulates:

- The RPS is applicable to investor owned utilities only. They are mandated to purchase 20 percent of electricity from renewable sources by 2017.
- Increase use of renewable energy by 1 percent annually.
- Renewable energy projects above a market price threshold will receive supplemental energy payments from a limited pool of subsidies
- Applicable technologies include wind, solar thermal, photovoltaic, biomass, digester gas, landfill gas, municipal solid waste, and hydro below 30 MW.

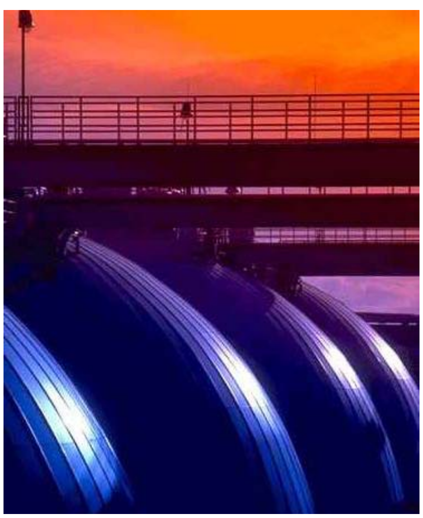

Figure B-7. Anaerobic Digesters at Los Angeles Hyperion Wastewater Treatment Plant.

In addition to the state RPS, a number of programs have been enacted to support existing and new utility scale and residential renewable energy technologies. These include aggressive buy-down on solar photovoltaic equipment and a generous net metering program. As a result of these incentives, solar photovoltaic installations grew by 60 percent in California last year.

The first major installation of wind turbines for grid-connected power generation occurred in California. In fact, California was once home to 90 percent of the world's wind power in the mid 1980's. The wind industry currently provides about 10,000 direct and indirect jobs state-wide, with a current installed capacity of over 1,900 MW (5.26 jobs/MW)[1].

Table B-4 details the current number and installed capacity of renewable energy projects in California.

Table B-4. California Renewable Capacity.

Technology	Number of Units	Capacity ,MW
Biomass	185	1,022
Geothermal	63	2,463
Hydro	624	13,265
Photovoltaic	836	41
Solar Thermal	9	354
Wind	148	1,922
Total	1,865	19,066

Source: NREL REPIS Database, Nov, 2003

Illinois

With the passage of electric utility restructuring legislation in December of 1997, Illinois began to pursue a number of renewable energy support programs. Illinois implemented a non-binding Renewable Portfolio Goal in June 2001.

- The law sets a goal of 5 percent of the state's energy production from renewable sources by 2010, and 15 percent by 2020.
- The law authorizes the state to issue $600 million in bonds to support development of wind, solar, and biomass technologies.

The state government is currently considering implementation of an RPS to solidify and mandate the Renewable Portfolio Goal.

[1] www.repp.org

In addition to the Renewable Portfolio Goal, the Illinois Clean Energy Community Foundation was formed to support the development of consumer demand, develop utility-scale renewable energy projects, and provide funding for demonstration projects. The Chicago Solar Partnership was formed in an effort to expand the use of photovoltaics in Chicago, and provide consumer education on the benefits of the technology. To date over 500 kW of photovoltaic generation has been installed on schools and museums.

Table B-5 details the current number and installed capacity of renewable energy projects in Illinois.

Table B-5. Illinois Renewable Capacity.

Technology	Number of Units	Capacity, MW
Biomass	36	66.4
Geothermal	–	–
Hydro	24	32.9
Photovoltaic	35	0.60
Solar Thermal	–	–
Wind	–	–
Total	**95**	**99.9**

Source: NREL REPIS Database, Nov, 2003

Nevada

Nevada enacted an RPS with the electric utility restructuring legislation in 1997, and later revised it in 2001. The RPS stipulates the following:

- Utilities must provide 5 percent of electricity sold from renewable sources by 2005.
- The requirement increases by 2 percent every year to a requirement of 15 percent by 2013.
- By 2013, 5 percent of electricity sold must be provided by solar technology.
- Applicable technologies include solar, wind, biomass, and geothermal generation.
- In November 2002, the public utilities commission passed a temporary regulation that allowed utilities to meet the requirement by trading renewable energy credits. This system has not been implemented.

Figure B-8. Caithness Geothermal Power Plant in Dixie Valley, Nevada (source: BLM).

Table B-6 details the current number and installed capacity of renewable energy projects in Nevada.

Table B-6. Nevada Renewable Capacity.

Technology	Number of Units	Capacity, MW
Biomass	–	–
Geothermal	50	238
Hydro	19	1,046
Photovoltaic	8	0.11
Solar Thermal	–	–
Wind	–	–
Total	**77**	**1,284**

Source: NREL REPIS Database, Nov, 2003

A number of renewable energy projects are in development to support the RPS requirements for Nevada Power and Sierra Pacific. Table B-7 lists several projects that are in various stages of development and construction.

Table B-7. Announced Nevada Projects.

Developer	Technology	Capacity, MW
Solargenix Energy	Solar	50
Cielo Desert Queen	Wind	80
BHP Billiton Mine	Wind	50
Earth Power Resources	Geothermal	25
ORNI 9	Geothermal	20.2
ORNI 3	Geothermal	20.2
Steamboat IV	Geothermal	42
Total		**287.4**

Table B-8. Texas Renewable Capacity.

Technology	Number of Units	Capacity, MW
Biomass	20	219
Geothermal	–	–
Hydro	51	629
Photovoltaic	78	0.97
Solar Thermal	–	–
Wind	17	1,105
Total	**166**	**1,955**

Source: NREL REPIS Database, Nov, 2003

Texas

In December, 1999 the Public Utility Commission of Texas issued the Renewable Energy Mandate Rule, which stipulates the following:

- The rule calls for the installation of 400 MW, 850 MW, 1,400 MW, and 2,000 MW of renewable energy by 2002, 2004, 2006, and 2008, respectively.
- A Capacity Conversion Factor will be used to calculate the MWh produced by renewable technologies for allocation of responsibility of generation installation between the utilities based on their respective share of retail sales.
- The Rule set up a renewable energy credit trading market effective until 2019.
- Applicable renewable energy sources installed after September 1999, and include solar, wind, biomass, and landfill gas.

Texas has received national attention for its innovative approach in supporting renewable energy. Since the inception of the RPS to the end of 2002, 9 new wind projects with a total capacity of 913 MW came online. Further, the use of a credit trading program to track compliance with the standard is now seen as a best-practice for RPS policies.

Table B-8 details the current number and installed capacity of renewable energy projects in Texas.

Figure B-9. Wind Farm near McCamey, Texas (source: http://www.mccameycity.com).

5. REVIEW OF RENEWABLE ENERGY DEVELOPMENT IN PENNSYLVANIA

Renewable energy currently is a small niche in the Pennsylvania energy market. Efforts to increase market penetration include various policy applications, including implementation of a Renewable Portfolio Standard.

There are examples of successes, failures and opportunities for renewable energy in Pennsylvania. Sample projects and industries are profiled in this section.

5.1 CURRENT POWER SUPPLY MIX

Pennsylvania has traditionally relied on coal for power generation. The state has extensive coal reserves of approximately 28.2 billion short tons with estimated recoverable reserves of 12.4 billion short tons, and currently accounts for about 7 percent of total national coal production.

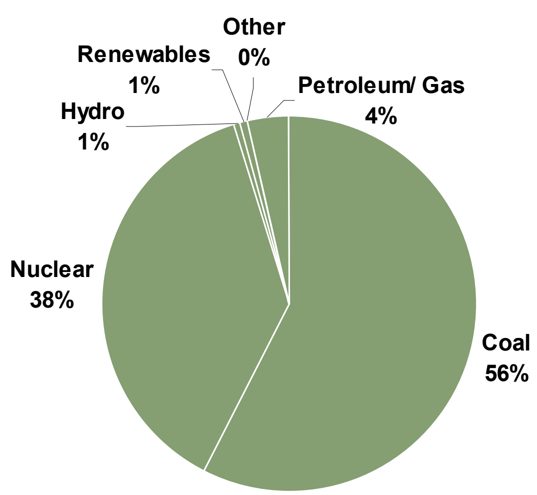

Figure B-10. 2002 Generation by Fuel in Pennsylvania

Table B-9 shows the installed electric generating capacity in Pennsylvania by fuel type.

Table B-9. Pennsylvania Electricity Mix

Source	Capacity MW	Capacity %	Generation GWh	Generation %
Coal	18,578	51%	111,900	57%
Petroleum / Gas	7,430	20%	7,211	4%
Nuclear	9,130	25%	73,730	37%
Hydroelectric*	811	2%	1,034	1%
Renewables	458	1%	2,661	1%
Other	0	0%	37	<1%
Total	36,407	100%	196,573	100%

Source: Energy Information Administration
* Excludes pumped storage.

Figure B-10 shows the electric generation by source for 2002. Coal and nuclear generation accounted for over 90 percent of the total of 196 million MWh generated. Renewable energy sources including biomass (such as wood waste), landfill gas, and wind energy accounted for about 1.4 percent of total generation (1.9 percent including hydro).

5.2 INSTALLED RENEWABLE ENERGY

Pennsylvania has a broad variety of renewable energy technologies in operation. Table B-10 shows the installed capacity of renewable energy.

Hydroelectric has the highest installed capacity of all renewables, but it is unlikely that any significant new capacity, aside from incremental hydro, will be installed. After hydroelectric, biomass is the largest source of renewable energy in Pennsylvania. As reported by EIA, **biomass** consists of agricultural residues, biogas, landfill gas, municipal solid waste (MSW) and timber residues. MSW dominates the installed capacity of biomass, but is not included here in the reported figures. Landfill gas and timber residues, in turn, dominate the remaining portion.

Table B-10. Installed Renewable Capacity.

Technology	Operating Capacity (MW)
Biomass	423
Geothermal	0
Hydro	736
Photovoltaic	0
Solar Thermal	0
Wind	34
Total	1,193

Source: Energy Information Administration

Wind projects are capturing much of the public attention with a few projects added in the past three years and several projects under construction or in active development. A list of planned and operating wind projects is shown in Table B-11.

Table B-11. Installed and Planned Wind

Project	Capacity (MW)	County
Installed		
PA Humboldt	0.13	Luzerne
Mill Run	15	Fayette
Green Mountain	10.4	Somerset
Somerset	9	Somerset
Total	34.5	
Under Construction / Planned		
Waymart	61.5	Wayne
Meyersdale	30	Somerset
Keystone	30	Somerset
Bear Creek	46.5	Luzerne
Forward	36	Somerset
Mountain High	26	Luzerne
Stony Creek	54	Somerset
Brothers Valley	15	Somerset
Total	299	

Source: www.pennfuture.org

There a few **solar PV** installations in Pennsylvania, but the cumulative capacity of those is quite small.

5.3 CURRENT POLICIES

The electric industry restructuring law was passed in December, 1996 and went into effect in January 1999. The law allows residential, commercial, and industrial customers to choose electric providers. The law also instituted electric price caps for residential and commercial customers, and provided for an 8 percent rate reduction for these customers.

Pennsylvania has adopted a number of programs supporting the development of renewable energy technologies since 1996.

Renewable Portfolio Standard

Pennsylvania does not currently have an effective Renewable Portfolio Standard. Renewable energy portfolio requirements were not established with the electric industry restructuring law, but rather with separate restructuring settlements with the electric utilities. A percentage of each utility's customers were to be assigned to a provider of last resort other than the utility. Only these suppliers were required to adhere to the renewable portfolio standard. Table B-12 shows the requirements negotiated with each utility.

Table B-12. Renewable Portfolio Standards

Company	Customers	Base Percent	Escalation
FirstEnergy	20 %	0.2 %	
PECO	20 %	2.0 %	0.5 %
PP&L	20 %	2.0 %	0.5 %
West Penn	20 %	2.0 %	0.5 %

Source: http://www.ucsusa.org/documents/State_Renewable_Energy_Standards.pdf

The bid process for PECO was the only one successful, with New Power and Green Mountain Power acquiring 299,000 and 50,000 customers, respectively. However, New Power has since gone out of business and Green Mountain Power's customer base has dropped to 32,000. Thus, the current RPS has had little impact on renewable energy development in the state.

Public Benefits Fund

Public Benefits Funds were not established with the electric restructuring law, but rather through settlements with the four major electric utilities. The public benefits funds were charged with the goal of promoting:

- The development and use of renewable energy and advanced clean energy technologies
- Energy conservation and efficiency
- Sustainable energy businesses

Table B-13 details the agreements reached with each of the utilities. The table shows the size of the fund after the initial period and the Public Benefits Charge (PBC) that will be collected in the future.

Table B-13. Public Benefits Funds

Company	PBF ($M)	Initial PBF Period	PBC (¢/kWh)	PBC Start Date
FirstEnergy	17.1	'99-'04	0.01	2007
PECO	32	'99-'06	0.02	2007
PP&L	20.5	'99-'04	0.01	2005
West Penn	11.4	'99-'05	0.01	2005

Source: http://www.ucsusa.org/documents/State_Renewable_Energy_Standards.pdf

Thus far, the funds have been used to support a wide variety of projects including photovoltaic installations, solar water heating, and wind energy development.

Million Solar Roofs Initiative

Pennsylvania is participating in the Million Solar Roofs Initiative announced in June 1997 with the goal of installing solar photovoltaic or water heating systems on one million US buildings. The program is led by the Pennsylvania Weatherization Task Force and is administering partnership financing and incentive programs. The initiative has a goal of installing 1,000 systems by 2010; 78 systems have been installed to date.

5.4 PA RENEWABLE ENERGY INDUSTRY PROFILES

The Pennsylvania renewable energy market is a diverse mixture of installed projects, manufacturers , consultants, engineers, and constructors. There are currently over 200 companies engaged in renewables in the Commonwealth. Projects and technologies encompass all major renewable resources including wind, biomass, biogas, hydro, solar, geothermal and ocean. In spite of a limited resource in the state, there is a strong showing of solar manufacturers and engineers. As could be expected, there are also large numbers of biomass and wind companies. A list of the active renewable energy companies is shown in Appendix B.

To illustrate the variety of renewable projects and companies operating in Pennsylvania, the following six case studies are presented.

Wind Developments, Atlantic REC[2]

Atlantic Renewable Energy Corporation (AREC), a Virginia-based company, is one of the most active wind developers in Pennsylvania. Their projects include those at Mill Run, Somerset and Meyersdale and total 54 MW. All three of these projects have since been purchased by FPL Energy.

The local economic benefits of the AREC projects have been fourfold: ongoing maintenance expenditures, construction costs, land owner royalty payments and local property taxes. AREC estimates that the 30 MW Meyersdale wind project will employ three or four full time staff for operation and maintenance (O&M). This staff is hired out of the local area and provides service for both the project owner and equipment vendor. Spare parts are typically not local products, so the O&M benefits are primarily restricted to labor.

AREC estimates that a utility scale windfarm generally costs $1,000,000 per turbine to erect. Construction efforts for the Meyersdale project will temporarily employ 20 craftpersons over its duration. Likewise, the combined construction force for the 9 MW Somerset and 15 MW Mill Run projects was roughly 50 craftpersons. The workforce is largely local with the possible exception of the turbine erection team. As with the O&M costs, a large part of the equipment and materials are imported from outside the state, so a small percentage of the total project cost is spent within the state.

Figure 5-11. Mill Run Under Construction. (source: www.newwindenergy.com)

The owners of the land upon which the wind project is sited are compensated for the use of their land. Each turbine requires approximately one acre of land during construction, although the actual turbine footprint is much smaller. The surrounding land remains productive for other uses. AREC typically pays landowners on a royalty basis dependent on the revenue from the turbine(s) sited on their property. Royalties vary by landowner, but typical amounts are between $3,000 to $5,000 per year.

The local municipality receives property taxes from the wind projects. AREC has provided some payments in excess of the property tax requirements. The Meyersdale project is paying an amount equal to the royalties from two turbines. Fayette County is paid roughly $20,000 per year from the 15 MW Mill Run project. Somerset County is paid roughly $12,000 per year by the 9 MW Somerset project.

AREC noted benefits to developing projects in the PJM control area include a guaranteed marketplace for generation without penalties for generation or transmission intermittency. Additionally, the New Jersey RPS is showing some benefits to Pennsylvania wind projects, as utilities with New Jersey RPS commitments have begun to show interest in Pennsylvania wind energy.

Landfill Gas, Lebanon County Landfill[3]

The Lebanon County Landfill gas project became operational in 1985. It was installed as a 1.2 MW project burning methane generated by the decomposition of the landfill waste. The project was led by Lebanon Methane Recovery, Inc. (LMRI), the power producer. The project initially signed a power purchase agreement with Metropolitan Edison that included an on-peak sales rate of $92.50/MWh and an off-peak rate of $32.50/MWh. This resulted in an average rate of $65/MWh. In exchange for the landfill gas, LMRI pays a royalty of 12 percent of revenues to the landfill operator, the Greater Lebanon Refuse Authority.

The project has generated economic benefits through local employment, discounted trash service, and local taxes. The largest economic impact is

[2] Based on conversation with Sam Enfield, Atlantic Renewable Energy Corporation, on December 1, 2003.

[3] Based on conversations with Mike Pavelek, Greater Lebanon Refuse Authority, on November 25, 2003, and

created by maintenance work required to operate the plant. A staff of two full time employees has been supplemented by two primary subcontracts to provide maintenance. The average annual cost of maintenance has been $65,000. In addition to this, $20,000 is spent every three years to replace engine bearings and $100,000 is spent every ten years to rebuild the engines. Through the royalties collected, the landfill authority was able to reduce costs to its customers by approximately $50,000 per year during the duration of the power purchase agreement. A small local real estate tax of $2,000 per year is paid by LMRI.

The original power purchase agreement expired in 2001. In the deregulated Pennsylvania market, the Lebanon landfill gas project has only been able to obtain the PJM average price for power, which is roughly $25/MWh. With operating costs near $40/MWh, the project is struggling to remain in operation. Maintenance efforts have been reduced to cut costs, but this is a short term solution. Already, one of the two engine generators has been removed from service as a result of insufficient maintenance.

Biomass Utilization, Weyerhauser Co.[4]

Weyerhauser Company operates production facilities for building products, pulp, paper and packaging materials throughout the world. Their facility in Johnsonburg produces paper pulp. A byproduct of this process is black liquor, a mixture of processing chemicals and woody residue called lignin. After recovering the chemicals from the liquor, Weyerhauser burns the residue in a boiler to produce power and steam for their operations. Because the source of the black liquor is wood, it is considered a renewable energy source.

Paper pulping is an energy intensive process. The total steam production capacity for the facility is 680,000 lbs/hr. Of this, roughly 50 percent is produced by burning black liquor, while the remainder comes from bituminous coal. The two primary benefits to the company for burning black liquor are decreased fuel costs and avoided liquor disposal issues. The first benefit is clear; burning the waste liquor avoids the cost of purchasing additional coal. At around 72 ¢/MBtu, this amounts to a significant savings for the company. The second benefit is also clear, the color and strength of black liquor are very difficult to adequately treat for discharge with the rest of the plant waste. Having a disposal alternative such as combustion is positive for Weyerhauser.

The Johnsonburg plant is a well-established facility that incorporates renewable energy into its daily operations. This is frequently one of the most cost-effective implementations of biomass. Weyerhauser complements their renewable generation with responsible waste disposal practices. They obtained a Beneficial Use Permit issued by the Department of Environmental Protection for disposal of fly ash in mine reclamation sites. This is an example of finding innovative means of accomplishing necessary industry processes in sustainable ways.

Ocean Energy Technology Development, Sea Solar Power[5]

Through considerable funding by the Abell Foundation, Sea Solar Power (SSP) is pioneering development of an ocean thermal energy conversion (OTEC) technology. SSP is based in York, Pennsylvania. The inventor of the technology was formerly the Chief Engineer at York International, a major manufacturer of commercial and industrial refrigeration equipment. York is assisting with the fabrication of the first full scale demonstration plant.

with Trond Grenanger, Lebanon Methane Authority, Inc., on December 1, 2003.

[4] Based on conversation with Tom Detwiler, Weyerhauser Company, on December 2, 2003.

[5] As accessed from http://www.seasolarpower.com on December 1, 2003 and based on conversation with Robert Nicholson, Sea Solar Power on November 24, 2003.

OTEC utilizes the water temperature difference between the warm surface water and cold depths to evaporate a fluid that spins a turbine generator. In addition, the process can be used to produce potable water from ocean water, thus providing two long term revenue streams. If OTEC can be proven commercial, it has virtually limitless potential for power generation. The stored solar energy in the ocean around the earth's equatorial region contains over 300 times the world's current electrical consumption.

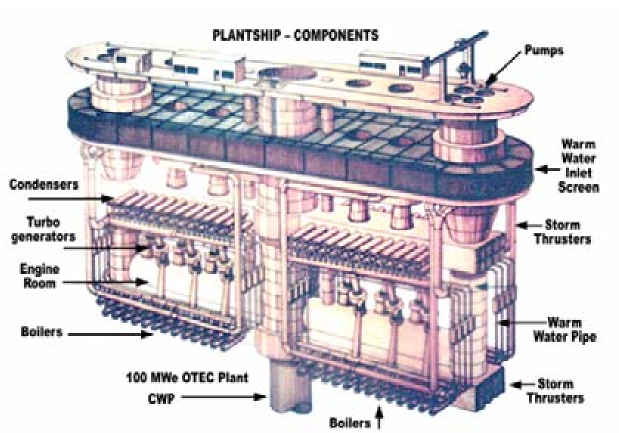

Figure 5-12. OTEC Schematic Diagram.
(Source: www.seasolarpower.com)

Except for Hawaii, ocean temperatures around the US are not suitable for OTEC. However, SSP has developed a floating OTEC plant based on conventional shipbuilding methods. The plants could be manufactured in ports around the world and floated to their destinations. SSP has estimated that construction of six 100 MW plants would create 25,000 jobs. This employment potential has attracted the interest of the Baltimore-based Abell Foundation, which is funding development of a $50 million, 10 MW demonstration project currently under construction in York. After the demonstration has been proven successful, SSP intends to move its operations to Baltimore. The company is not interested in remaining in Pennsylvania due to the commitments made by the Abell Foundation.

Solar Manufacturing, Ebara Solar[6]

The Ebara Corporation established Ebara Solar to manufacture thin film solar cells by purchasing the former Westinghouse Electric Alternative Energy Division. The anticipated market was water pumping applications in Third World countries. In 2001, Ebara Solar opened a $7 million fabrication facility in Belle Vernon. At its peak, Ebara employed over 100 in high tech jobs and had plans for a major expansion. Financial difficulties forced the company to close its solar manufacturing operations and lay off all of its employees. In September 2003 all of its assets, valued at $11 million, were put up for auction.

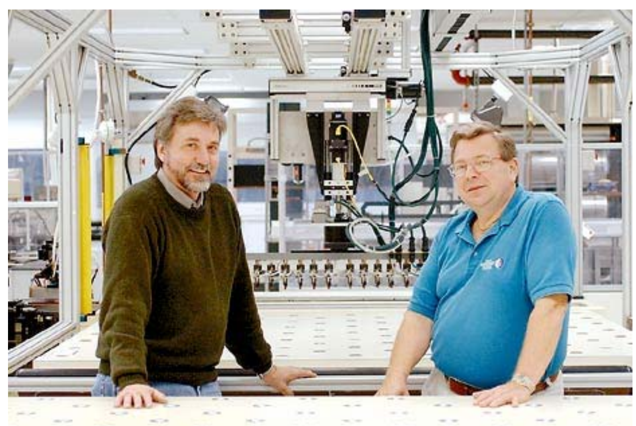

Figure 5-13. Ebara Solar Employees.
(Source: Pittsburgh Tribune-Review)

King of Fans, based in Ft. Lauderdale, Florida, bought the assets at auction for $900,000 and has worked with the former principals of Ebara to form

[6] Micheal Yeomans, "Solar cell firm struggles to stay in spotlight," Pittsburgh Tribune-Review, September 18, 2003.
Micheal Yeomans, "Ebara see the light at the end of the tunnel," Pittsburgh Tribune-Review, November 6, 2003.
Buckley, "Rostraver park is taking flight," Valley Independent, November 7, 2003.

Solar Power Industries, Inc. In so doing they have created hope of adding new high tech jobs in an area that needs economic investment.

King of Fans plans to provide a small market for Solar Power Industries through its solar-powered garden product line. Solar Power Industries ultimately wants to be a major manufacturer of thin film solar panels, but will manufacture crystalline cells as a means to generate enough revenue to support thin film development efforts. Thin film panels have a high potential for deployment in architectural uses in urban settings if their costs can be reduced to affordable levels.

Incremental Hydro, American Hydro Corporation [7]

American Hydro Corporation is a York company that manufactures hydroelectric turbines and specializes in incremental hydro. Incremental hydro is broadly defined as increases in power output at existing hydro facilities either through efficiency improvements or capacity additions. Since no new water impoundments or diversions are made, incremental hydro is often considered a renewable energy source without adverse environmental impact.

American Hydro primarily focuses on increasing the rated capacity of an existing facility through relatively inexpensive, but technically sophisticated, upgrades. By replacing critical components of the turbine with modern ones they routinely boost existing plant capacity by 10 to 30 percent. Since 1987, they have installed over 350 new runners in existing hydro facilities around the world, including retrofits at the Hoover Dam, Grand Coulee and other major hydroelectric facilities. Their projects have ranged from small hydro installations of less than 1 megawatt to over 600 megawatts. The payback period for such projects is typically three to five years, although in several instances the timeframe was less than six months.

The firm has grown from a four person engineering company in 1986 to an employer of 115, including engineers and skilled craftsmen. This is the largest U.S. owned hydro manufacturing facility of its type in the United States, fabricating large steel components that can exceed 100 tons. Business has flourished in the past several years and the company has received state and regional accolades for being one of the fastest growing companies in the region. During the past three years their annual revenues averaged over $24 million including domestic and international markets.

Figure 5-14. New Replacement Runners from 1 to 194 MW. (Source: American Hydro).

American Hydro elected to build its factory in Pennsylvania due to the local skilled workforce and manufacturing base and low interest financing from the state. These factors were key to keeping American Hydro in Pennsylvania as it weighed offers from other states. Continued growth prospects are strong as electric utility owners, including the U.S. Government, seek to modernize their facilities and increase productivity. According to the company, the Commonwealth continues to provide useful assistance in development of foreign markets through the Office of International Business

[7] Based on conversation with Doug Miller, American Hydro, on December 1, 2003.

Development. The company has been very happy with their decision to stay in Pennsylvania and looks forward to continuing its sustained growth there.

Appendix A. STATE RENEWABLE ENERGY POLICY DEVELOPMENT

Renewable Energy Policies

State	Formation Law	Applicable Companies	Requirement	Applicable Technologies	Credit Trading
Connecticut	Electric Utility Restructuring Act of 1998, with revisions in 1999 and June 2003	Electric distribution companies providing standard offer, transitional standard offer, standard service or back-up electric generation.	10 percent of electricity from renewable resources by 2010.	Class 1: solar thermal electric, photovoltaic, new sustainable biomass, wind, landfill gas, fuel cells, low impact run of river hydro, ocean thermal, wave, tidal, and low emissions renewable technologies. Class 2: trash-to-energy, biomass facilities not included in Class 1, and approved hydro projects.	Yes
Iowa	Alternate Energy Production Facilities Law of 1999	Investor Owned Utilities	Purchase a combined 105 MW from renewable sources.	Photovoltaic, wind, biomass, and hydroelectric.	No
Maine	Electric Utility Restructuring Law of 1999	Electric Utilities and Cooperatives.	30 percent	Biomass, waste, or renewable resources with a capacity below 80 MW, including other generation facilities at the site. Facilities below 100 MW powered by fuel cells, tidal power, solar, wind, geothermal, hydroelectric, municipal solid waste, and certain cogeneration facilities.	Yes
Massachusetts	Electric Utility Restructuring Law of 1997, final rules issued in April 2002.	Retail Electric Providers	1 percent in 2003, increasing by 0.5 percent until 2009, and by 1 percent thereafter.	Solar, wind, ocean thermal, wave, tidal, fuel cells with renewable fuels, landfill gas, and low emission biomass technologies.	Yes
Minnesota	Renewable Energy Objective in 2001, and amended in 2003	Electric Utilities	Good Faith effort to provide 1 percent of energy from renewable sources. Increases by 1 percent annually to 2015.	Solar, wind, hydro below 60 MW, biomass, and hydrogen (hydrogen used after 2010 must be generated from renewable sources).	Yes
New Mexico	Renewable Energy Law of 2002	Public Utilities	5 percent by 2006, increasing by 1 percent annually until 2011.	Different credit values are assigned to each applicable technology: 1 kWh generated with wind or hydroelectric resources is worth 1 kWh credit; 1 kWh generated with biomass, geothermal, landfill gas, or fuel cells is worth 2 kWh credits; 1 kWh generated with solar technology is worth 3 kWh credits.	Yes
Wisconsin	Renewable Energy Law of 1999	Electric Service Providers	0.5 percent in 2001, increasing to 2.2 percent in 2010.	Solar thermal, photovoltaic, wind, biomass, geothermal, wave, tidal, and fuel cells powered by renewable fuels.	Yes

Source: www.dsireusa.org

Appendix B. PENNSYLVANIA RENEWABLE ENERGY COMPANIES

Company	Location	Service	Technology	Source
ALSTOM T&D	Eddystone	T&D	Wind	AWEA
Case Foundation Company	Broommall	Foundations	Wind	AWEA
Conservation Consultants, Inc. (CCI)	Pittsburgh	Consultant	Wind	AWEA
Crouse & Company	Pittsburgh	Consultant	Wind	AWEA
Deer River Ranch	Middletown	Developer	Wind	AWEA
Energy Unlimited, Inc.	West Conshohocken	Developer	Wind	AWEA
Hodge Foundry, Inc.	Greenville	Equipment Manufacturer	Wind	AWEA
Hopwood, Inc.	Washington	Consultant	Wind	AWEA
HYDAC International	Bethlehem	hydraulics, valves, etc	Wind	AWEA
InfraSource	Aston	Engineer / Construction	Wind	AWEA
Nicholson Construction Company	Cuddy	Engineer / Construction	Wind	AWEA
PennSummit Tubular, LLC	West Hazleton	Wind Towers	Wind	AWEA
Phoenix Contact	Middletown	Electrical equipment, Towers	Wind	AWEA
PPG Industries, Inc.	Pittsburgh	Fiberglass	Wind	AWEA
QinetiQ Inc.	Philadelphia	Consultant	Wind	AWEA
Ragnar Benson, Inc.	Pittsburgh	Engineer / Construction	Wind	AWEA
Renewable Corporation of Pennsylvania	Baden	Wind Towers, Measurement, IPP	Wind	AWEA
SKF USA Inc.	Kulpsville	mechanical equipment	Wind	AWEA
US Wind Force, LLC	Wexford	Developer	Wind	AWEA
333 Suppliers		Material Handling Equipment	Biomass Co-firing	b2byellowpages.com
4 Seasons Waste & Construction Management	Pocono Summit	Waste Management, Recycling	Biomass	b2byellowpages.com
A & R Tire Sales & Recycling	Lancaster	Waste Management, Recycling	Biomass	b2byellowpages.com
Aalborg Industries, Inc.	Erie	Steam Generators	Biomass Direct	b2byellowpages.com
All Seasons Comfort Systems-Heating Cooling	East Berlin	Geothermal Heat	Geothermal	b2byellowpages.com
Alstom Power Inc	Wexford	Boiler Distributors & Manufacturers	Biomass Direct	b2byellowpages.com
Alternative Resources Inc A R I	Stroudsburg	Waste Management, Recycling	Biomass	b2byellowpages.com
Atlantic Turbines International	Easton	Turbomachinery	Biomass Direct / LFG	b2byellowpages.com
B E Equipment Inc	Quakertown	Waste Management, Recycling	Biomass	b2byellowpages.com
Babcock Borsig Power	Erie	Boiler Distributors & Manufacturers	Biomass Direct	b2byellowpages.com
Balzer's Heating & Air Conditioning	West Bridgewater	Geothermal Heat	Geothermal	b2byellowpages.com
Besco Systems Inc	Mechanicsburg	Waste Management, Recycling	Biomass	b2byellowpages.com
BGS Precision	Wellsboro	Wood Burning Furnaces	Biomass Direct	b2byellowpages.com
Blast Off Cleaning Equipment Inc	Uniontown	Waste Management, Recycling	Biomass	b2byellowpages.com
C.C.R. Heating And Cooling	Butler	Geothermal Heat	Geothermal	b2byellowpages.com
C.E.Stirne Plumbing,Heating,Air Conditioning	Elizabethtown	Geothermal Heat	Geothermal	b2byellowpages.com
Calhoun's Hearth & Home	Athens	Wood Burning Furnaces	Biomass Direct	b2byellowpages.com
Cohen Louis & Son Inc	Wilkes Barre	Waste Management, Recycling	Biomass	b2byellowpages.com
Cohen Louis & Sons Inc	Hanover Township	Waste Management, Recycling	Biomass	b2byellowpages.com
Conmec Incorporated	Bethlehem	Turbomachinery	Biomass Direct / LFG	b2byellowpages.com
Cyclechem of Lewisberry Inc	Lewisberry	Waste Management, Recycling	Biomass	b2byellowpages.com

Davis Plumbing & Heating	Conshohocken	Solar Energy Equipment & Systems Manufacturers & Distributors	Solar	b2byellowpages.com
Delval Equipment Corporation	Strabane	Boiler Distributors & Manufacturers	Biomass Direct	b2byellowpages.com
East Coast Management	Ardmore	Turbomachinery	Biomass Direct / LFG	b2byellowpages.com
Eastern Environmental Systems Inc	West Chester	Waste Management, Recycling	Biomass	b2byellowpages.com
ECM	Philadelphia	Turbomachinery	Biomass Direct / LFG	b2byellowpages.com
Egotrips Inc	Philadelphia	Waste Management, Recycling	Biomass	b2byellowpages.com
Energy Alternatives	Philadelphia	Solar Energy Equipment	Solar	b2byellowpages.com
Environmental Solutions Group Inc	Chester Heights	Waste Management, Recycling	Biomass	b2byellowpages.com
Equipco Division Phillips Corporation	Bridgeville	Waste Management, Recycling	Biomass	b2byellowpages.com
Foster Wheeler Energy Corporation	Coraopolis	Boiler Distributors & Manufacturers	Biomass Direct	b2byellowpages.com
H & W Disposal Service Inc	Phoenixville	Waste Management, Recycling	Biomass	b2byellowpages.com
Harris R Services	Mechanicsburg	Solar Energy Equipment	Solar	b2byellowpages.com
Hartman Metals CO	Pittsburgh	Waste Management, Recycling	Biomass	b2byellowpages.com
Heil Equipment of Phila Inc	Philadelphia	Waste Management, Recycling	Biomass	b2byellowpages.com
Heliotek Inc	Dalmatia	Solar Energy Equipment	Solar	b2byellowpages.com
Huckleberry Associates	Allentown	Waste Management, Recycling	Biomass	b2byellowpages.com
Industrial Boiler & Chimney Co Inc	Ambler	Boiler Tubes	Biomass Direct	b2byellowpages.com
Ironstone Mills	Leola	Wood Burning Furnaces	Biomass Direct	b2byellowpages.com
JMW Inc	Perkasie	Solar Energy Equipment	Solar	b2byellowpages.com
JPS Equipment CO	Edgemont	Waste Management, Recycling	Biomass	b2byellowpages.com
K & K Manufacturing	Meadville	Wood Pellets Fulel	Biomass	b2byellowpages.com
Kasper BROS	Bristol	Waste Management, Recycling	Biomass	b2byellowpages.com
Ken Rex Plbg Htg & Clg	Kingston	Solar Energy Equipment & Systems Manufacturers & Distributors	Solar	b2byellowpages.com
Knight Hauling Inc	Marcus Hook	Waste Management, Recycling	Biomass	b2byellowpages.com
Lancaster County Solid Waste Management Authority - Office	Lancaster	Waste Management, Recycling	Biomass	b2byellowpages.com
Liberty Waste Services Limited	Pittsburgh	Waste Management, Recycling	Biomass	b2byellowpages.com
McCusker & Ogborne Waste	Chester	Waste Management, Recycling	Biomass	b2byellowpages.com
Medifor X	Scranton	Waste Management, Recycling	Biomass	b2byellowpages.com
Mid-Atlantic Agrisystems	Quarryville	Waste Management, Recycling	Biomass	b2byellowpages.com
Mill Service Inc	Bulger	Waste Management, Recycling	Biomass	b2byellowpages.com
Miller Enviromental Inc	Reading	Waste Management, Recycling	Biomass	b2byellowpages.com
Nebraska Boiler	Wayne	Boiler Distributors & Manufacturers	Biomass Direct	b2byellowpages.com
Newburg-Hopewell Sewer Authority	Newburg	Waste Management, Recycling	Biomass	b2byellowpages.com
Northern Tier Solid Waste Authority	Burlington	Waste Management, Recycling	Biomass	b2byellowpages.com
Omni-Cycle CO	Johnstown	Waste Management, Recycling	Biomass	b2byellowpages.com
Onyx Environmental Services	York	Waste Management, Recycling	Biomass	b2byellowpages.com
Pallet Express Inc	Easton	Wood Waste & Recycling	Biomass	b2byellowpages.com
Penn Waste Systems	Mc Kees Rocks	Waste Management, Recycling	Biomass	b2byellowpages.com
Philadelphia Solar Energy Systems Co	Manayunk	Solar Energy Equipment & Systems Service & Repair	Solar	b2byellowpages.com
Pike County Environmental Inc	Matamoras	Waste Management, Recycling	Biomass	b2byellowpages.com
Pocono Solar Systems Inc	Stroudsburg	Solar Energy Equipment	Solar	b2byellowpages.com
Power Services	Philadelphia	Turbomachinery	Biomass Direct / LFG	b2byellowpages.com
Precision Hydraulic Service CO	Worcester	Waste Management, Recycling	Biomass	b2byellowpages.com
Price H W & Sons	Kingston	Solar Energy Equipment & Systems Service & Repair	Solar	b2byellowpages.com

Raimo Alfred Rubbsh Removal	Ardmore	Waste Management, Recycling	Biomass	b2byellowpages.com
Ridgewood Soils Inc	Reading	Wood Waste & Recycling	Biomass	b2byellowpages.com
S L M Waste & Recycling	Ambler	Waste Management, Recycling	Biomass	b2byellowpages.com
Safety Kleen Corporation	New Kingstown	Waste Management, Recycling	Biomass	b2byellowpages.com
Schramer WM	Stroudsburg	Solar Energy Equipment	Solar	b2byellowpages.com
SDF Solar PV Program	Cheltenham	Solar Energy Equipment	Solar	b2byellowpages.com
SEM Corporation	Pittsburgh	Waste Management, Recycling	Biomass	b2byellowpages.com
Skinner Engine Company, Inc.	Erie	Turbomachinery	Biomass Direct / LFG	b2byellowpages.com
Sleepyheads Power Equipment Center	Brookville	Wood Burning Furnaces	Biomass Direct	b2byellowpages.com
Solar Atmospheres of Western Pennsyl	Hermitage	Solar Energy Equipment	Solar	b2byellowpages.com
Solid Waste Management Authority	Lancaster	Waste Management, Recycling	Biomass	b2byellowpages.com
Somat CO	Coatesville	Waste Management, Recycling	Biomass	b2byellowpages.com
Stanko Products Inc Dens-A-Can International	Greensburg	Waste Management, Recycling	Biomass	b2byellowpages.com
Stewart Well Drilling	New Castle	Geothermal Heat	Geothermal	b2byellowpages.com
Stilp & Sun	Harrisburg	Solar Energy Research Development & Design	Solar	b2byellowpages.com
Stoey's Trucking	Fayetteville	Waste Management, Recycling	Biomass	b2byellowpages.com
Sun Harvest Renewable Energy	State College	Solar Energy Equipment	Solar	b2byellowpages.com
Sun Spot Solar & Heating Inc	Delaware Water Gap	Solar Energy Equipment	Solar	b2byellowpages.com
Sunline Solar	Gordonville	Solar Energy Equipment	Solar	b2byellowpages.com
Swcma	Tidioute	Waste Management, Recycling	Biomass	b2byellowpages.com
The Warm Up Shop	Williamsport	Wood Burning Furnaces	Biomass Direct	b2byellowpages.com
Tinari Container Service	Southampton	Waste Management, Recycling	Biomass	b2byellowpages.com
TLC Hauling	Altoona	Waste Management, Recycling	Biomass	b2byellowpages.com
Turbine Services Inc	Aliquippa	Turbomachinery	Biomass Direct / LFG	b2byellowpages.com
USA Waste Services	Monroeville	Waste Management, Recycling	Biomass	b2byellowpages.com
Voltz Peter C Custom Builder	Waynesboro	Solar Heating Contractors	Solar	b2byellowpages.com
Waste Management	Washington	Waste Management, Recycling	Biomass	b2byellowpages.com
Waste Recovery Designed Products Inc	Mc Donald	Waste Management, Recycling	Biomass	b2byellowpages.com
White J J Incorporated BLDR	Philadelphia	Turbomachinery	Biomass Direct / LFG	b2byellowpages.com
Wiegand R L Inc	Ephrata	Solar Energy Equipment	Solar	b2byellowpages.com
York Waste Disposal Inc	Mechanicsburg	Waste Management, Recycling	Biomass	b2byellowpages.com
American Governor	Langhorne	Manufacturer	Hydro, Biomass	Energy Source Guide
AvisAmerica	Avis		Green Buildings	Energy Source Guide
B.L. Myers Bros., Inc.	Glenmoore	Geothermal Heat	Geothermal	Energy Source Guide
BATTERY SYSTEMS, INC.	Washington	Batteries	Solar	Energy Source Guide
Belyea Company Inc.	Easton	Used Equipment	Biomass	Energy Source Guide
Delta T Geothermal	Albion	Geothermal Heat	Geothermal	Energy Source Guide
Galaxy Power, Inc.	Valley Forge	Charge Controllers	Solar	Energy Source Guide
Huret Associates, Inc.	Yardley	Batteries	Solar	Energy Source Guide
LMF Manufacturing	Lock Haven	Biomass Boiler	Biomass	Energy Source Guide
Motors & Controls International	Hazleton	Power Electronics	Solar	Energy Source Guide
Sun Spot Solar & Heating, Inc.	Delaware Water Gap		Solar	Energy Source Guide
Sun-El Corporation	Latrobe	Solar Thermal Manufacturer	Solar	Energy Source Guide
Suntara Energy	Pittsburgh		General RE	Energy Source Guide
The Right Way Solar	Williamsburg		Solar	Energy Source Guide
Erie Power Technologies	Erie		Biomass Direct	Internal
Ascor Inc	York	Equipment Manufacturer	Solar	James & James
Delta Precision Alloys	Montgomeryville	Material Manufacturer	Solar	James & James

Filpro Corporation	West Point	Equipment Manufacturer	Biomass	James & James
Hollander Associates	Wyomissing	Consultant	Biomass	James & James
Key Bellevilles Inc	Leechburg	Equipment Manufacturer	Wind	James & James
Sibos Ascor	York	Equipment Manufacturer	Solar	James & James
Schutte & Koerting	Bensalem	Equipment Manufacturer	Biomass	James & James
Skinner Power Systems	Erie	Equipment Manufacturer	Biomass	James & James
DAI Management Consultants Inc	Bridgeville	Equipment Manufacturer	Biomass	James & James
Electro-science Laboratories Inc - ESL	King of Prussia	Equipment Manufacturer	Solar	James & James
TRI Transmission & Bearing Corporation	Lionville	Equipment Manufacturer	Wind	James & James
TorcUp	Easton	Equipment Manufacturer	Wind	James & James
Kuljian Corporation	Philadelphia	Consultant	Biomass	James & James
Aggregates Equipments Incorporated	Leola	Equipment Manufacturer	Biomass	James & James
Airfoils Incorporated	Port Matilda	Consultant	Wind	James & James
Crucible Compaction Metals	Oakdale	Equipment Manufacturer	General RE	James & James
Hamel Geotechnical Consultants	Monroeville	Consultant	General RE	James & James
Affordable Comfort, Inc.	Coraopolis			National Directory Of Sustainable Energy Companies
Allegheny Power System	Greensburg			National Directory Of Sustainable Energy Companies
American Environmental Outfitters	Clarks Summit			National Directory Of Sustainable Energy Companies
Applied Carbochemicals, Inc.	Cranberry Township			National Directory Of Sustainable Energy Companies
Arcadia Air, Inc.	Douglasville			National Directory Of Sustainable Energy Companies
ARCO Chemical Company	Newtown Square			National Directory Of Sustainable Energy Companies
Bertoia Studio, Ltd.	Bally			National Directory Of Sustainable Energy Companies
Bio-Sun Systems, Inc.	Millerton			National Directory Of Sustainable Energy Companies
Community Power Corporation	Finleyville			National Directory Of Sustainable Energy Companies
Concurrent Technologies Group	Johnstown			National Directory Of Sustainable Energy Companies
Construction & Energy Options	Aspers			National Directory Of Sustainable Energy Companies
Donald Prowler & Associates	Philadelphia			National Directory Of Sustainable Energy Companies
East Penn Manufacturing Co.	Lyons Station			National Directory Of Sustainable Energy Companies
Elf Atochem NA, Inc.	Philadelphia			National Directory Of Sustainable Energy Companies
Energy Retrofit	Philadelphia			National Directory Of Sustainable Energy Companies
EPS Capitol Corporation	Doylestown			National Directory Of Sustainable Energy Companies
Exelon Energy Services	King of Prussia			National Directory Of Sustainable Energy Companies
Frankfort Solar	Philadelphia			National Directory Of Sustainable Energy Companies
Hutton Communications	Camp Hill			National Directory Of Sustainable Energy Companies
IBACOS, Inc.	Pittsburgh			National Directory Of Sustainable Energy Companies
Jacobs/Wyper Architects	Philadelphia			National Directory Of Sustainable Energy Companies
Lockheed Aeroparts, Inc.	Johnstown			National Directory Of Sustainable Energy Companies
New Society Publishers	Philadelphia			National Directory Of Sustainable Energy Companies
Paul Macht Architect	Rydal			National Directory Of Sustainable Energy Companies
Phila Solar Electric	Philadelphia			National Directory Of Sustainable Energy Companies
Seasoned Energy Development, Ltd.	Philadelphia			National Directory Of Sustainable Energy Companies
Solar Light	Philadelphia			National Directory Of Sustainable Energy Companies
Solar Strategies Builders & Developers, Inc.	Philadelphia			National Directory Of Sustainable Energy Companies
Solar Techniques, Inc.	Philadelphia			National Directory Of Sustainable Energy Companies
Springhouse Energy Systems, Inc.	Washington			National Directory Of Sustainable Energy Companies
Sun ReSning & Marketing Co.	Philadelphia			National Directory Of Sustainable Energy Companies
Sunpower Builders	Collegeville			National Directory Of Sustainable Energy Companies
Susan Maxman Architects	Philadelphia			National Directory Of Sustainable Energy Companies
Sustainable Systems Research	Lancaster			National Directory Of Sustainable Energy Companies
Synergic Resources Corp.	Bala Cynwyd			National Directory Of Sustainable Energy Companies
Alternate Energy Sources, Inc.	West Chester		General RE	Pennsylvania Technology Directory

BioTek	Pittsburgh	Biomass Technology	Biomass	Pennsylvania Technology Directory
Elliot	Jeannette	Turbomachinery	Biomass	Pennsylvania Technology Directory
Solar Technology, Inc.	Allentown	Solar Devices	Solar	Pennsylvania Technology Directory
Allied Resource Corporation	Wayne		Biomass	Solar Access
American Biomass Corp.	Bridgeport		Biomass	Solar Access
B.E.A.R. LLC	Collegeville		Wind	Solar Access
C & D Technologies inc. Power Solutions	Blue Bell		Solar	Solar Access
Captus Energy Company	Riegelsvilles		Biomass / LFG	Solar Access
Carlisle SynTec	Carlisle		Green Buildings	Solar Access
Centria	Moon Township		Green Buildings	Solar Access
COBRA WIRE & CABLE	Hatboro		Wind	Solar Access
Community Energy, Inc.	Wayne		Wind	Solar Access
Concordians.org	Marysville		General RE	Solar Access
Connor Communications Inc	Bala Cynwyd		General RE	Solar Access
Ebara Solar, Inc.	Belle Vernon		Solar	Solar Access
Energy Opportunities	Wllsville		General RE	Solar Access
EnerSys	Reading	Equipment Manufacturer	Solar	Solar Access
Fibrowatt LLC	Yardley		Biomass	Solar Access
Free Agent Systems	New Hope		???	Solar Access
Ganakee Energy Company	Huntingdon		Solar, Wind	Solar Access
Healing Arts Planet	Philadelphia		General RE	Solar Access
Mesa Environmental Sciences, Inc.	Malvern		General RE	Solar Access
Morningstar Corporation	Washington Crossing		Solar	Solar Access
Nanomat, Inc.	North Huntingdon		Fuel cells	Solar Access
Nautilus Water Turbine Inc.	Pottstown	Small Hydro	Hydro	Solar Access
Penn Energy Project	Harrisburg		Green Buildings	Solar Access
Philadelphia Million Solar Roofs Partnership	Philadelphia		Solar	Solar Access
Pine Associates, Ltd.	Collegeville		Solar	Solar Access
Pure Energy	Lancaster		Biofuels	Solar Access
RealWinWin, Inc.	Philadelphia		Green Buildings	Solar Access
SEC Industrial Battery	Lower Gwynedd		Batteries Solar / Wind	Solar Access
ABB Power Lines	Greensburg	Towers (general)	Wind	Thomas Register
American Hydro Corp.	York	Manufacturer	Hydro	Thomas Register
Chesmont Engineering Co., Inc.	Exton		Biomass LFG	Thomas Register
Custer Services Inc.	Pittsburgh		Biomass LFG	Thomas Register
Doucette Inudstires	York		Solar HX	Thomas Register
Dynamic Metal Forming, Inc.	Koppel		Solar	Thomas Register
Electronic Technology Systems, Inc.	Natrona Heights		Hydro	Thomas Register
Geneco Services, Inc.	Dallas	Boiler Manufacturer	Biomass	Thomas Register
General Air Products, Inc.	Exton		Biomass LFG	Thomas Register
Hansen Engineering, Inc.	West Alexander	Towers (general)	Wind	Thomas Register
Hart International, Inc.	Ambler	Towers (general)	Wind	Thomas Register
Hartell Div. Milton Roy	Ivyland		Solar	Thomas Register
Impsa International, Inc.	Pittsburgh		Hydro	Thomas Register
Machine Technologies, Inc.	Hatfield		Hydro	Thomas Register
McGrory Glass, Inc.	Aston		Solar	Thomas Register
NAO, Inc	Philadelphia		Biomass LFG	Thomas Register
NEU DYNAMICS CORPORATION	Ivyland PA 18974		Fuel Cells (Component	Thomas Register

			Molds)	
Penn Tech International, Inc.	West Chester	Towers (general)	Wind	Thomas Register
Pennram Diversified Mfg. Corp.	Williamsport	Boiler Manufacturer	Biomass	Thomas Register
Roediger Pittsburgh, Inc.	Allison Park		Biomass LFG	Thomas Register
Schmidt, W. A., Inc.	Souderton	Towers (general)	Wind	Thomas Register
Sea Solar Power, Inc.	York		Solar	Thomas Register
Suburbia Systems Corp.	Wilkes Barre		Biomass LFG	Thomas Register
Tuckey Metal Fabricators, Inc.	Carlisle		Solar	Thomas Register
Van Gas Technologies	Lake City		Biomass LFG	Thomas Register
Voith Hydro, Inc.	York		Hydro	Thomas Register
Witherup Fabrication & Erection, Inc.	Kennerdell	Towers (general)	Wind	Thomas Register

Economic Impact of Renewable Energy in Pennsylvania

C. RENEWABLE TECHNOLOGIES ASSESSMENT

5 March 2004

building a world of difference™ BLACK & VEATCH

1. SUMMARY AND INTRODUCTION

The objective of this section is to characterize the various renewable energy technologies suitable for application in Pennsylvania.

Renewable energy sources are practically inexhaustible in that most derive their energy from the sun. Technologies to harness renewable energy are diverse and include wind, solar, biomass, biogas, geothermal, hydroelectric, and ocean energy.

Steady advances in equipment and operating experience spurred by government incentives have lead to many mature renewable technologies. The technical feasibility and cost of energy from nearly every form of renewable energy have improved since the early 1980s. However, most renewable energy technologies struggle to compete economically with conventional fossil fuel technologies, and in most countries the renewable fraction of total electricity generation remains small. This is true despite a huge resource base that has potential to provide many multiples of current electricity demand. Nevertheless, the field is rapidly expanding from niche markets to making meaningful contributions to the world's electricity supply.

This section provides an overview of commercially available renewable energy technologies:

- Wind
- Solar
- Geothermal
- Biomass
- Biogas
- Hydroelectric

Table C-1 compares the most promising renewable technologies for application in Pennsylvania. The characteristics of each technology are also summarized here with further details discussed later in this section. Estimates for costs and performance parameters are based on Black & Veatch project experience, vendor inquiries, and a literature review. This section also discusses distributed resources as they apply to the renewable energy market.

Table C-1. Comparison of Renewable Electric Generation Technologies (Excluding Incentives).

Technology	2002 Installed Capacity (MWe)		Capacity Factor (percent)	Capital Cost (US$/kW)	Levelized Cost of Energy (US$/MWh)	Pennsylvania Potential
	US	PA				
Wind (Utility Scale)	5,326	34	26-40	1,000-1,800	40-110	Good
Solar Photovoltaic	212	<1	13-15	7,100-9,000	490-680	Niche Markets
Biomass - Direct	4,425*	33*	70-90	2,000-2,500	44-100**	Moderate
Biomass - Cofiring	2,100*	50*	70-90	100-700	0-65**	Excellent
Biogas (Landfill gas)	1,100	70	70-90	1,300-2,700	40-70	Good
Biogas (Digestion)	<50	<1	70-90	2,300-3,800	80-120	Good
Hydro (New)	79,842	736	40-60	2,500-4,500	90-160	Moderate
Hydro (Incremental)	NA	NA	40-60	6,00-3,000	25-110	Good

Sources: Black & Veatch. Energy Information Agency, *Renewable Energy Annual 2002*. "PV market update", *Renewable Energy World*. EPA Landfill Methane Outreach Program.

Notes:

* Black & Veatch estimate. Actual capacity unknown as cofiring rates can vary significantly.

** Levelized cost for biomass ranging from $0-2/MBtu fuel cost.

Wind

- Fastest growing energy source (30 percent average annual growth in last five years)
- Areas with greatest wind potential often distant from load centers
- Advantages: relatively inexpensive, quick construction, favorable regulatory environment
- Disadvantages: intermittent, visual disruption, potential avian impacts if improperly sited
- Pennsylvania potential: *Good* for properly sited farms or small clusters of turbines

Solar

- Two types: solar photovoltaic (PV) and solar thermal
- Total PV panel shipments in 2003 topped 562 MW; current installed grid connected solar thermal is 350 MW
- For economic reasons, two-thirds of PV applications are off-grid
- Growth rates for PV exceeding 20 percent annually
- Advantages: PV is very low maintenance, modular, easy to install
- Disadvantages: intermittent, expensive
- Pennsylvania potential: *Poor* for solar PV except for niche applications. Solar thermal electricity generation is not practical in the near-term in Pennsylvania, but there are a few opportunities for solar water heating.

Biomass

- Biomass is material of recent biological origin; includes agricultural residues, sewage sludge, wood chips, energy crops, etc.
- Conversion methods: solid fuel combustion in power plants (including cofiring), gasification, pyrolysis, etc.
- Advantages: dispatchable, beneficial use of waste streams, familiar technology, cofiring inexpensive, can be used for combined heat and power
- Disadvantages: poor (if any) public perception, still releases some pollution
- Pennsylvania potential: *Very good*, especially for cofiring at existing coal plants

Biogas

- Biogas is produced from decay of waste in landfills and anaerobic digestion of sewage, animal manure, or other wastes
- Most technologies designed to burn natural gas can burn biogas
- Advantages: baseload resource, some low cost cases, addresses other environmental issues
- Disadvantages: Limited resource potential
- Pennsylvania potential: *Good*, although best opportunities already taken

Geothermal

- Geothermal plants use heat from the earth to generate steam and drive turbine-generators
- Geothermal fluids usually reinjected; minimal environmental impact
- Advantages: dispatchable, relatively low cost, mature technology
- Disadvantages: wells can be depleted, significant development risk in drilling wells, limited resource
- Pennsylvania potential: *Limited* to ground source heat pumps

Hydro

- Most mature and widespread renewable energy technology
- Some opposition to large projects because of environmental and socioeconomic concerns
- Small, "low-impact" projects (< 50 MW) may be considered renewable
- Other developmental water technologies: wave, tidal, ocean thermal, tidal stream
- Advantages: dispatchable, mature, low cost
- Disadvantages: long development times, environmental concerns for large projects
- Pennsylvania potential: *Moderate* potential for new low-impact hydro schemes; *good* potential for incremental hydro at existing sites

2. WIND

Wind power systems convert the movement of the air to power by means of a rotating turbine and a generator. Wind power has been the fastest growing energy source of the last decade in percentage terms and has realized around 30 percent annual growth in worldwide capacity for the last five years. Cumulative worldwide wind capacity is now estimated to be more than 32,000 MW. Europe now leads in wind energy, with more than 20,000 MW installed; Germany, Denmark, and Spain are the leading European markets. Installations of wind turbines have outpaced all other energy technologies in Europe for the past two years.

In the US, the American Wind Energy Association (AWEA) has predicted that wind turbine capacity may exceed 6,000 MW by the end of 2003. The booming US wind market is driven by a combination of growing state mandates, such as that proposed for Pennsylvania, and the production tax credit (PTC), which provides a 10-year 1.8 cent/kWh incentive for electricity produced from wind. The PTC expired at the end of 2003. Its long-term absence would severely dampen the US wind market. However, it is widely believed that the credit will be revived in 2004.

Applications

Typical utility-scale wind energy systems consist of multiple wind turbines that range in size from 0.10 MW to 2 MW. Wind energy system installations may total 5 to 300 MW, although single and small groupings of turbines are common in Denmark and Germany. Use of single smaller turbines is also increasingly common in the United States for powering schools, factories, water treatment plants, and other distributed loads. Furthermore, off-shore wind energy projects are now being planned, which is encouraging the development of both larger turbines (up to 5 MW) and larger wind farm sizes.

Wind is an intermittent resource with average capacity factors ranging from 25 to 40 percent. The capacity factor of an installation depends on the wind regime in the area and energy capture characteristics of the wind turbine. Capacity factor directly impacts economic performance, thus reasonably strong wind sites are a must for cost effective installations.

Figure C-1. 9 MW Wind Farm near Somerset.

Because wind is intermittent it cannot be relied upon as firm capacity for peak power demands. To provide a dependable resource, wind energy systems may be coupled with some type of energy storage to provide power when required, but this adds considerable expense and is not common. For larger wind farms numerous studies have shown that relatively low levels of wind grid penetration will not necessitate additional backup generation. Efforts are currently underway by research agencies to predict wind intensities more accurately, thereby increasing confidence in wind power as a generation resource and dependability in utility dispatching.

Cost and Performance Characteristics

Table C-2 provides typical characteristics for a 50 MW wind farm and a single 600 kW turbine for distributed applications in Pennsylvania. Substantially higher costs are necessary for wind projects that require upgrades to transmission and distribution lines.

Table C-2. Wind Technology Characteristics.

Performance	Wind Farm	Distributed
Net Plant Capacity (MW)	50	0.6
Capacity Factor (percent)	26 – 40	20 – 30
Economics		
Capital Cost ($/kW)	1,000–1,800	1,800–2,600
O&M ($/kW-yr)	30	35
Levelized Cost ($/MWh)*	40 – 110	100 – 200
Technology Status		
Commercial Status		Commercial
Installed US Capacity (MW)		5,326
Pennsylvania Potential		Good

* Excludes incentives.

Capital costs for new onshore wind projects have remained relatively stable for the past few years. The greatest gains have been made by identifying and developing sites with better wind resources and improving turbine reliability. These both lead to improved capacity factors. The average capacity factor for all installed wind projects in the US has dramatically increased, from just 20 percent in 1998 to more than 30 percent in 2002.[1]

Environmental Impacts

Wind is a clean generation technology from the perspective of emissions. However, there are still environmental considerations associated with wind turbines. First, opponents of wind energy frequently cite visual impacts as a drawback. Turbines are approaching and exceeding 300 feet tall and for maximum efficiency tend to be located on ridgelines and other elevated topography. Combining turbines of different type, manufacturer, color and rotation can increase the visual impact of turbine developments. Second, turbines can cause avian fatalities if they are located in areas populated by native birds or on migratory flyways. To some degree, these issues can be partially mitigated through proper siting, environmental review, and the involvement of the public during the planning process.

Pennsylvania Outlook

Wind energy is a mature renewable energy technology providing competitive power. Pennsylvania has sufficient wind resources distributed throughout the state to support continued wind development. The potential is good for properly sited farms, small clusters of turbines or individual turbines powering distributed loads.

[1] Based on annual wind generation and capacity data from the Energy Information Administration's *Renewable Energy Annual 2002*.

3. SOLAR

Solar resources can be captured in numerous ways with a variety of technologies. The two major groups of technologies include solar photovoltaics and solar thermal.

3.1 SOLAR PHOTOVOLTAIC

Photovoltaics (PV) have achieved much wider consumer acceptance over the last few years, and PV production tripled between 1999 and 2002. In 2002, worldwide photovoltaic cell and module manufacturing output rose to 562 MW. Worldwide grid-connected residential and commercial installations grew from 120 MW/yr in 2000 to nearly 270 MW/yr in 2002. The majority of these installations were in Japan and Germany. Large scale (>100 kW) photovoltaic installations have been added at a rate of about 5 MW per year over the last two years.[2]

Photovoltaic cells convert sunlight directly into electricity by the interaction of photons and electrons within the semiconductor material. To create a photovoltaic cell, a material such as silicon is doped (i.e., mixed) with atoms from an element with one more or one less electron than occurs in its matching substrate (e.g., silicon). A thin layer of each material is joined to form a junction. Photons striking the cell cause this mismatched electron to be dislodged, creating a current as it moves across the junction. The current is gathered through a grid of physical connections. Various currents and voltages can be supplied through series and parallel cell arrays.

Figure C-2. Photovoltaic Solar Panel Installation.

The DC current produced depends on the material involved and the intensity of the solar radiation incident on the cell. Single crystal silicon cells are most widely used today. The source silicon is highly purified and sliced into wafers from single-crystal ingots or is grown as thin crystalline sheets or ribbons. Polycrystalline cells are another alternative. These are inherently less efficient than single crystal solar cells but are less expensive to produce. Gallium arsenide cells are among the most efficient solar cells and have other technical advantages, but they are also more costly.

Thin film cells are another type of photovoltaics that show great promise. Commercial thin films are principally made from amorphous silicon; however, copper indium diselenide and cadmium telluride also show promise as low-cost solar cells. Thin film solar cells require very little material and can be manufactured on a large scale. Furthermore, the fabricated cells can be flexibly sized and incorporated into building components.

Applications

The modularity, simple operation, and low maintenance requirements of solar photovoltaics makes them ideal for serving distributed, remote,

[2] Maycock, P., "PV market update", *Renewable Energy World*, July-August 2003.

and off-grid applications. Most PV applications are smaller than 1 kW. However, larger utility-scale installations are becoming more prevalent. Current grid-connected photovoltaic systems are generally below 100 kW. However, several larger projects ranging from 1 to 50 MW have been proposed. A 3.4 MW project is under construction in Arizona. This is one of the largest PV installations in the world. Most grid-connected PV applications require large subsidies (50 percent or more) to overcome inherently high initial costs.

Resource Availability

Generally, stationary PV arrays will receive the highest average insolation if they are mounted at an angle equal to the latitude at which they are located. This configuration will give the highest year-round performance. To optimize performance for winter, the array may be tilted at an angle equal to the latitude plus 15 degrees. Conversely, for maximum output during summer months the array should be tilted at an angle equal to the latitude minus 15 degrees. Single and double axis tracking systems are also available that increase the system output, but at a significantly higher capital cost and increased O&M requirements.

Cost and Performance Characteristics

Numerous variations in photovoltaic cells are available such as single crystalline silicon, polycrystalline, and thin films, and several support structures are available such as fixed-tilt, one-axis tracking, and two-axis tracking. For evaluation purposes, fixed-tilt, single crystalline photovoltaic system are characterized in Table C-3. This technology is representative of most photovoltaic systems installed today. Two applications are characterized: a 2 kW residential system and a 50 kW commercial system.

Environmental Impacts

One of the strongest attributes of solar PV cells is that they are virtually non-polluting after installation. However, manufacturing processes for producing some types of PV cells discharge heavy metals and can be harmful if not monitored and controlled. Compared to conventional technologies, these impacts are generally inconsequential.

Table C-3. Solar Photovoltaic Technology Characteristics.

Performance	Residential	Commercial
Net Plant Capacity (kW)	2	50
Capacity Factor (percent)	14	14
Economics		
Capital Cost ($/kW)*	9,000	7,100
Fixed O&M ($/kW-yr)	12	12
Levelized Cost ($/MWh)	490	680
Technology Status		
Commercial Status		Commercial
Installed US Capacity (MW)		212
Pennsylvania Potential		Niche applications

* Excludes 10 percent investment tax credit. Residential application assumes low-interest home equity financing.

Pennsylvania Outlook

Although rapidly maturing, solar photovoltaics are currently a very expensive option for grid connected power supply in Pennsylvania. In the near future, PV installations will likely be limited to niche applications where it can offer competitive costs (for example, remote power) or public demonstration projects (for example, solar schools).

3.2 SOLAR THERMAL

Solar thermal technologies convert the sun's energy to productive use by capturing the heat from it. Early developments in solar thermal technology focused on heating water for domestic use. Advances have expanded the applications of solar thermal to high magnitude energy collection and power conversion on a utility scale. Numerous solar thermal technologies have been explored in the past two decades as potential sources of renewable power generation. The leading technologies currently include parabolic trough, parabolic dish, central receiver, and solar chimney.

With adequate resources, solar thermal technologies are appropriate for a wide range of intermediate and peak load applications including central station power plants and modular power stations in both remote and grid-connected areas. Commercial solar thermal parabolic trough plants in the United States currently generate more than 350 MW.

Figure C-3. Central Receiver Installation

Solar thermal systems convert the heat in solar insolation to heat in a high temperature thermal energy carrier, usually steam, which is then used to drive heat engines, turbine/generators, or other devices for electricity generation. Solar thermal technologies may be combined with co-utilization of fossil fuels or energy storage to provide a dependable dispatchable resource. Solar chimneys do not generate power using a thermal heat cycle as the other three technologies do. Instead, they generate and collect hot air in a large greenhouse. Located in the center of the greenhouse is a tall chimney. As the air in the greenhouse is heated by the sun, it rises and enters the chimney. The natural draft produces a wind current, which rotates a collection of air turbines in the current. The first commercial solar chimney is currently under development in Australia.

Applications

The larger solar thermal technologies (parabolic trough, central receiver and solar chimney) are currently not economically competitive with other central station generation options (such as natural gas combined cycle). Parabolic dish engine systems are small and modular and can be placed at load sites, thereby directly offsetting retail electricity purchases. However, these systems are still under development and have not been used in commercial applications. Furthermore, significant advantages over quiet, more reliable PV systems are not evident.

Figure C-4. Parabolic Dish Receiver (Source: Stirling Energy Systems).

Of the four technologies, parabolic trough represents the vast majority of installed capacity, primarily in the US desert southwest. The Global Environment Facility is currently investigating several integrated solar combined cycle projects that will likely make use of parabolic troughs as incremental solar capacity. Small parabolic dish engine systems have been developed by a few companies and are now being actively marketed. These systems are typically below 50 kW in size. The US government has funded two utility-scale central receiver power plants: Solar One and its successor/replacement, Solar Two. Solar Two was a 10 MW installation near Barstow, California, but it is no longer operating due to reduced federal support and high operating costs.

Solar chimney technologies are receiving significant interest around the world. A project is proposed in Australia to build 200 MW solar chimney. The estimated cost is $700 million and would include a chimney one kilometer (0.62 mi) tall with an accompanying greenhouse 5 km (3.1 mi) in diameter.

Resource Availability

In general, solar thermal potential is measured in terms of capacity for solar concentration. Concentrators can only gather direct sunlight for energy generation. Because of this, lower latitudes with minimum cloud cover offer the greatest solar concentrator potential. An advantage of solar thermal systems, and all solar technologies generally, is that peak output typically occurs on summer days when electrical demand is high.

Cost and Performance Characteristics

Representative characteristics for the four solar thermal power plant technologies are presented in Table C-4.

Pennsylvania Outlook

Pennsylvania's poor concentrating solar resource precludes consideration of solar thermal technologies as practical electricity generation options.

Table C-4. Solar Thermal Power Technology Characteristics.

Receiver Type	Parabolic Trough	Parabolic Dish	Central Receiver	Solar Chimney
Performance				
Net Plant Capacity (MW)	80	1.2	10	200
Capacity Factor (percent)	30	24	50	50 - 70
Economics				
Capital Cost ($/kW)	2,700-3,200	3,000-4,000	3,500-4,500	3,500
Fixed O&M ($/kW-yr)	25-45	Incl. below	300	Incl. below
Variable O&M ($/MWh)	3-5	15	incl. above	10-20
Levelized Cost ($/MWh)	110-140	150-190	160-185	65-100
Technology Status				
Commercial Status	Commercial	Early Commercial	Development	Development
Installed US Capacity (MW)	~350	< 1	10	< 1
Pennsylvania Potential	Poor	Poor	Poor	Poor

4. GEOTHERMAL

Geothermal resources can provide energy for power production or a wide variety of direct use applications. Geothermal power plants use heat from the earth to generate steam and drive turbine generators for the production of electricity. There are three basic types of geothermal technology: dry steam, flash steam, and binary cycle steam. Dry steam power plants are suitable where the geothermal steam is not mixed with water, and operate at high temperatures of between 356º-662ºF (180º-350ºC). Flash steam power plants tap into reservoirs of water with temperatures greater than 360ºF (182ºC). Binary cycle power plants operate on water at lower temperatures of 225º-360ºF (107º-182ºC).

Figure C-5. Geothermal District Heating Equipment.

As of 2002 the global installed capacity for geothermal power plants was 8,227 MW_e (megawatt electrical). An additional 15,580 MW_{th} (megawatt thermal) was used in direct heat applications. It is estimated that geothermal resources using today's technology could support between 35,500 and 72,000 MW_e of electrical generating capacity. Using enhanced technology that is currently under development (permeability enhancement, drilling improvements) geothermal resources have the potential to support between 65,500 and 138,000 MW_e.[3]

Applications

In addition to generation of electricity and direct space heating applications, hot water and saturated steam from a geothermal resource can be used for a wide variety of process heat applications such as fish hatching, mushroom growing, refrigeration, washing and drying of wool, drying and curing of light aggregate cement slabs, evaporation in sugar refining, canning of food, drying of timber, and digestion of paper pulp.[4]

Resource Availability

Geothermal power is limited to locations where geothermal pressure reserves are found. Well temperature profiles determine the potential for geothermal development and the type of geothermal power plant installed. High energy sites are suitable for electricity production, while low energy sites are suitable for direct heating. There are no known conventional geothermal resources suitable for power production in Pennsylvania.

Cost and Performance Characteristics

For representative purposes, a binary cycle power plant is characterized in Table C-5. Capital costs of geothermal facilities can vary widely as the drilling of individual wells can cost as much as four million dollars, and the number of wells drilled depends on the success of finding the resource.

[3] *Renewable Energy World*, 2002
[4] Geothermal Resources Council, 2003.

Table C-5. Geothermal Power Technology Characteristics.

Performance	Binary Cycle
Net Plant Capacity (MW)	30
Capacity Factor (percent)	70
Economics	
Capital Cost ($/kW)	2,500 - 3,500
Fixed O&M ($/kW-yr)	40 - 80
Variable O&M ($/MWh)	1.5 - 4
Levelized Cost ($/MWh)	60 - 90
Technology Status	
Commercial Status	Commercial
Installed US Capacity (MW)	2,216
Pennsylvania potential	Poor

Environmental Impacts

Dissolved minerals and hazardous non-condensable gases in geothermal fluids can be an environmental concern if not handled correctly (fluid reinjection addresses many concerns). Geothermal power plants with modern emission control technologies have minimal environmental impact. They emit less than 0.2 percent of the carbon dioxide, less than 1 percent of the sulfur dioxide and less than 0.1 percent of the particulates of the cleanest fossil fuel plant.

There is the potential for geothermal production to cause ground subsidence. This is rare in dry steam resources, but possible in liquid-dominated fields. However, carefully applied reinjection techniques can effectively mitigate this risk.

Pennsylvania Outlook

There are no known conventional geothermal resources suitable for power production in Pennsylvania. Pennsylvania geothermal resources are more suitable for geothermal heat pumps for building space conditioning and direct heating applications.

5. SOLID BIOMASS

Biomass is any material of recent biological origin. There is a huge variety of biomass resources, conversion technologies, and end products, as shown in the figure below. This report focuses on electricity generation technologies. Electricity generation from biomass is the second most prolific source of renewable electricity generation after hydro.

This section of the report describes solid biomass power options: direct fired biomass and cofired biomass. The next section describes biogas technologies. Combustion of municipal solid waste is not considered in this study due to its perceived negative environmental effects.

5.1 DIRECT FIRED BIOMASS

According to the US Department of Energy (2002) there is currently 35,000 MW of installed biomass combustion capacity worldwide. The majority of this capacity is in the pulp and paper industry in combined heat and power systems.

Direct biomass combustion power plants in operation today essentially use the same steam Rankine cycle introduced into commercial use 100 years ago. By burning biomass, pressurized steam is produced in a boiler and then expanded through a turbine to produce electricity. Prior to combustion in the boiler, the biomass fuel may require some processing to improve the physical and chemical properties of the feedstock. Furnaces used in the combustion of biomass include spreader stoker-fired, suspension-fired, fluidized bed, cyclone and pile burners. Advanced technologies, such as integrated biomass gasification combined cycle and biomass pyrolysis, are currently under development and are not considered for commercial applications in this study.

Applications

Wood is the most common biomass fuel. Other biomass fuels include agricultural residues, dried manure and sewage sludge, black liquor, and dedicated fuel crops such as switchgrass and coppiced willow. There are also many municipal waste burners installed throughout the world. However, the construction of new municipal waste combustion plants has become almost impossible in

Biomass Sources	Processing	Fuel Products	Markets
§ Forests - Natural regrowth - Energy forests - Forest residues - Processing residues § Agriculture - Crop residues - Processing residues - Energy crops § Wastes - Municipal - Industrial	§ Drying § Extrusion § Compression § Chipping § Carbonization § Anaerobic digestion § Fermentation § Gasification § Pyrolysis § Fischer tropsch etc.processors	§ Solid Fuels - Charcoal - Wood chips - Pellets/ briquettes § Gaseous fuels - Methane - Pyrolysis gas - Producer gas § Liquid fuels - Plant esters/oils - Ethanol - Methanol/alcohols - Pyrolysis liquids - Other liquids	§ Electricity § Heat § Solid fuels e.g.(domestic) § Transport

Source: Renewable Energy World, March-April 2003.

Figure C-6. Diverse Biomass Sources, Processing, Fuels and Markets.

the United States due to environmental concerns regarding toxic air emissions.

Figure C-7. 35 MW Biomass Combustion Plant.

The capacity of biomass plants is usually less than 50 MW because of the dispersed nature of the feedstock and the large quantities of fuel required. Furthermore, biomass plants will commonly have lower efficiencies compared to modern coal plants. The lower efficiency is due to the lower heating value and higher moisture content of the biomass fuel compared to coal. Additionally, biomass is typically more expensive and lower in density than coal. These factors usually limit use of direct fired biomass technology to inexpensive or waste biomass sources.

In addition to electrical generation, there are many industrial plants that burn their own biomass waste to produce thermal energy for heating and process applications. The small scale production of combined heat and power is seen as one of the more promising biomass applications.

Resource Availability

Wood and wood waste are the primary biomass resources and are typically concentrated in areas of high forest products industry activity. In rural areas the agricultural economy can produce significant fuel resources that may be collected and burned in biomass plants. These resources include corn stover, rice hulls, wheat straw, and other agricultural residues. Energy crops, such as switchgrass and short rotation woody crops, have also been identified as potential biomass sources. In urban areas, a biomass project might burn wood wastes such as construction debris, pallets, yard and tree trimmings, and railroad ties. Generally, availability of sufficient quantities of biomass is not as large of a concern as delivering the biomass to the power plant at a reasonable price.

Cost and Performance Characteristics

Table C-6 provides typical characteristics of a 30 MW biomass plant using wood waste as fuel.

Table C-6. Direct-Fired Biomass Technology Characteristics.

Performance	
Net Plant Capacity (MW)	30
Net Plant Heat Rate (Btu/kWh)	14,500
Capacity Factor (percent)	70-90
Economics	
Capital Cost ($/kW)	2,000-2,500
Fixed O&M ($/kW-yr)	60
Variable O&M ($/MWh)	8
Levelized Cost, $2/MBtu Fuel ($/MWh)	83-100
Levelized Cost, $0/MBtu Fuel ($/MWh)	44-61
Technology Status	
Commercial Status	Commercial
Installed US Capacity (MW)	4,425*
Pennsylvania potential	Moderate

*Black & Veatch estimate for direct-fired plants only.

Environmental Impacts

Biomass power projects must maintain a delicate balance to ensure long term sustainability with minimal environmental impact. Several states impose specific criteria on biomass power projects for them to be classified as "renewable". A key concern is sustainability of the feedstock. Most biomass projects target utilization of biomass waste material for energy production, saving valuable landfill space. Targeting certain wastes for power production (such as animal manure) can also address other emerging environmental problems. Projects relying on forestry or agricultural products must be careful to ensure that fuel harvesting and collection practices are sustainable and provide a net benefit to the environment.

Biomass utilization has several positive impacts. Unlike fossil fuels, biomass is viewed as a carbon-neutral power generation fuel. While carbon dioxide is emitted during biomass combustion, a nearly equal amount of carbon dioxide is absorbed from the atmosphere during the biomass growth phase. Further, biomass fuels contain little sulfur compared to coal, and so produce less sulfur dioxide. Finally, unlike coal, biomass fuels typically contain only trace amounts of toxic metals, such as mercury, cadmium, and lead.

On the other hand, biomass combustion still must cope with some of the same pollution issues as larger coal plants. Primary pollutants are nitrogen oxides, particulate matter, and carbon monoxide. Standard air quality control technologies are used to manage these pollutants.

Pennsylvania Outlook

Ready availability of biomass resources contributes to good potential for biomass power projects in Pennsylvania, particularly for combined heat and power applications. However, the economics of cofiring biomass are much more attractive as discussed in the next section.

5.2 BIOMASS COFIRING

An economical way to burn biomass is to cofire it with coal in existing plants. Cofired projects are usually implemented by retrofitting a biomass fuel feed system.

A major challenge to biomass power is that the dispersed nature of the feedstock and high transportation costs generally preclude plants larger than 50 MW. By comparison, coal power plants rely on the same basic power conversion technology but have much higher unit capacities, exceeding 1,000 MW. Due to their scale, modern coal plants are able to obtain higher efficiency at lower cost. Through cofiring, biomass can take advantage of this high efficiency at a more competitive cost than a stand-alone direct fired biomass plant.

Applications

There are several methods of biomass cofiring that could be employed for a project. The most appropriate system is a function of the biomass fuel properties and the coal boiler technology.

Provided they were initially designed with some fuel flexibility, stoker and fluidized bed boilers generally require minimal modifications to accept biomass. Simply mixing the fuel into the coal pile may be sufficient.

Cyclone boilers and pulverized coal (PC) boilers (the most common in the utility industry) require smaller fuel size than stokers and fluidized beds and may necessitate additional processing of the biomass prior to combustion. There are two basic approaches to cofiring in this case. The first is to <u>blend the fuels</u> and feed them together to the coal processing equipment (crushers, pulverizers, etc.). In a cyclone boiler, generally up to 10 percent of the coal heat input could be replaced with biomass using this method. The smaller fuel particle size of a PC plant limits the fuel replacement to perhaps 3 percent. Higher cofiring percentages (around 10 percent) in a PC unit can be accomplished by developing a separate biomass processing system at somewhat higher cost.

Even at these limited cofiring rates, plant owners have raised numerous concerns about negative impacts of cofiring on plant operations. These include:

- Negative impact on plant capacity
- Negative impact on boiler performance
- Ash contamination impacting ability to sell coal ash
- Increased operation and maintenance costs
- Limited potential to replace coal (generally accepted to be 10 percent on an energy basis)
- Minimal NOx reduction potential
- Boiler fouling/slagging due to high alkali in biomass ash
- Negative impacts on selective catalytic reduction air pollution control equipment (catalyst poisoning)

These concerns have been a major obstacle to more widespread biomass cofiring adoption. Most of these concerns can be addressed by using an external biomass gasifier to convert the energy of the solid biomass into a low energy gas ("syngas") to be fired in the boiler. Using gasification technology, it is expected that 25 percent or more of the coal heat input could be displaced without significant operational problems. Additionally, the syngas can be used as a reburn fuel to significantly reduce NO_x emissions. The gasification system has a higher cost than the other cofiring approaches, but still a fraction of the cost of a new direct-fired plant.

Resource Availability

For viability, the coal plant should be within 100 miles of a suitable biomass resource. The broad distribution of coal plants and biomass resources across Pennsylvania is a good match.

In the United States, which has the largest installed biomass power capacity in the world, biomass power plants provide 6,200 MW of power to the national power grid. Of the total electricity produced in 2001, coal accounted for 1.9 trillion kWh, or 51 percent. Conversion of as little as five per cent of this generation to biomass cofiring would nearly quadruple electricity production from biomass.

Cost and Performance Characteristics

Table C-7 provides typical characteristics for a cofired plant using wood waste as fuel. If biomass fuel is available at a lower cost than the plant's coal supply, biomass cofiring could actually result in cost savings at the plant and a "negative cost" renewable energy resource.

Table C-7. Cofired Biomass Technology Characteristics.

Performance	
Net Plant Capacity, Biomass (MW)	5-50
Net Plant Heat Rate (Btu/kWh)	8,000 -15,000
Capacity Factor (percent)	50-90
Economics (Incremental Costs)	
Capital Cost ($/kW)	50-600
Fixed O&M ($/kW-yr)	5-20
Levelized Cost, $2/MBtu Fuel ($/MWh)	25-65
Levelized Cost, $0/MBtu Fuel ($/MWh)	0-25
Technology Status	
Commercial Status	Commercial
Installed US Capacity (MW)	2100*
Pennsylvania potential	Excellent

*Black & Veatch estimate for direct-fired plants only.

Environmental Impacts

As with direct fired biomass plants, the biomass fuel supply must be collected in a sustainable manner. Assuming this is the case, cofiring biomass in a coal plant generally has overall positive environmental effects. The clean biomass fuel typically reduces emissions of sulfur, carbon dioxide, nitrogen oxides and heavy metals, such as mercury. Further, compared to other renewable resources, biomass cofiring directly offsets fossil fuel use.

Critics are opposed to cofiring biomass with coal because they feel it is a form of "green washing" dirty coal plants. They believe that biomass could be used to justify extended lives for coal plants. For these reasons, they argue that the cofired biomass should not be counted as renewable.

Figure C-8. Willow Energy Crop in New York.
(source: State University of New York)

Pennsylvania Outlook

Pennsylvania has excellent potential for cofiring biomass with coal. There are a large number of potential coal plants in Pennsylvania that could cofire biomass, including many fuel flexible fluidized bed plants originally built for waste coal. With the proper incentives (or mandates) these plants would be motivated to increase renewable penetration in the state relatively easily.

6. BIOGAS

The biogas technology characterization generally pertains to the products of anaerobic digestion of manure and gas produced from landfills. The following sections detail the formation of these fuels and how each can be used to produce useful energy.

6.1 ANAEROBIC DIGESTION

Anaerobic digestion is the process that occurs when bacteria decompose organic materials in the absence of oxygen. The byproduct gas has 60 to 80 percent methane content. The most common applications of anaerobic digestion use wastewater, animal manure, or human sewage as the organic resource. The most common types of digesters are plug flow, covered lagoon and complete mix digesters.

According to the European Network of Energy Agencies' ATLAS Project the world wide deployment of anaerobic digestion in 1995 was approximately 6,300 MW_{th} for agricultural and municipal wastes. This is estimated to increase to 20,130 MW_{th} in 2010 with the majority of that growth being in municipal wastewater digestion.

Applications

Anaerobic digestion is commonly used in municipal wastewater treatment as a first stage treatment process for sewage sludge. Digesters convert the organic material or sewage sludge into safe and stable biosolids and methane gas. The use of anaerobic digestion technologies in wastewater treatment applications is increasing because it results in a smaller quantity of biosolids residue compared to aerobic technologies.

In agricultural applications, anaerobic digesters can be installed anywhere there is a clean, continuous source of manure. Dairy and hog farms both fit this description. (Poultry litter is dryer and more suitable for direct combustion.) Dairy farms use all three types of digesters depending upon the type of manure handling system in place at the farm and the land area available for the digester. A 600 to 700 head dairy farm produces sufficient manure to generate about 85 kW. Hog farms typically use lagoon digesters because of the manure characteristics and quantities produced.

Figure C-9. 135 kW Dairy Manure Digester.[5]

Along with direct heat applications, the biogas produced by anaerobic digestion can be used for power generation. Reciprocating engines are the most common conversion device, although trials with microturbines are underway. Agricultural digesters frequently satisfy the power demands for the farm on which they are installed, but do not provide significant exports to the grid. Municipal sewage sludge digesters produce enough gas to power up to about half the wastewater treatment plant electrical load.

Resource Availability

For on-farm manure digestion, the resource is readily accessible and only some modifications are

[5] C. Nelson and J. Lamb, “"Final Report: Haubenschild Anaerobic Digester", August 2002.

required to existing manure management techniques. For central plant digestion of manure, the availability of a large number of livestock operations within a close proximity is necessary to provide a sufficient flow of manure to the facility. However, the larger size of regional facilities does not necessarily guarantee better economics because of high manure transportation costs. For anaerobic digestion of municipal wastes the resource is readily available at the wastewater treatment plant.

Cost and Performance Characteristics

Table C-8 provides typical characteristics of farm-scale anaerobic digestion systems.

Table C-8. Anaerobic Digestion Technology Characteristics.

Performance	
Net Plant Capacity (MW)	0.085
Capacity Factor (percent)	70–90
Economics	
Capital Cost ($/kW)	2,300–3,800
Variable O&M ($/MWh)	15
Levelized Cost ($/MWh)	80–120
Technology Status	
Commercial Status	Commercial
Installed Worldwide Capacity (MW_{th})	6,300
Pennsylvania Potential	Good

Environmental Impacts

Anaerobic digesters have multiple positive environmental impacts. First, they provide a dependable waste stabilization process that significantly reduces pathogens in the waste stream. Second, they eliminate odor problems. Third, they reduce methane emissions from atmospheric decomposition of manure. These emissions are a significant contributor to greenhouse gas emissions. Fourth, they can be incorporated as an important part of the nutrient management planning of a farm to prevent nutrient overloading in the soil due to manure spreading. Finally, biogas used for power production replaces the use of fossil fuels for the same purpose.

Pennsylvania Outlook

Opportunities for utilization of biogas produced by anaerobic digestion are moderate to good. Power production is typically a secondary consideration in these projects. Increasingly stringent agricultural manure management regulations will enhance opportunities.

6.2 LANDFILL GAS

Landfills generate gas as a byproduct of the decomposition of their contents. This landfill gas (LFG) typically has a methane content between 45 and 55 percent and is considered to be an environmental risk. Political and public pressure is rising to reduce air and groundwater pollution and the risk of explosion associated with LFG. From an energy generation perspective, LFG is a valuable resource that can be burned as fuel by reciprocating engines or small gas turbines.

LFG was first used as a fuel in the late 1970s. Since then, technology to collect and use the LFG has steadily improved. LFG energy recovery is now regarded as one of the more mature and successful of the waste to energy technologies. There are more than 600 LFG energy recovery systems in 20 countries.

Applications

Landfill gas is produced by the decomposition of the organic portion of waste stored in landfills. This gas is flammable and can be collected and converted to electricity through various schemes. LFG can also be used directly for process heat or may be upgraded for pipeline sales. The major constituents released from landfill wells are carbon dioxide and methane. LFG contains trace contaminants such as hydrogen sulfide and siloxanes that should be removed prior to use.

Power production from LFG facilities is typically less than 10 MW. As discussed earlier, several types of conversion devices can be employed to generate electricity from LFG. Typically the equipment requires only minor modification so long as the gas is properly cleaned and prepared. Internal combustion engines are by far the most common generating technology choice. About 75 percent of landfills that generate electricity use engines.[6]

Depending on the scale of the gas collection facility, it may be feasible to generate power via a combustion turbine and/or a steam turbine. Testing with microturbines and fuel cells is also underway, although these technologies do not appear to be economically competitive for current applications (see Section 8).

Resource Availability

Gas production in a landfill is dependent upon the depth of waste in place and amount of precipitation received by the landfill. Each landfill is unique because each has a different volume, receives a different amount of water, and has a different material composition. This variability makes it important to measure the quantity and quality of gas at a landfill before installing a power generation system.

In general, LFG recovery may be economically feasible at sites that have more than one million tons of waste in place, more than 30 acres available for gas recovery, a waste depth greater than 40 feet, and the equivalent of 25+ inches of annual precipitation. There are methods of changing both the quantity and quality of the LFG, if required, but doing so will affect the life span of the LFG supply. It is particularly important to understand that every landfill will reach a point after closure at which time the LFG production will decrease and eventually diminish below economically viable levels.

Figure C-10. LFG Well Drilling.

Many existing landfills have collection systems to remove leachate and LFG from the landfill to prevent it from infiltrating ground water supplies and causing other nuisance problems. These systems are usually connected to a flare system if there is not a power generation system installed. The flares burn off the methane in the LFG.

In some cases, the payback period of LFG energy facilities is between 2 and 5 years, especially when environmental credits are available. Capital costs are dependent on the conversion technology and landfill characteristics, especially the presence of a gas collection system. The cost of installing a gas collection system at an existing landfill can be prohibitive. Performance and cost estimates for typical LFG projects are summarized in Table C-9.

[6] EPA Landfill Methane Outreach Program.

Table C-9. Landfill Gas Technology Characteristics.

Performance	
Net Plant Capacity (MW)	0.2-15
Capacity Factor (percent)	70-90
Economics	
Capital Cost ($/kW)	1,300-2,700
Variable O&M ($/MWh)	15
Levelized Cost ($/MWh)	40-70
Technology Status	
Commercial Status	Commercial
Installed US Capacity (MW)	1,100
Pennsylvania Potential	Good

Environmental Impacts

Combustion of landfill gas, as with nearly any other fuel source, does release some environmental pollutants. However, landfill gas to energy systems are generally viewed in a positive light by environmentalists because landfill gas that is otherwise released to the atmosphere is a significant source of greenhouse gas emissions. Collecting the gas and converting the methane to carbon dioxide through combustion greatly reduces the potency of LFG as a source of greenhouse gas emissions.

Pennsylvania Outlook

The potential for landfill gas power projects in Pennsylvania is good; however, many of the best opportunities have already been developed. Installed LFG power generation capacity in Pennsylvania is about 70 MW.

7. HYDROELECTRIC

Hydroelectric power is generated by capturing the kinetic energy of water as it moves from one elevation to a lower elevation by passing it through a turbine. Often, the water is raised to a higher potential energy by blocking its natural flow with a dam. The amount of kinetic energy captured by a turbine is dependent on the head (distance the water is falling) and the flow rate of the water. Another method of capturing the kinetic energy is to divert the water out of the natural waterway, through a penstock and back to the waterway. This allows for hydroelectric generation without the impact of damming the waterway. The existing worldwide installed capacity for hydroelectric power is by far the largest source of renewable energy at 740,000 MW.[7]

Applications

Hydroelectric projects are divided into a number of categories based upon their size. Micro hydro projects are below 100 kW. Systems between 100 kW and 1.5 MW are classified as mini hydro projects. Small hydro systems are between 1.5 and 30 MW. Medium hydro is up to 100 MW, and large hydro projects are greater than 100 MW. Medium and large hydro are good resources for baseload power generation because they have the ability to store a large amount of potential energy behind the dam and release it consistently throughout the year. Small hydro projects generally do not have large storage reservoirs and are not dependable as peaking resources.

An especially attractive hydro resource is the upgrading and modernization of existing facilities, many of which were built more than 30 years ago. Such "incremental" hydro includes unit additions, capacity upgrades, and efficiency improvements.

[7] International Energy Agency, 2002.

Resource Availability

Hydroelectric resource can generally be defined as any flow of water that can be used to capture the kinetic energy of its water. Projects that store large amounts of water behind a dam regulate the release of the water through turbines over time and generate electricity regardless of the season. These facilities are generally baseloaded. Pumped storage hydro plants pump water from a lower reservoir to a reservoir at a higher elevation where it is stored for release during peak electrical demand periods. Run-of-the-river projects do not impound the water, but instead divert a part or all of the current through a turbine to generate electricity. This technique is used at Niagara Falls to take advantage of the natural potential energy of the waterfall. Power generation at these projects varies with seasonal flows.

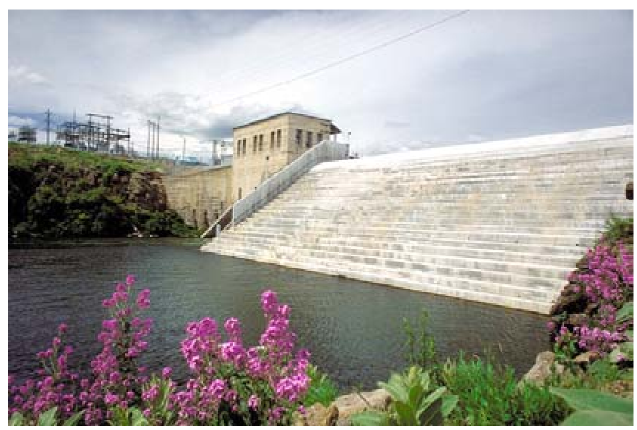

Figure C-11. 3 MW Small Hydro Plant.

All hydro projects are susceptible to drought. In fact the variability in hydropower output is rather large. The aggregate capacity factor for all hydro plants in the US has ranged from a high of 47 percent to a low of 31 percent in just the last five years.[8]

[8] Energy Information Administration, *Renewable Energy Annual 2002*.

Cost and Performance Characteristics

Hydroelectric generation is usually regarded as a mature technology that is unlikely to advance. Turbine efficiency and costs have remained somewhat stable; however, construction techniques and costs continue to change. Capital costs are highly dependent on site characteristics and vary widely.

Table C-10 has ranges for performance and cost estimates for Pennsylvania hydro projects for two categories: new projects at undeveloped sites and incremental hydro at existing sites. These values are for representative comparison purposes only. Capacity factors are highly resource dependent and can range from 10 to more than 90 percent. Capital costs also vary widely with site conditions. To be able to predict specific performance and cost, site and river resource data would be required.

Table C-10. Hydro Technology Characteristics.

Performance	New	Incremental
Net Plant Capacity (MW)	<50	1-160
Capacity Factor (percent)	40-60	40-60
Economics		
Capital Cost ($/kW)	2500-4500	600-3000
Fixed O&M ($/kW-yr)	5 - 25	5 - 25
Variable O&M ($/MWh)	2.5 - 6	2 - 6
Levelized Cost ($/MWh)	90-160	25-110
Technology Status		
Commercial Status	Comm.	Comm.
Installed US Capacity (MW)	79,842	NA
Pennsylvania Potential	Moderate	Good

Environmental Impacts

The damming of rivers for small and large scale hydro applications may result in significant environmental impacts. The first issue involves the migration of fish and disruption of spawning habits. One of the few viable abatements of this issue is construction of "fish ladders" to aid the fish in bypassing the dam when they swim upstream to spawn.

The second issue involves flooding existing valleys that often contain wilderness areas, residential areas, or archeologically significant remains. There are also concerns about the consequences of disrupting the natural flow of water downstream and disrupting the natural course of nature.

More positively, reservoirs resulting from dams can be valuable recreation areas, and dams assist in flood control efforts, thereby preventing economic hardship and loss of life.

Many environmental groups object to the broad definition of hydroelectric resources as renewable. Numerous classification systems for hydro have developed in an attempt to distinguish "renewable" projects. Generally this distinction is based on size, although "low-impact," low-head, and run-of-river plants are also often labeled renewable. Incremental hydro, which generally does not alter water flows any more than the existing dam may also qualify as renewable.

Pennsylvania Outlook

The potential for hydropower in Pennsylvania is largely determined by environmental factors. There are still numerous new sites with good potential and many opportunities for incremental additions that have low environmental impact.

ECONOMIC IMPACT OF RENEWABLE ENERGY IN PENNSYLVANIA

D. RENEWABLE RESOURCES ASSESSMENT

5 March 2004

building a world of difference™ BLACK & VEATCH

1. SUMMARY AND INTRODUCTION

The objective of this section is to assess the renewable energy resources of Pennsylvania. The total technical and near-term potential for each resource is quantified, levelized generation costs are calculated, and a set of supply curves is developed. Results are presented for two general classes of resources:

- Relatively large scale generating technologies built to meet a 10 percent Renewable Portfolio Standard (RPS).
- Distributed renewable resources adopted by the market for "behind the meter" applications.

The end result of this section is a projection of the portfolio of technologies that will be built to satisfy the Pennsylvania renewable energy market. Section E then compares the economic impacts of this renewable portfolio compared to "business as usual" development of fossil fuel technologies.

This initial section describes the resource assessment methodology and presents summary results. It is followed by the resource assessment and supply curve development for each of the candidate technologies.

1.1 GENERAL METHODOLOGY

The resource potential for utility-scale power generation and utilization of distributed resources was estimated by the following general methodology:

- Resource characterization
- Technology selection
- Definition of assumptions
- Technical and near-term potential estimation
- Levelized generation cost estimation
- Supply curve generation

An overview of these steps is provided below.

Resource Characterization

Information on the various renewable energy resources in Pennsylvania were obtained from government agencies (NREL, ORNL, and USDA), and recent studies of renewable energy potential (INEEL). The available renewable energy resources were filtered to remove portions of the resource that are not technically feasible or face other obstacles which prevent their large-scale adoption. Each resource was then further divided into categories based on development cost.

Technology Selection

Potential technologies for renewable energy generation were identified in Section C, including the following:

- Wind Turbines (wind farms and single turbines)
- Solar Photovoltaic
- Solar Thermal (parabolic trough, parabolic dish, central receiver, and solar chimney)
- Geothermal (dry steam, flash steam, and binary cycle)
- Biomass Direct Firing
- Biomass Cofiring
- Landfill Gas (internal combustion engines, microturbines, and fuel cells)
- Digester Gas (internal combustion engines, microturbines, and fuel cells)
- Hydroelectric turbines

This list of possible technologies was narrowed for detailed analysis to include only those technologies that are fully commercial, economically competitive, and applicable to the available renewable energy resources in Pennsylvania. The technologies chosen for the detailed analysis include the following:

- Wind Turbines (wind farms)
- Biomass Cofiring
- Landfill Gas - internal combustion engines
- Digester Gas - internal combustion engines
- Hydroelectric turbines
- Solar Photovoltaic

Assumptions

Conservative technical and economic assumptions were developed for each technology to calculate realistic estimates of electric generation potential and costs. Technical assumptions included efficiency, project capacity, and capacity factor. Economic assumptions included capital cost, operating cost, economic life, fuel cost (where applicable), and financing costs.

Section D.2 summarizes the general assumptions used in the analysis. Additional technology-specific assumptions are described in the later portions of this document.

Pennsylvania Renewable Energy Potential

The technology assumptions were applied to the resource classes to obtain an estimate of the total technical and near-term potential in the state. The technical potential estimate represents resource that could be implemented considering constraints on land use, resource quality, theoretical efficiency, etc. The near-term potential is an estimate of the market potential of the resource within the next 10 to 15 years. This estimate was developed based on consideration of market barriers, technology status, penetration rates, environmental impacts, and relative economic competitiveness. Table D-1 shows the near-term and technical potential for the large scale renewable resources evaluated for RPS compliance.

The analysis shows that Pennsylvania has enough long term renewable energy potential to satisfy its entire electrical power needs. According to the EIA, in 2002, the total electrical consumption in Pennsylvania was 139,960 GWh. This study identified 224,037 GWh of long term renewable energy technical potential, or 160% of the 2002 consumption. Most of this potential energy is from relatively high cost solar. In the near-term, it appears feasible and economically viable to develop over 5,200 MW of renewable energy capacity in Pennsylvania, enough to generate over 17,600 GWh of electricity. This is 12.6 percent of the 2002 energy consumption.

Table D-1. Pennsylvania Renewable Energy Potential.

Capacity	Technical, MW	Near-Term, MW
Biogas	223	89
Biomass Cofiring	4,361	1,023
Biomass Direct*	1,072*	—
Hydro	2,142	561
Solar	114,000	4
Wind	14,777	3,531
Total	136,575	5,208
Energy	**Technical, GWh**	**Near-Term, GWh**
Biogas	1,563	624
Biomass Cofiring	24,305	5,900
Biomass Direct*	7,512	—
Hydro	9,194	2,408
Solar	137,812	4.8
Wind	43,651	8,696
Total	224,037	17,633

* It is assumed that available biomass will be used in cofiring applications before direct use.

Supply Curves

Supply curves were developed for each renewable resource and then aggregated to determine the overall mix of technologies developed in response to the RPS. A supply curve is used in economic analysis to determine the quantity of a product that is available at various prices. In this study, the renewable generation added by each resource class is plotted against its levelized cost of electricity in ascending order. For example, the near-term potential (GWh) from high speed wind resources was plotted against its levelized cost ($/MWh); lower speed wind projects have higher costs and represent the next "step" up on the supply curve. Cost and technical potential were estimated for all the resources and then aggregated such that an overall supply curve for all renewable resources was developed, as shown in Figure D-1.

This curve compares the quantities and costs for the renewable resources and shows which products can be brought to market at the lowest cost (resources on the left side). Incremental hydro and biomass cofiring are the lowest cost resources.

In addition to the RPS technologies shown in the chart below, the potential for utilization of distributed resources was estimated by assessing the market for each technology. Plausible assumptions about the rate of adoption by homeowners and commercial enterprises were made to estimate the potential conventional energy savings from adoption of distributed technologies.

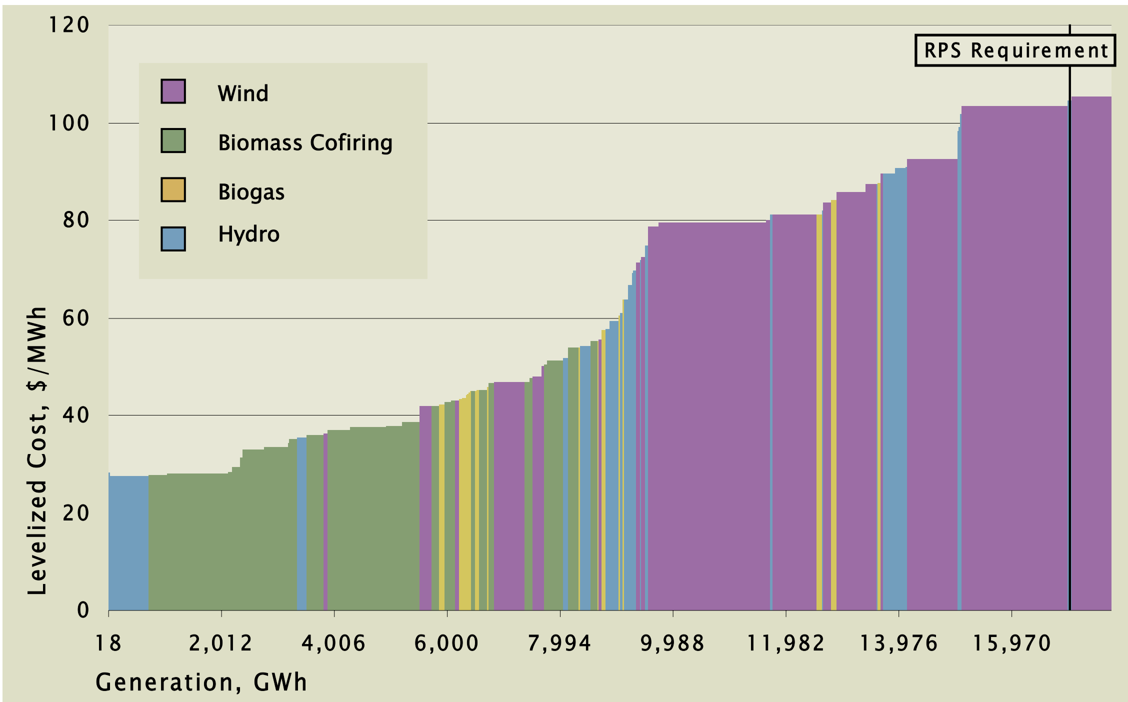

Figure D-1. Near-Term Potential Renewable Energy Generation Supply Curve.

1.2 SUMMARY CONCLUSIONS

The mix of renewable resources developed to meet the RPS was estimated from the projected energy demand for Pennsylvania and the aggregated levelized cost supply curve. The supply curve was then compared against the requirements of the proposed RPS, Table D-2.

Based on the resource assessment, wind, biomass cofiring, biogas and hydro electric generation technologies appear to be the most likely technologies to be developed under an RPS, with wind and biomass co-firing accounting for around 80 percent of the total required renewable generation. In addition, despite its high cost, a small level of solar photovoltaic energy is assumed to contribute to the RPS. Each of these technologies has sufficient resource potential to produce far more energy than would be applied towards the RPS requirements. This generation mix represents an estimate of one potential renewable energy portfolio capable of meeting the requirements of the RPS.

Table D-2. Projected RPS Requirements

Year	Projected Demand, GWh	RPS Requirement, %	RPS Requirement, GWh
2006	148,548	1.0	1,485
2015	169,848	10.0	16,985
2025	197,116	10.0	19,711

Table D-3 shows the cost and generation contributed by each technology towards the RPS. This table presents the weighted average values for all resources that make up the supply mix. In some cases, this weighted average is substantially higher than the current economic environment. For example, wind projects in Pennsylvania are currently seeking power purchase agreements at around $40/MWh, while the table shows an average levelized cost value of around $82.50/MWh for wind. There are a few reasons for this

- The table represents the average of all wind projects expected to be developed in response to the RPS. These projects include many relatively poor Class 3 resources. The costs range from $33/MWh to $103/MWh.
- The capital and operating cost assumptions are intentionally conservative
- The assumed financing costs for the study are higher than current market conditions
- For the purposes of this study, available wind resources were limited to Pennsylvania. Lower cost wind resources are likely available in surrounding states.

The analysis of the potential for distributed resources found that considerable conventional energy savings could be realized if these technologies were adopted on a large scale, 30 percent of homeowners in Pennsylvania. Fuel cell and microturbine technology have the potential to generate power from renewable fuels efficiently; however, these technologies are not yet commercial and are not expected to have an impact within the term of the RPS (2015). Small wind turbines have the potential to provide power to rural communities and farms. Solar photovoltaic technology has the potential to supply all of the electricity needs for the state; however, near-term potential is only a fraction of total demand. Large-scale adoption of solar thermal and geothermal heat pump technologies could reduce the residential consumption of fossil fuels for space and water heating by 40 percent. Green building practices, if applied consistently across new building and renovation projects could conserve considerable amounts of fossil fuels and electricity in the state.

Table D-3. RPS Renewable Energy Portfolio (Weighted Average Values).

Technology	Wind*		Biomass	Landfill	Digester	Hydro	Solar
	Low	High	Cofiring	Gas	Gas		
Share of RPS Mix (energy), %	23	23	34.6	3.7	1.5	14.2	0.0
Generation, GWh	3,901	3,914	5,900	625	258	2,424	4.84
Capacity, MW	1616	1,529	1,023	89	37	554	4
Capacity Factor,	27.6	29.2	65.8	80.0	80.0	49.9	13.8
Capital Cost, $/kW	1,293	1,823	346	1,590	2,510	1,502	7,245
Variable O&M, $/MWh	7.0	7.4	0.0	15.0	15.0	2.7	0.0
Fixed O&M, $/kW/yr	20.5	20.5	12.1	0.0	0.0	10.3	0.0
Fuel Cost, $/MBtu	–	–	2.05	–	–	–	–
Heat Rate, Btu/kWh	–	–	11,146	–	–	–	–
Levelized Cost Range, $/MWh	33–81	66–103	28–55	42–68	81–88	27–104	488–681
Average Levelized Cost, $/MWh	70	95	36.58	48.20	83.72	57.62	551.42

*Note: In addition to cost differences for transmission distance and wind class, two general cost categories were modeled for wind for this study: "inexpensive" and "expensive". Inexpensive, low cost projects will be the first to be developed, while expensive sites are remote, have difficult construction access, high land cost, etc. This study conservatively assumed that approximately 50 percent of Pennsylvania wind sites are classified as expensive.

2. GENERAL RESOURCE ASSESSMENT ASSUMPTIONS

Conservative assumptions for the performance and financing of renewable technologies were made to construct realistic estimates of the development potential and costs. This section describes the general assumptions, economic assumptions, and RPS assumptions used for the resource assessment. Additional technology-specific assumptions are described in the later portions of this section.

General Assumptions

Black & Veatch used conservative general assumptions about the implementation of the RPS to calculate the cost of compliance. These assumptions tend to increase the cost of compliance; however, they will also increase the apparent potential economic benefits of the RPS.

Except for wind, no relative technology learning is assumed. This assumption fixes the capital cost of a given technology for the life of the study period (adjusted for inflation), rather than assuming that the cost to install a given technology will decline as the technology improves and industry experience increases. This assumption is reasonable given that the technologies selected for compliance with the RPS are relatively mature and no major innovations are expected over the next 10 to 15 years. The major exception is for wind technology, which is expected to slightly improve in cost over the term of the RPS. Capital costs for wind projects were kept constant in real terms (zero escalation). Solar technologies are also expected to improve in cost; however, they comprise such a small portion of the RPS portfolio mix that this effect was neglected.

Economic Assumptions

A levelized generation cost for each of the technology classifications identified in the resource assessment was calculated. This cost allows the various technologies to be compared to identify the least cost renewable energy resources most likely to be developed under an RPS. By comparing only busbar costs the capacity value of the different renewable technologies is not considered. This issue is revisited in the next section where the renewables are compared to fossil fuel expansion options.

To develop an estimate of the cost to generate power over the life of a project, the following assumptions are required.

- Project performance
- Project life
- Financing structure (debt / equity)
- Debt cost
- Loan term
- Equity cost
- Depreciation cycle
- Levelized fixed charge rate

An RPS cost study recently completed for the New York Public Service Commission was used to confirm project financing and economic assumptions.[1] Table D-4 shows the economic assumptions made for the resource assessment.

The economic life of each technology was selected to reflect current industry expectations for the life of each type of project. Biomass cofiring and livestock manure digestion were given shorter economic lives due to the uncertainty of a coal-fired power plant or a farm continuing a project for longer than 10 years.

The financing structure of 60 percent debt and 40 percent equity was chosen for all technologies except residential PV and manure digestion, was selected to reflect current industry practice for independent power producers (the most likely party

[1] State of New York Public Service Commission, "New York Renewable Portfolio Standard Cost Study Report" July, 28, 2003.

developing projects in response to this RPS). Residential PV systems are assumed to be financed entirely through home equity loans. Manure digestion projects are assumed to financed through loans to the farms.

The interest rate for debt is indicative of current market rates, and those received by recent projects. The debt term for shown in Table D-4 was selected to reflect current industry practice for each technology.

The cost of equity is an approximation of the return on an investment a renewable energy project investor would require taking into account the rate of return that an investor could receive on a comparable investment.

Tax depreciation is the time period over which a project can deduct the initial capital investment from project revenues for tax purposes. Because of legislation enabling the accelerated depreciation of landfill gas, wind, and photovoltaic energy equipment, these technologies were allowed 5-year a double declining balance Modified Accelerated Cost Recovery System (MACRS) depreciation. Industry standard time periods for utility plant and equipment were used for the other projects by the MACRS method. The temporary "bonus" 30 percent first year depreciation was not included in the timeframe of the analysis.

The Levelized Fixed Charge Rate is used to calculate a constant annual charge to offset a project's fixed costs. This rate is applied to the total capital cost of a project and accounts for financing costs, taxes, and other fixed costs related to the plant. The project financial assumptions for each technology yielded the Levelized Fixed Charge Rates shown in Table D-5.

Federal tax incentive programs were included in the analysis of the cost to generate electricity from selected technologies. The production tax credit (PTC) was included for all wind resources at a rate of $18/MWh (2003$) escalated at 3 percent for the first 10 years of the project life. The PTC also applies to closed loop-biomass and poultry litter, but the study projects little use of these resources. Although the PTC expires at the end of 2003 and at this time has not been renewed, we have assumed that the PTC will be renewed within the next year, and will extend indefinitely through the study period. A federal investment tax credit for solar photovoltaic systems of 10 percent of the initial cost of the system was applied to solar projects.

Table D-4. Renewable Energy Technology Economic Assumptions

Technology	Economic Life	Financing Structure Debt / Equity	Debt Term	Interest Rate	Equity Cost	Tax Depreciation
Biomass Cofiring	10 yrs	60 / 40	10 yrs	8.0 %	16 %	10 yrs
Landfill Gas	20 yrs	60 / 40	10 yrs	8.0 %	16 %	5 yrs
Wind	20 yrs	60 / 40	15 yrs	8.0 %	16 %	5 yrs
Hydro (upgrades)	20 yrs	60 / 40	20 yrs	8.0 %	16 %	20 yrs
Hydro (new)	20 yrs	60 / 40	20 yrs	8.0 %	16 %	20 yrs
PV – Residential	20 yrs	100 / 0	20 yrs	5.0 %	16 %	5 yrs
PV – Commercial	20 yrs	60 / 40	20 yrs	8.0 %	16 %	5 yrs
Manure Digestion	10 yrs	60 / 40	10 yrs	8.0 %	16 %	10 yrs

Adapted from State of New York Public Service Commission, "New York Renewable Portfolio Standard Cost Study Report" July, 28, 2003.

Table D-5. Levelized Fixed Charge Rates

Technology	Rate, %
Biomass Cofiring	18.9
Landfill Gas	17.8
Wind	11.0
Hydro (upgrades)	15.0
Hydro (new)	15.0
Solar PV – Residential	7.0
Solar PV – Commercial	12.7
Manure Digestion	18.9

Pennsylvania RPS Baseline Assumptions

Table D-8 outlines a proposed implementation timeline for a 10 percent RPS. Table D-7 provides a list of baseline RPS assumptions made by Black & Veatch in the resource assessment and analysis of RPS economic impacts. These assumptions are made on the basis of other successful RPS programs deployed in the US and abroad. In the event that the final RPS rules are different from those assumed, the results of the analysis will invariably change.

The RPS analysis focuses on grid-connected renewable energy electric power generation. Further, this analysis assumes that all of the renewable energy capacity required to meet the RPS will be installed within Pennsylvania. Although the RPS is likely to allow credit trading that would enable renewable energy projects outside of the state to count towards the RPS, this assumption is conservative in that it will likely project the highest cost method of complying with the RPS.

Table D-6. RPS Implementation Timeline

Year	Pct of Load	Total Load, GWh	Required Renewables, GWh
2006	1%	148,548	1,485
2007	2%	150,777	3,016
2008	3%	153,038	4,591
2009	4%	155,334	6,213
2010	5%	157,664	7,883
2011	6%	160,029	9,602
2012	7%	162,429	11,370
2013	8%	164,866	13,189
2014	9%	167,339	15,060
2015	10%	169,849	16,985
2016	10%	172,397	17,240
2017	10%	174,982	17,498
2018	10%	177,607	17,761
2019	10%	180,271	18,027
2020	10%	182,975	18,298
2021	10%	185,720	18,572
2022	10%	188,506	18,851
2023	10%	191,333	19,133
2024	10%	194,203	19,420
2025	10%	197,116	19,712

Table D-7. RPS Analysis Assumptions

Renewable Portfolio Standard	Retail electricity suppliers must provide 10 percent of their electrical energy from new (post 2005) renewable sources. The mandate will begin at 1.0 percent of total load in 2006, and increase by 1 percentage point annually thereafter. After the target of 10 percent has been reached in 2015, sufficient renewable energy generation must be either installed, or additional renewable energy credits purchased to maintain the 10 percent standard.
Qualifying Technologies	Wind, solar photovoltaic, solar thermal, biomass (including energy crops, non-hazardous urban wood waste, forestry residues, and agricultural residues), landfill and digester gas, low-impact hydro, and geothermal. Municipal solid waste shall not qualify. Low-impact hydro shall include new undeveloped sites with minimal environmental impact, adding generation to dams without current generation, and upgrades to existing hydroelectric plants to increase generation
Imports / Exports	As a simplifying assumption, it is assumed that all renewable generation will come from in-state sources. The state policies regarding renewable energy in the northeast are in flux and promise to create a dynamic market. While imports would likely lower the RPS compliance cost, they would also have a negative impact on the potential economic impacts (for example, jobs) in Pennsylvania. Additionally, existing RPS policies in New York and New Jersey will limit imports from these states. In reality, Pennsylvania may actually export renewable generation, or renewable credits, to either of these states to assist out-of-state utilities in complying with their RPS mandates.
Energy Demand Growth	The energy demand will be assumed to be equal to the 1.5 percent annual growth rate forecast by PJM.

3. WIND

A number of potential sites suitable for wind power generation were identified. These sites were categorized by wind resource quality and distance from existing transmission infrastructure. Project criteria were assigned to each classification of wind resource, and a levelized cost of power was calculated for each type.

Resource Description

Wind speed increases significantly with height and wind turbine power output rises with the cube of wind speed, which makes small differences in wind speed very significant. Wind strength is rated on a scale from Class 1 to Class 7, see Table D-8. Wind speeds and power densities (W/m^2) at a Class 1 site and at a 50 m height can go as high as 5.5 m/s and 200 W/m^2. In comparison, wind speeds and power densities at a Class 7 site and at the same hub height may be above 8.80 m/s and 800 W/m^2. Class 4 sites and higher are usually considered the lowest economically viable for wind project development, although Class 3 sites were also examined for this study. At Class 3 sites wind speeds may reach 7.0 m/s with a power density of 400 W/m^2 at a 50 m height. Regardless of the existence of high resolution resource maps for some regions, a minimum of one-year of site data collection is typically required to determine if utility-scale wind energy is viable at a specific location.

Methodology

Black & Veatch performed a geographic information system (GIS) analysis of the potential for wind power generation in Pennsylvania. The National Renewable Energy Laboratory (NREL) provided data on the wind resource class in a 200 m grid across the state.[2]

Table D-8. US DOE Classes of Wind Power

Wind Power Class	Height Above Ground: 50 m (164 ft)* Wind Power Density W/m²	Speed** m/s
1	0 – 200	0 – 5.60
2	200 – 300	5.60 – 6.40
3	300 – 400	6.40 – 7.00
4	400 – 500	7.00 – 7.50
5	500 – 600	7.50 – 8.00
6	600 – 800	8.00 – 8.80
7	800 – 2,000	8.80 +

Notes:
*Vertical extrapolation of wind speed based on the 1/7 power law.
**Mean wind speed is based on Rayleigh speed distribution of equivalent mean wind power density. Wind speed is for standard sea-level conditions. To maintain the same power density, wind speed must increase 3%/1000 m (5%/5000 ft) elevation.

The data was plotted with PowerMAP®, and regions where wind farm development would be unlikely in the near-term were eliminated, including national parks, state parks, state forests, lakes, urbanized areas, and high slope areas. The assessment area included offshore wind resource in Lake Erie, which is relatively shallow and has vast areas of class 5 wind within 10 miles of shore. Finally, the proximity of wind resources to transmission was considered. Figure D-3 shows the areas in Pennsylvania suitable for wind resource development, as well as the operating and planned wind plants.

After Black & Veatch concluded its GIS analysis, new data from a recent NREL analysis was reviewed.[3]

[2] www.eren.doe.gov/windpoweringamerica
[3] www.ccap.org/Connecticut/2003-Oct-30--CT--Elec--Assumptions_for_IPM.pdf

The methodology and results of the two analyses were generally in agreement. The NREL GIS analysis was used as a basis for the near-term potential estimates as described below.

Assumptions

The following assumptions were made in the NREL GIS analysis of the technical potential of wind energy in Pennsylvania.[4]

- The following lands were completely excluded from the technical potential estimate:
  - Slope greater than 20%
  - All National Park Service and Fish and Wildlife Service lands; any other specially designated federal lands (wilderness, recreation area, monuments, etc); state parks or conservation areas or USGS GAP lands designated with the highest protection level
  - Water, Wetlands, Urban areas, Airports / airfields
  - 3 km buffer around all 100 percent exclusions (except water and slope)
- 50 percent of the following lands were excluded from the technical potential estimate: remaining Forest Service and DOD lands; non-ridge crest forest; state forests or USGS GAP lands designated with the second highest protection level
- A minimum density criteria of 5 sq. km. per 100 sq. km. was applied for class 3 or better wind resource.

These additional assumptions were made by Black & Veatch for cost and performance:

- Table D-9 shows base capital cost and capacity factor assumptions for the different wind classes.
- A 300 MW, class 5, offshore wind farm in Lake Erie is included in the resource.
- Capital costs for new transmission are estimated according to methodology developed by EIA for distance to existing transmission lines: $18/kW for 0-5 miles; $54/kW for 5-10 miles; and $108/kW for 10-20 miles. [5]

Table D-9. Wind Project Assumptions.

Wind Class	Capital Cost, $/kW*	Capacity Factor, %**
3	1,275	26
4	1,275	31
5	1,225	34
6	1,175	37
7	1,175	40

*Base cost excluding new transmission (+$18 to 108/kW) and additional cost for relatively expensive sites (+$500/kW)
** Net of losses.

- As the available wind resource is utilized, costs for new wind sites become increasingly higher. Reasons for this include: (1) declining natural resource quality, such as terrain slope, terrain roughness, terrain accessibility, wind turbulence, wind variability, or other natural resource factors, (2) increasing cost of upgrading existing local and network distribution and transmission lines to accommodate growing quantities of intermittent wind power, and (3) market conditions, the increasing costs of alternative land uses, including for aesthetic or environmental reasons.[6] Further, it is expected that the larger wind resource areas will be developed first, higher cost smaller wind farms will be developed later. To account for the higher cost for a portion of the resource, 50 percent of the wind resource available for development is classified as relatively "inexpensive". An additional capital cost of $500/kW has been included for the other half of the wind resource ("expensive").
- Capacity factors are net of losses
- Fixed O&M is estimated to be $20/kW-yr.
- Variable O&M is estimated to be $7/MWh. Costs for integrating wind into the electricity system to account for intermittency are generally relatively small (<$3/MWh) at low grid penetrations. These are included with the variable O&M costs.

[4] Email from Donna Heimiller at NREL, December 29, 2003.

[5] Email from Christopher Namovicz at EIA, July 18, 2003.

[6] Energy Information Administration, "Model Documentation Renewable Fuels Module of the National Energy Modeling System," March 2003.

Resource Assessment

Pennsylvania has a moderate wind resource. Although it is not generally considered to be on the level of the Central Plains, full development of the wind resources in Pennsylvania would still provide over 30 percent of current electric demand of 139,960 GWh for the state.

Table D-10 details the technical potential and wind energy generation in Pennsylvania. Table D-11 show the near term wind potential based on the latest NREL GIS analysis. Although nearly all wind resources in Pennsylvania are relatively close to transmission lines, over two-thirds of the overall resource is relatively low quality Class 3 wind resource. This raises the average levelized cost.

The levelized cost to generate power from each of the wind resource classes was estimated and plotted to construct a wind energy supply curve for Pennsylvania, see Figure D-2.

Table D-10. Wind Energy Technical Potential.

Wind Class	Technical Potential	
	Capacity, MW	Energy, GWh
3	2,598	6,600
4	2,394	6,920
5	9,527	29,210
6	257	855
Total	14,776	43,586

Table D-11. Near Term Wind Potential (MW).

Wind	Miles from transmission			
	0-5	5-10	10-20	Total
3	1,648	665	108	2,422
4	389	133	21.3	543
5	140	50.4	6.2	197
6	37.6	29.1	2.5	69
7	0.2	0.2	0	0.4
Total	2,214	878	138	3,231

Source: NREL, www.ccap.org/Connecticut/2003-Oct-30--CT--Elec--Assumptions_for_IPM.pdf

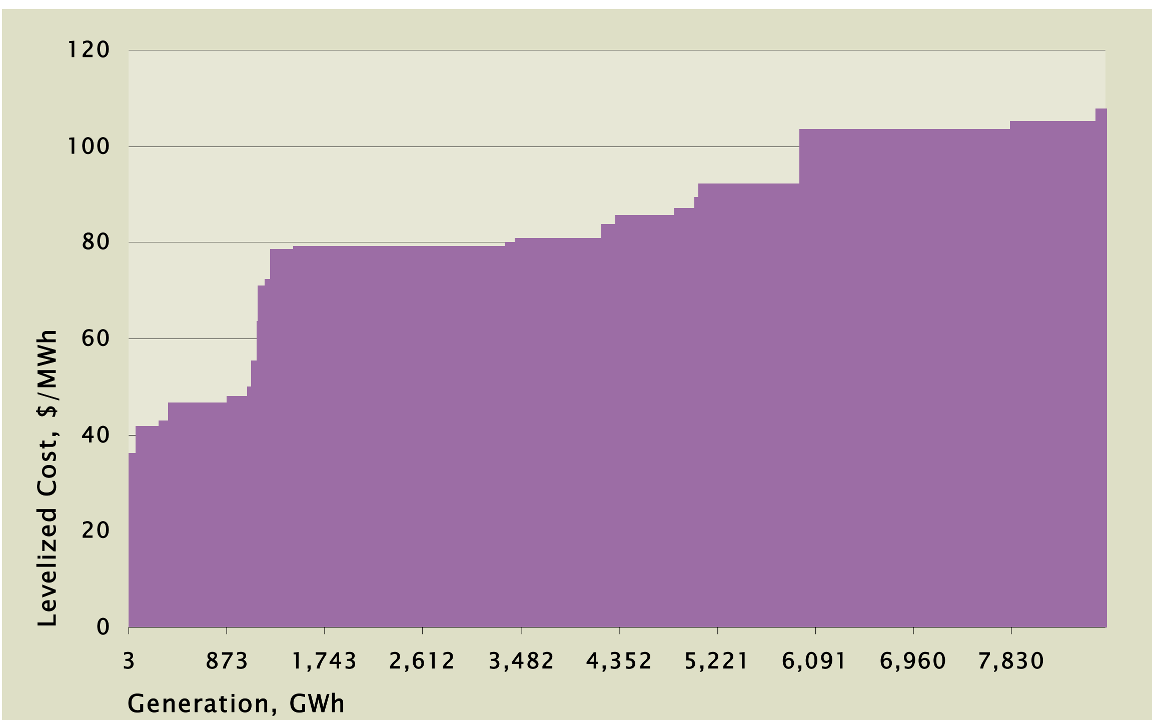

Figure D-2. Levelized Cost Supply Curve for Wind Energy.

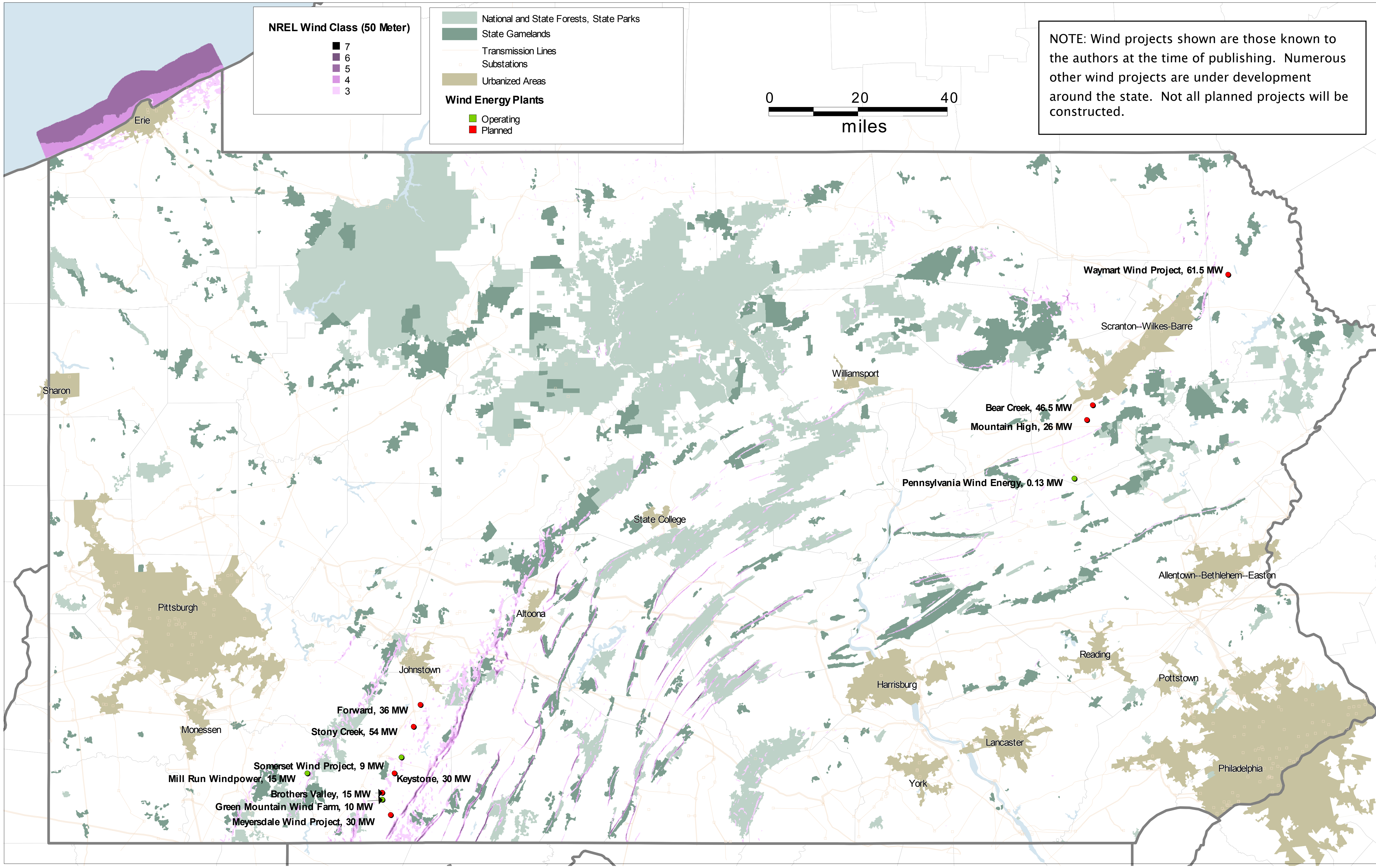

Figure D-3. Map of Wind Energy Potential in Pennsylvania.

4. BIOMASS

A state-wide estimate of the utilization of biomass cofiring at existing coal-fired power stations was conducted. A levelized cost of power was calculated for the incremental cost of generating a percentage of the electric output with biomass.

Biomass cofiring was selected as the preferred biomass utilization option because it can be implemented quickly, at high efficiency, and low cost. There are a large number of coal plants in Pennsylvania that can be retrofitted to burn biomass.

Resource Description

The resource data used for this analysis was provided by Oak Ridge National Laboratory (ORNL). Biomass resources included in the ORNL database include organic matter derived from farming, logging, urban wood wastes, and dedicated energy crops. Estimates of corn stover and wheat straw are based on the amount of crops planted in each county and consider sustainable agricultural practices. The energy crop supply is an estimate of potential production if a market should develop. Urban wood wastes typically include fuels such as construction debris, pallets, yard and tree trimmings. Estimates were derived in a 1999 study of urban wood waste production performed by ORNL. Forestry wastes include mill residues and wastes from logging processes. The supply curves (tons vs. $/dry ton) provided by ORNL include harvesting and collection for waste products (corn stover, wheat straw, and urban and forestry wastes), and profit needed to compete with conventional crops for energy crops.

Pennsylvania is ideal for biomass utilization with diverse, widespread, and sustainable biomass resources. Figure D-4 shows the density of biomass available for under $50 per dry ton in each county in Pennsylvania.

Methodology

Biomass resources were considered for Pennsylvania and the surrounding states that fell within a 75 mile radius around the coal-fired power plants in Pennsylvania. The percentage of the biomass resource from each state falling within the radius was included in the analysis. A portion or all of the states of Delaware, Maryland, New Jersey, New York, Ohio, and West Virginia were included. The available biomass supply was obtained from ORNL for corn stover, wheat straw, forest residues, energy crops, and urban wood waste.

Due to its competitive economics and the region's large installed base of suitable coal-fired plants, biomass cofiring was the only solid biomass technology modeled. A plausible cofiring scenario was developed based on review of Pennsylvania's existing coal power plants. The objective was to coarsely identify which units at the coal plants might be most suitable for cofiring of biomass. The following factors were taken into consideration:

- Coal conversion technology (fluidized bed boilers were favored)
- Age of the plant
- Efficiency
- Capacity factor
- Multiple unit facilities (generally only one unit was selected for cofiring)

Over 80 units were reviewed and, based on the above criteria, 38 were selected as a representative mix for estimation of the near-term potential for cofiring. These units and their characteristics are listed in Appendix D-2.

An appropriate cofiring technology was then established for each unit based on the host unit size, boiler technology, and biomass availability. Most of the host coal facilities use either pulverized coal or circulating fluidized bed boilers. The latter are relatively easy and low cost to adapt to biomass cofiring. However, pulverized coal boilers require special consideration, driving selection of more expensive gasification co-firing technology when cofiring rates exceed 10 percent of boiler heat input. Figure D-4 shows the current installed fleet of Pennsylvania coal fired power plants and the 25, 50, and 75 mile radii around the plants.

Assumptions

The following assumptions were made in the analysis of the technical potential for biomass cofiring in Pennsylvania.

- The total estimated supply of biomass within the 75 mile radius is available to all of the coal-fired power plants considered to have near-term development potential.
- A heat content of 8,500 Btu/dry lb is assumed for all biomass.
- A flat rate of $10/dry ton has been added to all raw biomass costs for transportation.
- Coal unit characteristics (capacity, capacity factor, and heat rate) were obtained from Platt's PowerDAT, or estimated when not reported.
- Economic impacts from efficiency degradation or emission profile improvement are assumed to be offsetting and were not included.
- Project cost assumptions are included in Table D-12.

Table D-12. Cofiring Generation Costs.

Boiler Type	Co-firing Percent	Capital Cost, $/kW	Fixed O&M, $/kW/yr
Stoker	<25	100	5
Fluidized Bed	<25	100	5
Cyclone	<3	100	5
	3-10	200	10
	10-25	700	20
Pulverized Coal	<2	100	5
	2-10	400	14
	10-25	700	20

Resource Assessment

Pennsylvania has excellent potential for biomass cofiring. If all of the biomass within a 75 mile radius of coal plants in Pennsylvania were used in cofiring, it would create over 4,300 MW of renewable energy capacity. At historic capacity factors for these plants, this would provide over 17 percent of current Pennsylvania electric energy demand. Table D-13 provides an estimate of the near-term potential for biomass cofiring in Pennsylvania.

Table D-13. Near-Term Cofiring Potential.

Cofiring Technology	Number	Capacity, MW
Direct Mixing	15	273
Dedicated Feed	20	659
Gasification	3	91
Total		1,023

The levelized cost to generate power from each of the coal-fired power plants selected for cofiring is provided in Figure D-5. The weighted average cost to generate power from all cofiring projects was estimated to be $36.6/MWh.

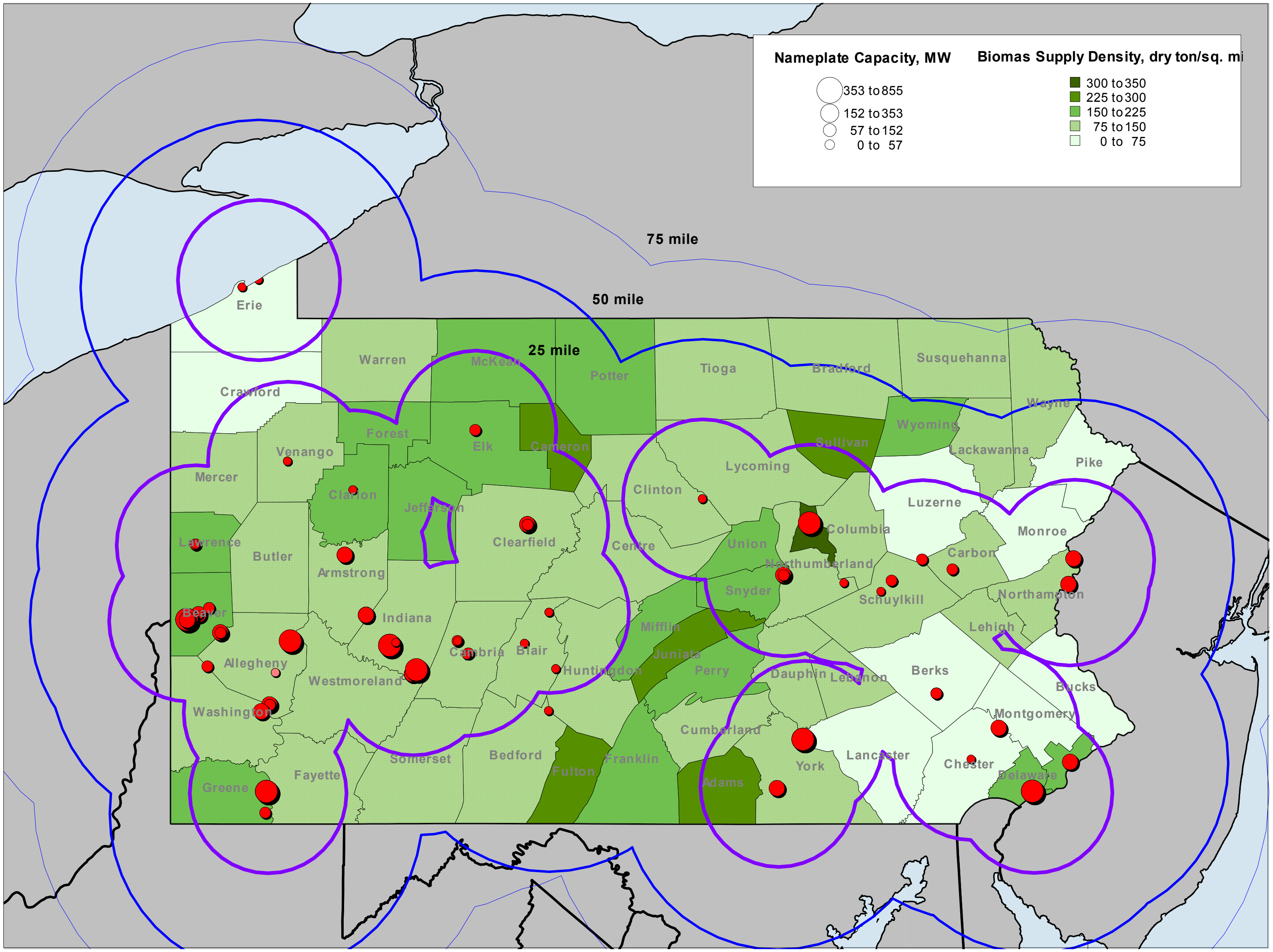

Figure D-4. Map of Installed Coal-Fired Generation and Biomass Resource Distribution.

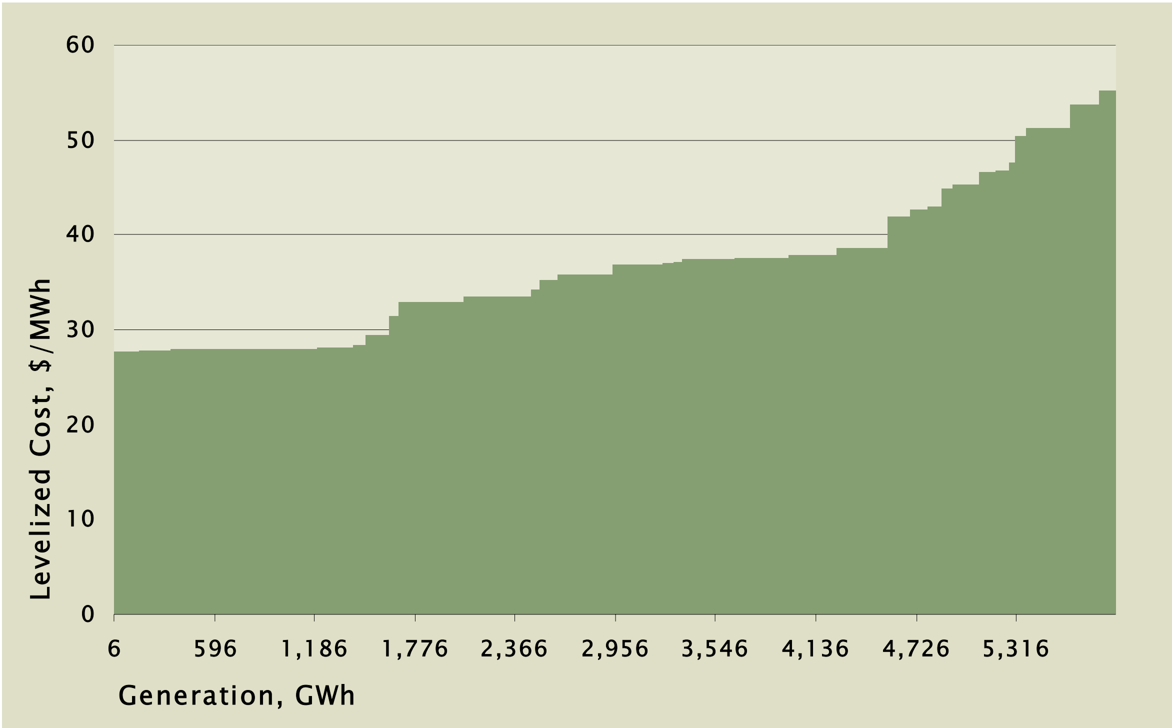

Figure D-5. Levelized Cost Supply Curve for Biomass Cofiring.

5. BIOGAS

An assessment of the potential for the utilization of landfill gas and digester gas was conducted. Several landfills were identified as having the potential for power generation. A county-level assessment of the potential for digester gas was also conducted. The technical potential for power generation and costs were estimated for both resources.

5.1 LANDFILL GAS

Several suitable sites were identified with landfill gas energy generation potential. Project criteria were assigned to each classification, and a levelized cost of power was calculated for each site.

Resource Description

Landfill gas is formed from the decomposition of waste buried in the landfill. The gas is primarily composed of methane and carbon dioxide, with sulfur oxides and other miscellaneous constituents making up the balance. Gas production varies significantly by site, depending on the composition of the waste, dimensions of the landfill, and precipitation. However, a strong correlation exists between the tons of waste in place and quantity of gas production.

Methodology

Black & Veatch utilized the Environmental Protection Agency (EPA) Landfill Methane Outreach Program (LMOP) database of landfills in Pennsylvania to estimate the technical potential for landfill gas power generation at 36 sites. The database provides figures for the landfill size, waste in place, gas generation, and in some cases power generation potential. For the sites where the LMOP database did not estimate the power generation potential, Black & Veatch estimated the generation potential with standard industry factors.

Assumptions

The following assumptions were made in the evaluation of landfill gas power generation potential.

- One million tons of waste in place can support 740 kW of generation capacity.
- Although microturbines, larger combustion turbines, and other types of power conversion equipment are used to convert landfill gas to electricity, internal combustion engines account for a great majority of installations. Cost and performance data for internal combustion engines was used as a basis for this study. Consideration of other technologies would not appreciably alter the results.
- An annual capacity factor of 80 percent is assumed for all landfill gas projects.
- Cost estimates were made for projects with greater than 200 kW of potential.
- Capital cost estimates were based on guidance from the EPA LMOP and ranged from about $1,490/kW for a 1 MW facility to $1,320/kW for a 10 MW facility. These estimates are for facilities with existing gas collection system. For landfills without collection systems, costs would be higher ranging from $2,340/kW for a 1 MW facility to $1,860/kW for a 10 MW facility.
- Operating and maintenance costs were estimated to be $15/MWh for all size ranges.

Resource Assessment

A number of Pennsylvania communities have opened commercial landfills. Because of this, there are a large number of landfills suitable for electric generation. Table D-14 shows the number of landfills identified with potential to generate electricity, and the estimated generation capacity.

The total estimated technical potential for new landfill gas projects in Pennsylvania is 89 MW. The near-term potential is assumed to be the same.

Table D-14. LFG Energy Generation Potential.

Landfill Class	Number	Capacity, MW
< 2.5 million tons	21	18
2.5 to 4 million tons	7	17
> 4 million tons	8	54
Total	36	89

The levelized cost to generate power from each of the potential landfill projects was calculated and is shown on the supply curve in Figure D-6.

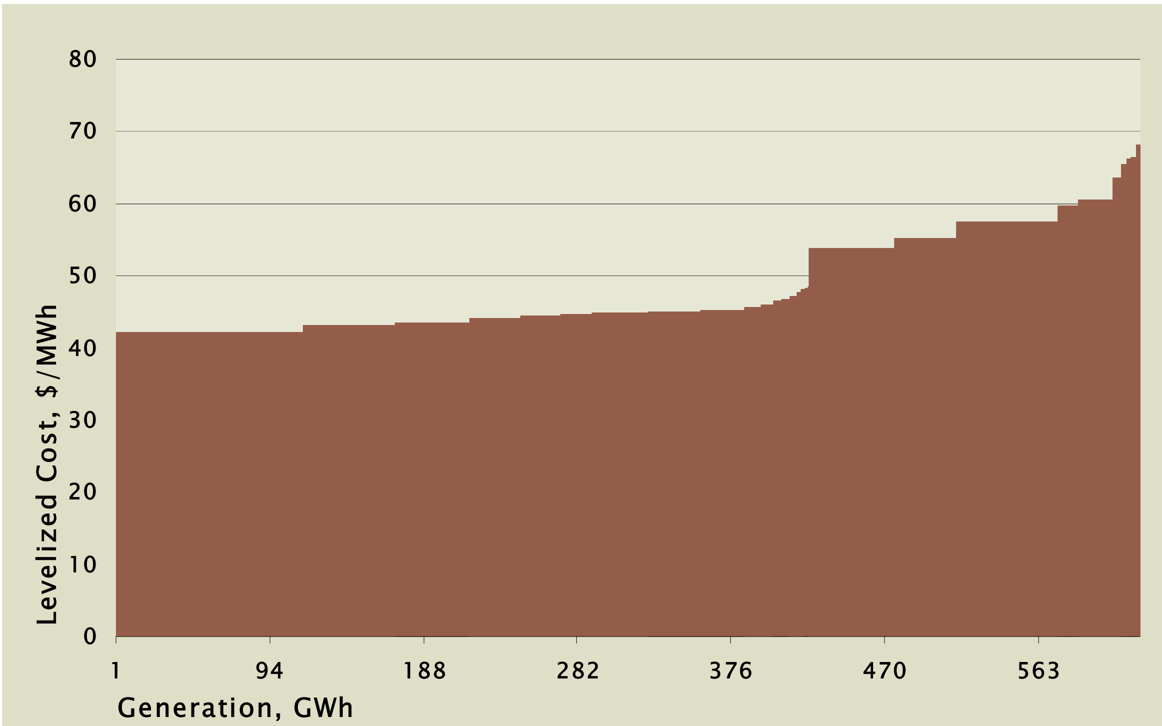

Figure D-6. Levelized Cost Supply Curve for Landfill Gas Power Generation.

5.2 DIGESTER GAS

A county-level assessment of the electric generation potential from anaerobic digestion of cow and swine manures was conducted. The resource was divided into resource classes based on the ease of project execution and efficiency. Project criteria were assigned to each classification, and the levelized cost of power was calculated for each classification.

Resource Description

Throughout rural Pennsylvania there are levels of livestock sufficient to support small digester systems. Power generation is possible if the biogas produced by anaerobic digestion can be captured. Each farm in Pennsylvania is currently required to have an agricultural waste management plan, which usually includes storing animal waste in a lagoon. For small farms, the existing lagoon would require a cover to harvest the gas, while larger farms would optimally require construction of a new digester.

Figure D-7 shows the potential for power generation from digester gas in each county in Pennsylvania.

Methodology

The number of cows and swine for each county in Pennsylvania was obtained from the U.S. Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) database. The data on cows was then divided into small, medium, and large sized farms from a demographic analysis performed previously by Black & Veatch on Bedford and Blair Counties. The generation potential from each of the classes was then calculated from standard industry factors and development costs were estimated.

Assumptions

The following assumptions were made in the evaluation of digester gas power generation potential.

- All digester projects are located on the farm where the manure was generated.
- All digester projects will be equipped with an internal combustion engine to generate power.
- Larger farms are more likely to install digesters in the near-term.
- Additional assumptions are summarized in Table D-15.

Resource Assessment

Pennsylvania has a relatively large potential for digester gas utilization due to the large number of swine and dairy farms. Table D-16 shows the technical potential for power generation from digester gas for Pennsylvania. The levelized cost to generate power from each of the farm types was calculated, and is shown in Figure D-8.

Table D-15. Manure Digester Assumptions.

	Dairy Farms			Swine Farms
Farm Size	Large	Med.	Small	All
Number of Animal Units	>380	220-380	<220	NA
Percent of Total Head	25	11	64	NA
Digester Type	Plug Flow	Plug Flow	Covered Lagoon	Covered Lagoon
Power Potential, head/kW	7.5	7.5	10	15.6
Capital Cost, $/kW	2,625	3,750	2,500	2,386
Operating Cost, $/MWh	15	15	15	15
Capacity Factor, %	80	80	80	80
Near-term Potential, %	80	50	20	20

Table D-16. Digester Energy Generation Potential.

Farm Type	Near-Term Potential		Technical Potential		Levelized Cost, $/MWh
	MW	GWh	MW	GWh	
Swine Farm	13.8	96.7	68.8	482.2	81.1
Small Cow Farm	7.5	52.6	37.4	262.1	84.2
Medium Cow Farm	4.3	30.1	8.57	60.1	87.6
Large Cow Farm	15.6	109.3	19.5	136.7	117.9
Total	**41.1**	**289**	**134**	**941**	**87.9**

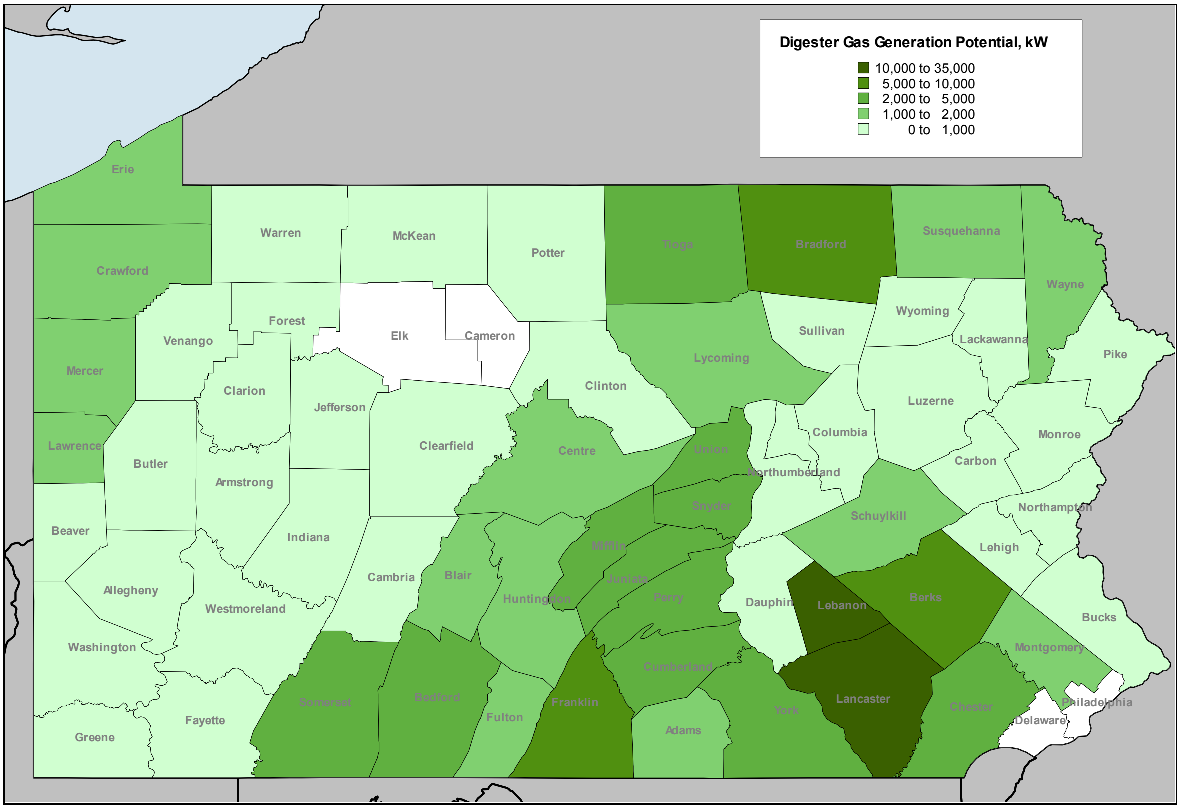

Figure D-7. Map of Digester Gas Power Generation Potential by County.

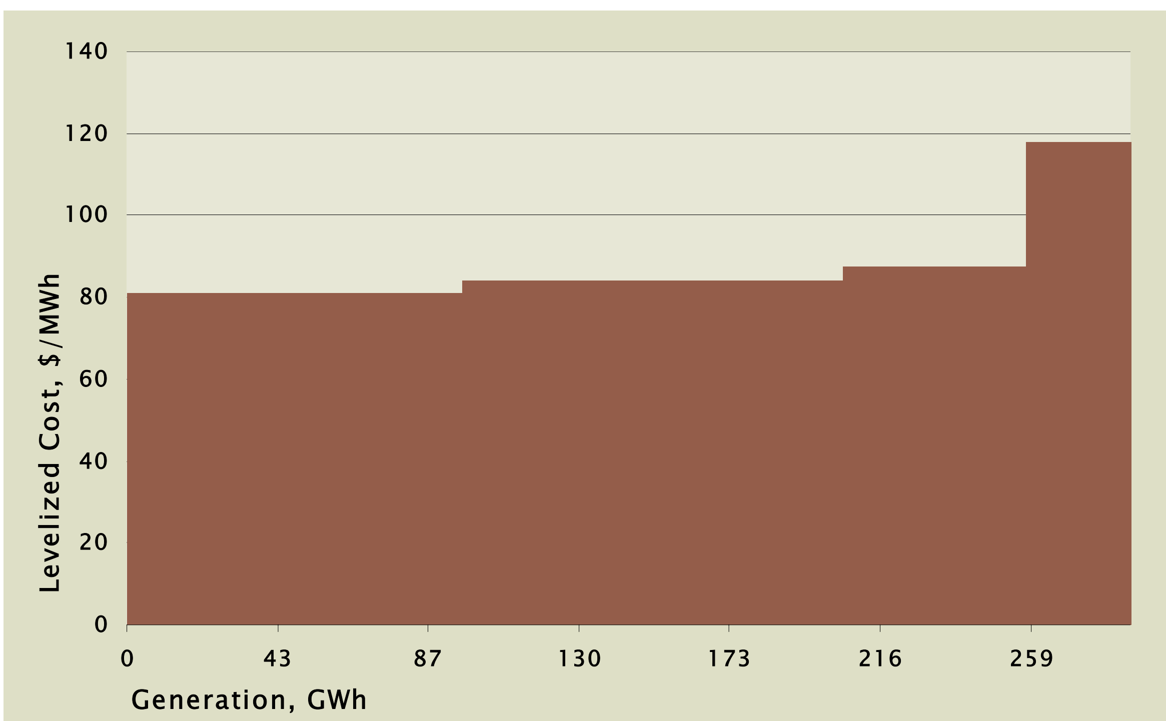

Figure D-8. Levelized Cost Supply Curve for Digester Gas Power Generation.

6. LOW IMPACT HYDRO

A number of suitable sites were identified for low impact hydroelectric generation. Project performance and development costs were estimated from recent reports by the Idaho National Engineering and Environmental Laboratory (INEEL).[7] [8] The levelized cost to generate power was calculated for each project based on the INEEL estimates.

Resource Description

Hydroelectric power is the transformation of the kinetic energy of water, a function of mass and velocity of water flow, into electric energy. Factors that enable the economic generation of hydroelectric energy are extremely site specific. In Pennsylvania, sites suitable for hydro generation are concentrated along the Ohio, Susquehanna, Delaware, and Juniata River systems. A number of sites have been developed, primarily in the early 20th century. In 2002, hydro accounted for about one percent of total electric generation and 6 percent of capacity in the state. Many of the existing facilities are aging, and could reap significant gains in efficiency and generation through refurbishment projects.

Methodology

Black & Veatch used recent studies performed by INEEL detailing the potential for hydroelectric generation in the US. The studies include a database of undeveloped sites, existing dams without generation, and existing hydroelectric plants with the potential to increase generation. Performance, development, and operating costs were estimated for each site. Further, INEEL assigned an Environmental Suitability Factor to each project based on environmental factors including scenic value, geologic value, historical value, rare/endangered wildlife, and location on federal lands. Black & Veatch eliminated projects from the estimate of near-term potential with Environmental Suitability Factors (that is likelihood of development) of less than 50 percent. This resulted in 42 potential projects, all of which are assumed to meet the low-impact definition for this study. Most of these projects are incremental additions to existing dams. However, there are five undeveloped sites identified that have a combined potential of 113 MW. The largest of these are 45 and 50 MW and have an Environmental Suitability Factor of 0.9, the highest possible score.

Assumptions

The following assumptions were made in the evaluation of hydro power generation potential.

- The cost estimates made by INEEL are accurate and reflect the current state of the market for hydro equipment.
- Sites with an Environmental Suitability Factor below 0.5 were considered infeasible and were removed from the estimate of near-term technical potential.
- Projects developed at existing dams are considered to be low impact.
- Undeveloped sites with no environmental restrictions identified are considered to be low impact.

Resource Assessment

Pennsylvania has average potential for low impact hydro generation development. Compared to other states in the INEEL study, Pennsylvania ranked twentieth when projects with an Environmental Suitability Factor below 0.5 were removed. Washington ranks first with an estimated

[7] INEEL, "Estimation of Economic Parameters of U.S. Hydropower Resources," INEEL/EXT-03-00662, June 2003.
[8] INEEL, "Hydropower Equipment Refurbishment or Replacement: Generation Increases and Associated Costs," INEEL/EXT-03-00840, July 2003.

incremental capacity potential of over 3,000 MW. Table D-17 shows the technical and near-term potential for incremental hydro development.

Table D-17. Low Impact Hydro Potential.

Site Type	Near-Term Potential, MW	Technical Potential, MW
Undeveloped	113	1,694
Dam w/o Generation	207	241
Refurbishment	241	207
Total	**561**	**2,142**

The levelized cost to generate power was calculated for each of the projects identified in the INEEL study. Figure D-9 shows the supply curve for hydro generation in Pennsylvania.

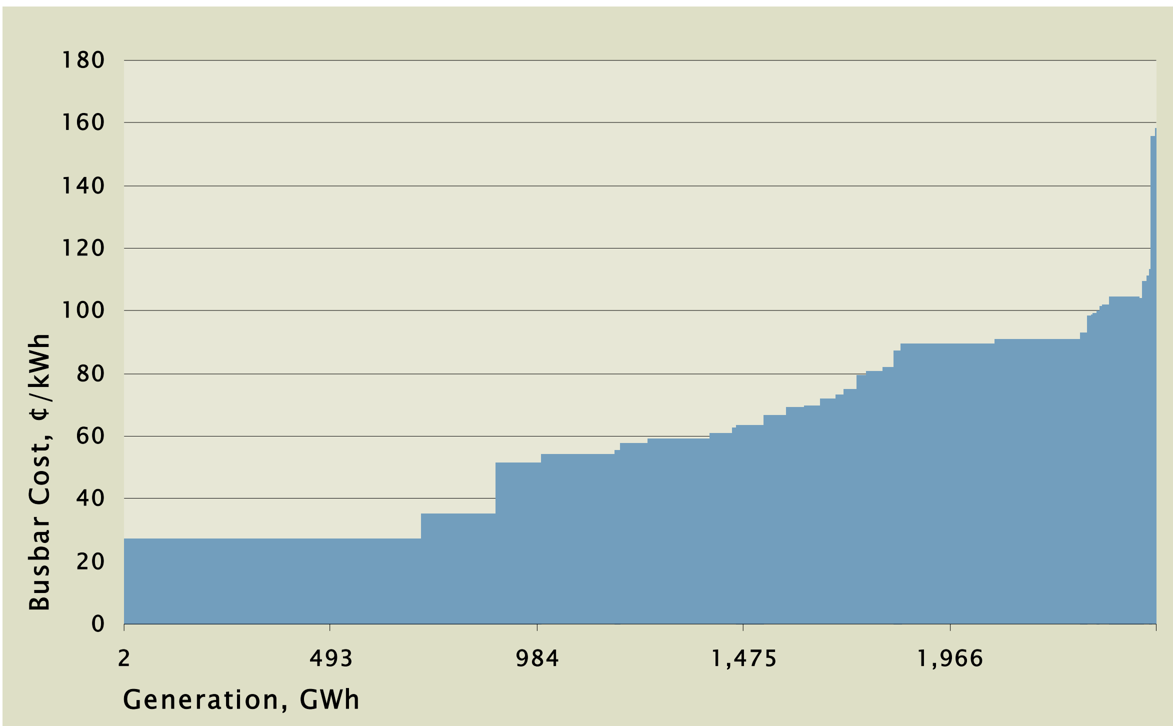

Figure D-9. Levelized Cost Supply Curve for Low Impact Hydro Generation.

7. DISTRIBUTED RENEWABLE RESOURCES

Distributed generation (DG) is the generation of electricity at the point of use or at the distribution system voltage. Typically, DG technologies are not as efficient as central station generators. However, DG systems often avoid transmission losses and can relieve congestion on the transmission grid. The technologies presented in this section have been employed in commercial and residential service to generate power and heat.

7.1 SMALL WIND

A state-wide estimate of small wind energy generation was conducted based on installation at farms across Pennsylvania. Small wind project criteria were assigned, and a levelized cost of power was calculated.

Resource Description

Small wind turbines can be applied to applications including remote water pumping, battery charging, and power generation. All of which are ideally suited to rural farming communities where extension of the utility grid may be prohibitively expensive. Pennsylvania has viable wind resources for considerable development of utility-scale and residential wind energy systems. Whereas utility-scale projects consist of dozens of turbines with a capacity 600 kW to 2 MW each, small wind turbines are available in sizes from below 1 kW to 10 kW. Both technologies require Class 3 wind resources and above to be considered economically viable, which are generally located in rural areas. In fact, the first use of wind power generation in the U.S. was in rural communities in the early 20th century before rural electrification. A further discussion of wind resources is available in Section 3.

Methodology

Methodologies were developed to analyze the technical and market potential for small wind energy utilization in Pennsylvania. Small wind turbines are typically mounted on towers that range in size from 40 to 120 ft. tall, which generally prohibits installation in suburban areas. For both analyses, only installations on farms were considered. An estimate of the total number of farms in the state was obtained from the Pennsylvania State Data Center. The technical potential was derived by assuming that 5 percent of the farms have suitable wind resources for a small wind turbine. The market potential for small wind turbines was estimated by assuming an annual growth rate of the installed capacity of small wind turbines.

Assumptions

The following assumptions were made in the analysis of the technical potential for small wind energy generation in Pennsylvania.

- Only farms in rural Pennsylvania would install small wind turbines.
- 5 percent of farms have suitable wind resources for small wind turbines.
- 10 percent annual growth rate of installed capacity for the market assessment.
- Small wind energy project technical and cost assumptions are presented in Table D-19.

Table D-18. Small Wind Project Assumptions.

System Size, kW	10
Annual Capacity Factor, %	15
Capital cost, $/kW	4,000
Annual O&M Cost, $/kW-yr	40

Resource Assessment

Although the current installed capacity of small wind turbines in Pennsylvania is only 72 kW, as reported by the NREL REPiS Database, there is potential for over 29 MW across the state. Considering the relatively slow adoption of small wind technology to date, the market assessment estimated that about 190 kW of installed capacity could be achieved within 10 years. Each of these installations would generate power at a levelized cost of $414/MWh.

7.2 SOLAR PHOTOVOLTAIC

A state-wide estimate of solar energy generation potential was constructed based on installation by home owners and commercial enterprises. Project criteria were assigned to each classification, and a levelized cost of power was calculated for each type.

Resource Description

Light received from the sun can be used to generate electricity with solar photovoltaic panels. Solar radiation received at the earth's surface is subject to variations in intensity caused by atmospheric attenuation. The earth's distance from the sun and the earth's tilt also influence the amount of available solar energy. The northern latitudes are tilted toward the sun during the summer months. This factor combined with the longer summer days increases the amount of solar energy available on summer as opposed to winter days. The optimum time frame for solar collection is between 9:00 a.m. and 3:00 p.m. It is important to avoid array shading during this time frame as even a small amount of shade can reduce PV module output by as much as 80 percent.

Methodology

An estimate of the potential for solar photovoltaic generation in Pennsylvania was performed. Monthly average solar insolation data was obtained from NREL for Bradford, Philadelphia, Allentown, Harrisburg, Wilkes-Barre, Williamsport, Erie, and Pittsburgh (all of the data collection stations available for Pennsylvania). The information from these sites was averaged to obtain an estimate of the monthly average solar insolation across the state. An estimate of the technical potential for solar generation was calculated. To obtain a more realistic estimate of the potential for solar photovoltaic generation, Black & Veatch performed a market assessment based on the assumption that solar photovoltaic panels will be installed by either homeowners or commercial enterprises. The number of single-family residences and commercial firms in Pennsylvania was obtained from the US Census Bureau. Characteristics were assigned to each type of installation, and the potential generation was estimated by assuming a percentage of each customer class installs photovoltaic generation. To further refine the estimate of the potential for solar generation, an estimate of the near-term potential for solar photovoltaic installations was calculated.

Assumptions

The following assumptions were made in the analysis of the technical potential for solar energy generation in Pennsylvania.

- 10 percent of home owners will install solar photovoltaic systems with an average size of 2 kW.
- 10 percent of the commercial enterprises included in the analysis will install solar photovoltaic systems with an average size of 50 kW.
- The following categories of commercial enterprises were included in the analysis: manufacturing; communications; electric, gas, and sanitary services; retail trade; hotels, rooming houses, camps, and other lodging places; and museums, art galleries, and botanical & zoological gardens.
- 15 percent efficiency for solar photovoltaic panels.
- Solar photovoltaic project costs are presented in Table D-19.

Table D-19. Solar Project Assumptions.

Project Type	Capital Cost, $/kW	Capacity Factor, %	O&M Cost, $/kW/yr
Residential	9,000	14	12
Commercial	7,100	14	12

Resource Assessment

The technical potential for solar photovoltaic generation is far greater than the realistic near-term potential for utilization. If 0.5 percent of the total land area in Pennsylvania were covered with solar panels, enough energy could be generated to supply 100 percent of the current energy demand, which corresponds to over 114,000 MW of capacity. The market assessment yielded an estimate of 1,063 MW of potential, which would provide over 1.3 percent of current electricity demand. Although the market assessment estimate more accurately reflects the potential for solar photovoltaic generation, the results were far beyond the reasonable near-term potential. Total world-wide shipments of PV modules totaled about 530 MW in 2002. Additionally, the total installed capacity in Pennsylvania is currently under one MW. Given these facts, a near-term achievable potential of about 4 MW is considered reasonable Table D-20 shows the potential solar photovoltaic capacity in Pennsylvania and levelized cost to generate electricity.

Table D-20. Solar Energy Generation Potential.

	Near-Term Potential, kW	Market Potential, kW	Levelized Cost, $/MWh
Residential	2,000	714,000	487.8
Commercial	2,000	349,000	681.4
Total	**4,000**	**1,063,000**	**551.4**

7.3 SOLAR THERMAL

An analysis of the potential for solar thermal energy utilization in Pennsylvania was conducted. The potential fossil fuel and electricity savings by the adoption of solar water heating, and the capital and operating costs for a typical residential system were estimated.

Methodology

Black & Veatch analyzed the potential for solar water heating utilization by households in Pennsylvania. The annual energy demand for water heating of households in the Northeast was obtained from the EIA. Black & Veatch then used this data to estimate the potential for conserving petroleum by installing solar water heating systems.

Assumptions

The following assumptions were made in the analysis of the technical potential, for solar water heating utilization in Pennsylvania.

- One million households that currently have fossil fueled water heating systems will install solar water heaters.
- The solar water heating system will account for 40 percent of the hot water demand.
- Average household energy consumption data for the Northeast is representative of the average household in Pennsylvania.

Resource Description

Pennsylvania does not have sufficient solar resources to support solar thermal electric generation in the near-term. However, resources exist to support the use of solar water heating systems.

Resource Assessment

Solar heating systems can be used to directly displace fossil fuel use in home and commercial furnaces. If one million households in Pennsylvania installed solar water heating systems, 8 trillion Btu of fossil fuel energy (1.4 million barrels of kerosene or 7.8 billion cubic feet of natural gas) could be saved annually.

Although the potential energy savings are impressive, the actual adoption of solar water heating systems will likely be much smaller.

Table D-21 shows the system design parameters and cost for an average residential solar water heating system.

Table D-21. Solar Water Heating Assumptions.

Home Size	2,000 sq ft.
System Size	40 % of demand
Capital Cost	$1,500 – $3,000
Annual Inspection Cost	$100

7.4 GEOTHERMAL HEAT PUMPS

An analysis of the potential for geothermal energy utilization in Pennsylvania was conducted. The potential fossil fuel and electricity savings by the adoption of geothermal heat pumps, and the capital and operating costs for a typical residential system were estimated.

Methodology

Black & Veatch analyzed the potential for geothermal heat pump use by households in Pennsylvania. The annual energy demand for heating and cooling of households in the Northeast was obtained from the EIA. Black & Veatch then used this data to estimate the potential for conserving petroleum and electricity by installing geothermal heat pumps.

Assumptions

The following assumptions were made in the analysis of the technical potential, for geothermal heat pump utilization in Pennsylvania.

- One million households that currently have fossil fueled space heating and electric air conditioning will install geothermal heat pumps.
- Once the heat pump is installed, no fossil fuels will be used for heating.
- The geothermal heat pump uses 35 percent less electricity than an air conditioning system.
- Average household energy consumption data for the Northeast is representative of the average household in Pennsylvania.

Resource Description

The geothermal resource in Pennsylvania is not suitable for electric generation. However, the resource is suitable for direct use and geothermal heat pump applications.

Resource Assessment

Although geothermal resources in Pennsylvania are not suitable for electric generation, use of geothermal heat pumps could save significant amounts of electricity and petroleum. If one million households that currently use fossil fuel for space heating and electricity for cooling converted to geothermal heat pumps, 92 trillion btu of fossil fuel energy (14.2 million barrels of kerosene or 78.5 billion cubic feet of natural gas) and 210 million kWh of electricity could be saved annually. The potential energy savings are impressive, but the actual adoption of geothermal heat pumps systems will likely be a much smaller portion of the population.

Table D-22 shows the system design parameters and cost for an average residential geothermal heat pump system.

Table D-22. Geothermal Heat Pump Assumptions.

Home Size	2,000 sq ft.
System Size	3 ton
Capital Cost	$7,500
Annual Inspection Cost	$100

7.5 FUEL CELLS AND MICROTURBINES

Fuel cells and microturbines are alternative energy conversion technologies to internal combustion engines for the combustion of renewable fuels such as landfill and digester gas. At this time, these technologies are in the pre-commercial phase; research and development efforts are ongoing to solve technical problems and reduce equipment costs. In addition, maintenance and support infrastructure for these technologies are not fully developed.

A recent study conducted for NYSERDA regarding the potential for renewable energy and energy efficient generation in New York examined the potential for fuel cell development.[9] Polymer Electrolyte, Phosphoric Acid, Solid Oxide, and Molten Carbonate fuel cells powered by hydrocarbon fuels were included in the analysis. The study estimates that the technical potential is huge, capable of supplying more than the state's current energy demand. However, fuel cells will not become cost-competitive with other technologies within 20 years. Further, the authors stated that if no new program or policy supports for fuel cells were put into place, it would be likely that there would be no new projects developed and existing projects would be retired by 2022.

Fuel cells promise higher efficiency than existing combustion-based energy conversion technologies. If policy support and technical advancements continue, it may have the potential to play a significant role in power generation with renewable fuels. However, within the 10 years of the RPS implementation in Pennsylvania, fuel cells are not expected to appreciably contribute to the RPS.

[9] Optimal Energy, Inc. for NYSERDA; Energy Efficiency and Renewable Energy Development Potential in New York State; August 2003.

8. CONCLUSION

The purpose of the resource assessment was to identify the development potential and cost to generate power for each of the renewable energy technologies. Resource data for each of the technologies was obtained and was used to estimate the technical and near-term development potential for each technology. The levelized cost to generate power with each technology was then calculated with performance and economic assumptions. The technologies with the lowest-cost to generate power were selected as the most likely to be developed to meet the RPS.

8.1 RPS RESOURCES

Wind

Extensive potential for wind energy generation was identified, in excess of 14,700 MW. However, we believe that the near-term potential, within the term of the proposed RPS, is about 3,500 MW, enough to generate 8,700 GWh annually. The cost to generate electricity with wind is moderate to high depending on the site, with a range of between $33/MWh and $81/MWh for better sites, and $66/MWh and $103/MWh for more expensive sites. The weighted average cost for inexpensive sites is $70/MWh and expensive sites $95/MWh. This average cost is driven upwards by the relatively limited number of high wind speed sites in Pennsylvania. Two-thirds of the developable wind resource are only Class 3 wind speed. The wind estimates in this study do not include the potential for lower cost resources from states such as West Virginia. This is a conservative assumption.

The cost estimates do include the federal production tax credit. Failure by Congress to re-adopt this policy would increase the price of wind energy generation and adversely affect the amount of wind energy generation installed for the RPS.

Biomass

Pennsylvania has excellent potential for biomass cofiring with a large fleet of coal-fired power stations and a large supply of biomass fuel in the region. Technical potential of over 4,300 MW was identified in the resource assessment, with 1,023 MW classified as near-term potential. This is enough to generate 5,900 GWh annually. The cost to generate power with biomass cofiring is low, with a range of between $27.7/MWh and $55.2/MWh and a weighted average cost of $36.6/MWh.

Biogas (Landfill and Digester Gas)

Pennsylvania has moderate potential for landfill gas and digester gas utilization. The near-term development potential is 89 MW for landfill gas and 37 MW for digester gas. The cost to generate power with landfill gas is relatively low, ranging between $42/MWh and $68/MWh with a weighted average cost of $48.2/MWh. The cost to generate power from anaerobic digestion is much higher, ranging between $81/MWh and $88/MWh with a weighted average cost of $83.72/MWh.

Low Impact Hydro

Pennsylvania has good potential to develop low impact hydro generation. The INEEL study identified 2,142 MW of technical potential, including refurbishment and new project development. Once the environmental considerations were taken into account, 561 MW of near-term development potential was identified. The cost to generate power with low impact hydro resources is highly variable, with a range of between $27/MWh and $104/MWh and a weighted average cost of $57.62/MWh.

RPS Analysis

The RPS is assumed to require that 10 percent of energy demand be provided by renewable energy generation in 2015. This amounts to about 16,985 GWh of the projected 2015 demand of 169,850 GWh. The 2002 electric demand for the state was provided by EIA, and the annual PJM load growth projection of 1.5 percent was used to estimate demand. The levelized cost supply curves for each of the technologies were then combined to produce a comprehensive supply curve of the near-term renewable energy potential for Pennsylvania, Figure D-10 and Figure D-11. The supply curve is ordered by ascending levelized cost to generate; therefore the technologies to the left of the line representing demand by 2015 comprise the least-cost portfolio of technologies to meet the requirements of the RPS.

The supply curve represented here provides a general representation of Pennsylvania renewable resources. It is influenced by many broad assumptions and is just one of an infinite number of possible conclusions that could be reached about the true potential for renewable energy resources in the state. However, even as an approximation, it conveys valuable information. For example, the curve is dominated by wind and biomass cofiring resources, with the latter being less expensive, but more limited in potential. Other resources, particularly hydro and biogas, are interspersed in the curve but because of their limited near-term potential, they do not dramatically impact the overall shape. Finally, the curve demonstrates that are many cost-effective renewable energy opportunities available for less than $60/MWh.

An expected portfolio of technologies and resources can be derived from the supply curve by assuming that projects with the lowest cost to generate power will be developed to meet the RPS. Table D-23 shows the cost and generation contributed by each technology towards the RPS. This table presents the weighted average values for all resources that make up the supply mix.

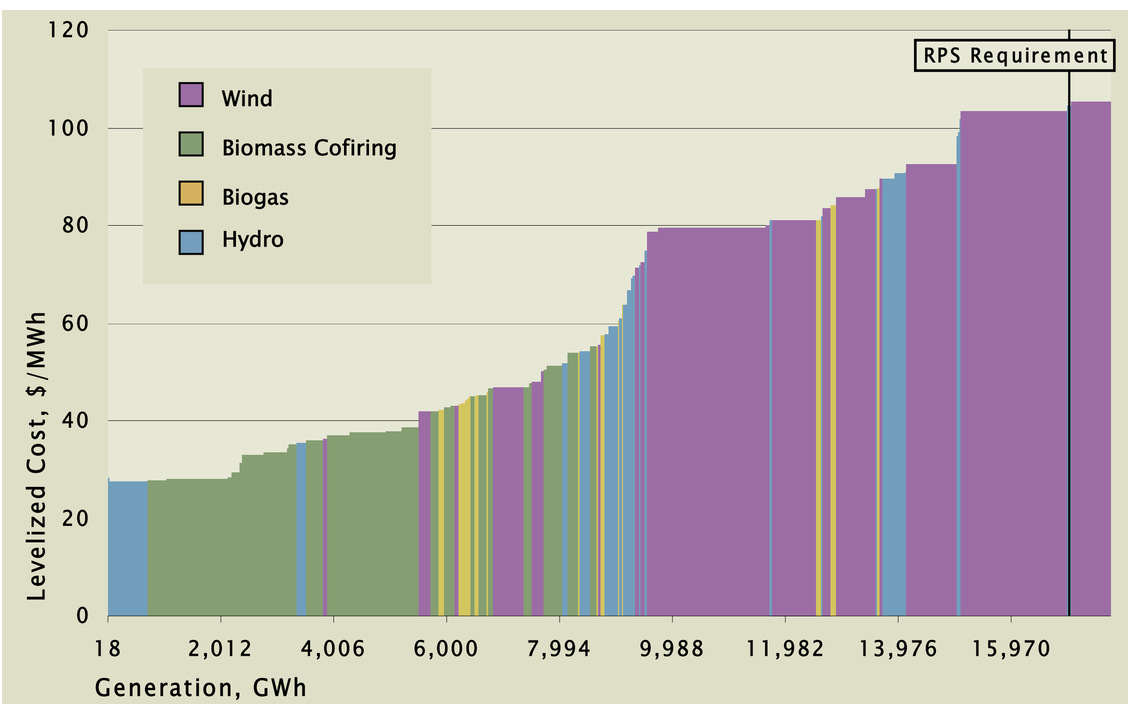

Figure D-10. Near-Term Potential Renewable Energy Generation Supply Curve.

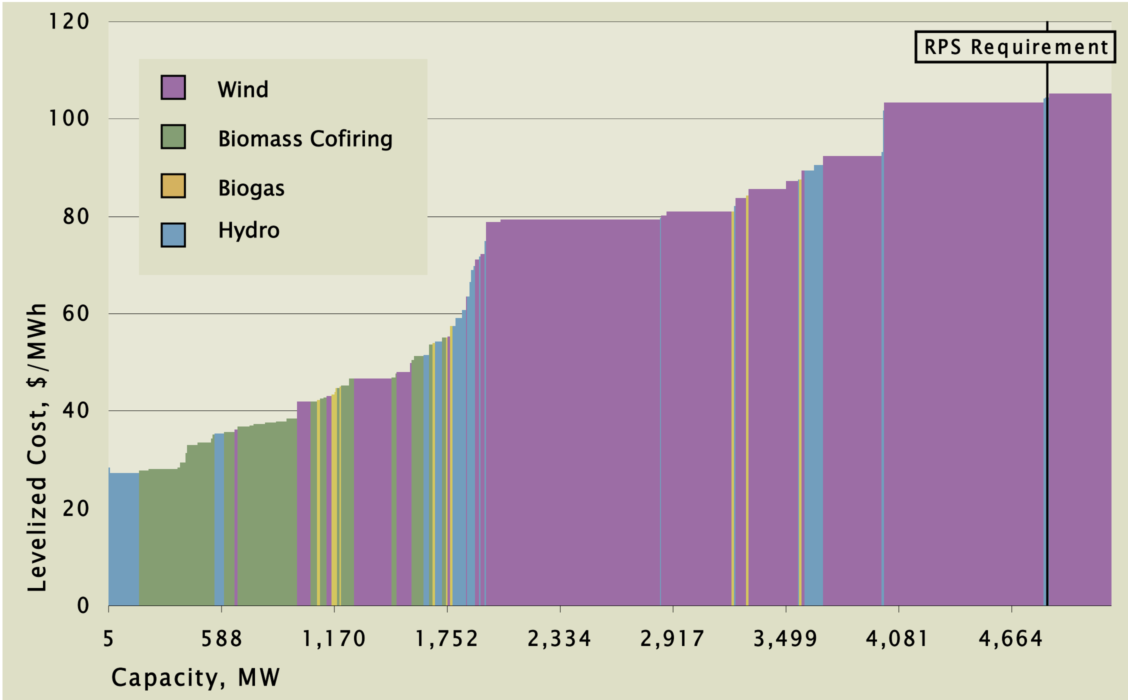

Figure D-11. Near-Term Potential Renewable Energy Capacity Supply Curve.

Table D-23. RPS Renewable Energy Portfolio (Weighted Average Values).

Technology	Wind*		Biomass	Landfill	Digester	Hydro	Solar
	Low	High	Cofiring	Gas	Gas		
Share of RPS Mix (energy), %	23	23	34.6	3.7	1.5	14.2	0.0
Generation, GWh	3,901	3,914	5,900	625	258	2,424	4.84
Capacity, MW	1616	1,529	1,023	89	37	554	4
Capacity Factor,	27.6	29.2	65.8	80.0	80.0	49.9	13.8
Capital Cost, $/kW	1,293	1,823	346	1,590	2,510	1,502	7,245
Variable O&M, $/MWh	7.0	7.4	0.0	15.0	15.0	2.7	0.0
Fixed O&M, $/kW/yr	20.5	20.5	12.1	0.0	0.0	10.3	0.0
Fuel Cost, $/MBtu	–	–	2.05	–	–	–	–
Heat Rate, Btu/kWh	–	–	11,146	–	–	–	–
Levelized Cost Range, $/MWh	33-81	66-103	28-55	42-68	81-88	27-104	488-681
Average Levelized Cost, $/MWh	70	95	36.58	48.20	83.72	57.62	551.42

*Note: In addition to cost differences for transmission distance and wind class, two general cost categories were modeled for wind for this study: "inexpensive" and "expensive". Inexpensive, low cost projects will be the first to be developed, while expensive sites are remote, have difficult construction access, high land cost, etc. This study conservatively assumed that approximately 50 percent of Pennsylvania wind sites are classified as expensive.

Figure D-12 shows the percent of each technology installed to meet the RPS on a capacity-basis (MW). Figure D-13 shows the percent of generation (GWh) required by the RPS contributed by each technology.

The supply curve analysis reveals that wind energy would be the largest contributor to the RPS, followed by biomass cofiring and hydro. Although biomass cofiring, landfill gas, and incremental hydro projects are sometimes easier to implement than new wind development, much of the technology installed early in the RPS will likely be wind generation. A number of wind projects are already in development in the state.

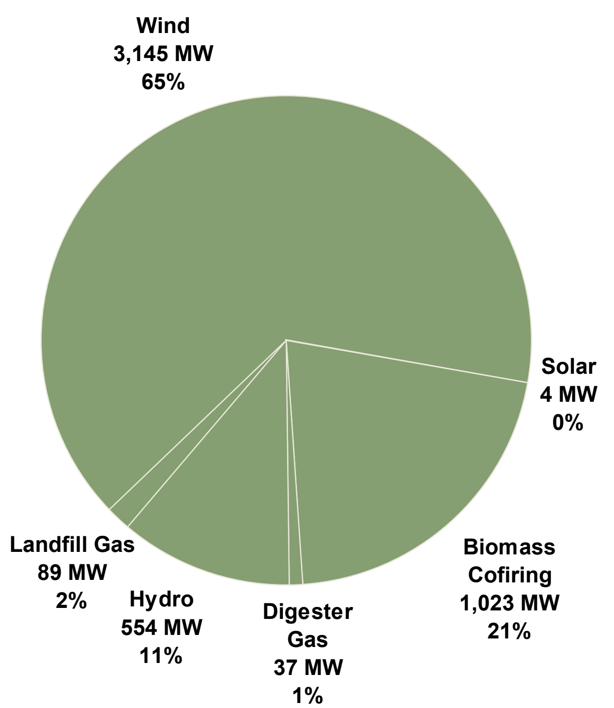

Figure D–12. RPS Capacity Breakdown.

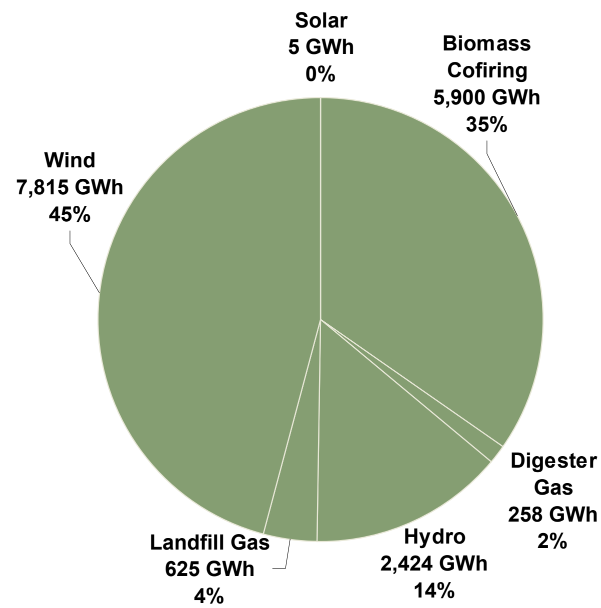

Figure D–13. RPS Generation Breakdown.

8.2 DISTRIBUTED RENEWABLE RESOURCES

It is not expected that distributed renewable resources will play a significant role in meeting the RPS. However, these technologies can be utilized to reduce demand for electricity and fossil fuels. Effective policy support for distributed resources can work to reduce out-of-state energy expenditures and create jobs for manufacturing, construction, and maintenance of these technologies.

Small Wind

Small wind turbines have the potential to provide power to rural communities in Pennsylvania. Assuming that only farms install these systems, an estimated potential of over 29 MW could be installed in the state. However, the near-term market potential was only estimated at about 190 kW considering the limited existing wind capacity in the state. The cost to generate power with small wind is high, with a levelized cost of $630/MWh. However, this cost is often less than that of extending the utility grid to provide power.

Solar Photovoltaic

The potential to generate all of Pennsylvania's energy demand from solar photovoltaic energy was identified in the resource assessment. Although this level of utilization is not realistic, potential of 1,000 MW was identified with modest assumptions about technology adoption by homeowners and commercial enterprises. However, the near-term potential is much less, considering current module production levels and the high cost of solar energy generation. Installation of 4 MW of solar generation is assumed to contribute to the RPS. The cost for solar photovoltaic generation is high, with a weighted average cost of $550/MWh.

Solar Thermal

Pennsylvania does not have sufficient solar thermal resources to generate electricity. However, sufficient resources exist for the utilization of solar water heating technologies. An assessment of the potential for solar thermal adoption was conducted to estimate the potential fossil fuel savings. There is potential to save about 8 trillion Btu of energy (1.4 million barrels of kerosene or 7.8 billion cubic feet of natural gas) annually if one million homes (about 20 percent of the state households) installed solar water heating systems.

Geothermal Heat Pumps

Pennsylvania does not have sufficient geothermal resources to generate electricity. However, sufficient resources exist for the utilization of geothermal heat pumps for residential and commercial space heating and cooling. An assessment of the potential for geothermal heat pump adoption was conducted to estimate the potential fossil fuel and electric savings. There is potential to save about 92 trillion Btu of fossil fuel (14.2 million barrels of kerosene or 78.5 billion cubic feet of natural gas) and 210 million kWh if one million homes installed geothermal heat pumps.

Fuel Cells and Microturbines

Fuel cells and microturbines have to potential to generate electricity from renewable fuels more efficiently than internal combustion engines. However, these technologies are not yet fully commercial on renewable fuels and are not expected to make a major impact within the term of the RPS.

Appendix A.
WIND RESOURCE CHARACTERISTICS

Wind Resource Class, Miles from Transmission, Relative Cost	Near-Term Potential, kW	Capacity Factor, %	Capital Cost, $/kW	Fixed O&M Cost, $/kW/yr	Variable O&M Cost, $/MWh	Levelized Cost, $/MWh
Class 7, 0-5 mi, Inexpensive	100	40%	1,193	20	0.007	33.01
Class 7, 5-10 mi, Inexpensive	100	40%	1,229	20	0.007	34.03
Class 6, 0-5 mi, Inexpensive	18,800	37%	1,193	20	0.007	36.32
Class 5, 0-5 mi, Inexpensive	69,950	34%	1,243	20	0.007	41.89
Class 5, 5-10 mi, Inexpensive	25,200	34%	1,279	20	0.007	43.09
Class 4, 0-5 mi, Inexpensive	194,400	31%	1,243	20	0.007	46.70
Class 4, 5-10 mi, Inexpensive	66,550	31%	1,279	20	0.007	48.01
Class 4, 10-20 mi, Inexpensive	10,650	31%	1,333	20	0.007	49.99
Class 6, 5-10 mi, Inexpensive	14,550	37%	1,229	20	0.007	55.41
Class 6, 10-20 mi, Inexpensive	1,250	37%	1,283	20	0.007	57.24
Class 5, 10-20 mi, Inexpensive	3,100	34%	1,333	20	0.007	63.59
Class 7, 0-5 mi, Expensive	100	40%	1,693	20	0.007	66.29
Class 7, 5-10 mi, Expensive	100	40%	1,729	20	0.007	67.42
Class 6, 0-5 mi, Expensive	18,800	37%	1,693	20	0.007	71.16
Class 6, 5-10 mi, Expensive	14,550	37%	1,729	20	0.007	72.38
Class 6, 10-20 mi, Expensive	1,250	37%	1,783	20	0.007	74.21
Class 5, 0-5 mi, Expensive	69,950	34%	1,743	20	0.007	78.74
Class 3, 0-5 mi, Inexpensive	824,200	26%	1,293	20	0.007	79.33
Class 5, 5-10 mi, Expensive	25,200	34%	1,779	20	0.007	80.07
Class 3, 5-10 mi, Inexpensive	332,700	26%	1,329	20	0.007	81.06
Class 5, 10-20 mi, Expensive	3,100	34%	1,833	20	0.007	82.06
Class 3, 10-20 mi, Inexpensive	54,150	26%	1,383	20	0.007	83.67
Class 4, 0-5 mi, Expensive	194,400	31%	1,743	20	0.007	85.76
Class 4, 5-10 mi, Expensive	66,550	31%	1,779	20	0.007	87.22
Class 4, 10-20 mi, Expensive	10,650	31%	1,833	20	0.007	89.40
Lake Erie Offshore Wind	300,000	34%	2,000	25	0.00875	92.40
Class 3, 0-5 mi, Expensive	824,200	26%	1,793	20	0.007	103.47
Class 3, 5-10 mi, Expensive	332,700	26%	1,829	20	0.007	105.21
Class 3, 10-20 mi, Expensive	54,150	26%	1,883	20	0.007	107.81

Appendix B.
BIOMASS COFIRED POWER PLANT CHARACTERISTICS

Coal Plant Unit Name	Capacity (MW)	Year Online	Boiler Type	Heat Rate (Btu/kWh)	Capacity Factor	County	Percent Cofiring	Cofiring Technology	Capital Cost ($/kW)	Fixed O&M ($/kW/yr)	Levelized Cost ($/MWh)
COLVER 1	122	1995	ACFB	13,889	79.8%	Jefferson	25%	Biomass Cofiring Direct Mixing	$100.00	$5.00	28.01
GIBRALTAR INTER 1	102	1995	ACFB	13,889	80.0%	Berks	25%	Biomass Cofiring Direct Mixing	$100.00	$5.00	28.01
CAMBRIA COUNTY COGEN 1	98	1991	ACFB	13,889	85.4%	Cambria	25%	Biomass Cofiring Direct Mixing	$100.00	$5.00	27.79
PANTHER CREEK 1	95	1992	ACFB	13,889	79.9%	Carbon	25%	Biomass Cofiring Direct Mixing	$100.00	$5.00	28.01
SCRUBGRASS 1	83	1993	ACFB	13,889	79.9%	Venango	25%	Biomass Cofiring Direct Mixing	$100.00	$5.00	28.01
ST NICHOLAS 1	80	1990	ACFB	13,889	76.8%	Schuylkill	25%	Biomass Cofiring Direct Mixing	$100.00	$5.00	28.16
JOHN B RICH 1	79.4	1988	ACFB	13,889	87.9%	Schuylkill	25%	Biomass Cofiring Direct Mixing	$100.00	$5.00	27.69
NEPCO 1	59	1989	ACFB	13,889	80.0%	Schuylkill	25%	Biomass Cofiring Direct Mixing	$100.00	$ 5.00	28.01
EBENSBURG 1	48.5	1991	ACFB	13,889	71.3%	Cambria	25%	Biomass Cofiring Direct Mixing	$100.00	$ 5.00	28.44
FRACKVILLE 1	42	1988	ACFB	13,889	79.4%	Schuylkill	25%	Biomass Cofiring Direct Mixing	$100.00	$ 5.00	28.04
PINEY CREEK 1	32	1993	ACFB	13,889	80.0%	Clarion	25%	Biomass Cofiring Direct Mixing	$100.00	$ 5.00	28.01
NORTHAMPTON 1	110	1995	ACFB	13,889	57.3%	Northampton	25%	Biomass Cofiring Direct Mixing	$100.00	$ 5.00	29.44
SPRING GROVE GLATFELTER 1	67.25	1989	Stoker & ACFB	15,000	45.6%	York	25%	Biomass Cofiring Direct Mixing	$100.00	$ 5.00	37.02
MOUNT CARMEL POWER 1	46.5	1990	ACFB	13,889	49.3%	Northumberland	25%	Biomass Cofiring Direct Mixing	$100.00	$ 5.00	34.27
WESTWOOD GENERATION 1	30	1988	ACFB	13,889	57.9%	Schuylkill	25%	Biomass Cofiring Direct Mixing	$100.00	$ 5.00	33.43
CONEMAUGH 2	936	1971	TANGENT	9,407	73.8%	Indiana	6%	Biomass Cofiring Dedicated Feed System	$400.00	$ 14.00	33.49
MONTOUR 2	819	1973	TANGENT	9,406	63.5%	Montour	7%	Biomass Cofiring Dedicated Feed System	$400.00	$ 14.00	35.80
HOMER CITY 3	692	1977	OPPOSED	9,608	60.9%	Indiana	8%	Biomass Cofiring Dedicated Feed System	$400.00	$ 14.00	36.92
CHESWICK 1	570	1970	TANGENT	10,011	62.0%	Allegheny	10%	Biomass Cofiring Dedicated Feed System	$400.00	$ 14.00	37.42
KEYSTONE (PA) 1	936	1967	TANGENT	9,400	76.8%	Indiana	6%	Biomass Cofiring Dedicated Feed System	$400.00	$ 14.00	32.94
BRUCE MANSFIELD 3	914	1980	OPPOSED	9,948	59.9%	Beaver	6%	Biomass Cofiring Dedicated Feed System	$400.00	$ 14.00	37.90
BRUNNER ISLAND 3	790	1969	TANGENT	9,683	60.1%	York	7%	Biomass Cofiring Dedicated Feed System	$400.00	$ 14.00	38.55
HATFIELDS FERRY 1	576	1969	OPPOSED	8,873	62.6%	Fayette	10%	Biomass Cofiring Dedicated Feed System	$400.00	$ 14.00	37.54
ELRAMA 4	185	1960	FRONT	11,076	63.0%	Washington	10%	Biomass Cofiring Dedicated Feed System	$400.00	$ 14.00	42.63
SHAWVILLE 4	188	1960	TANGENT	10,087	64.3%	Clearfield	25%	Biomass Cofiring Gasification	$700.00	$ 20.00	51.23
BEAVER VALLEY AES 3	100.26	1988	PC	13,380	79.29%	Beaver	25%	Biomass Cofiring Gasification	$700.00	$ 20.00	53.78
EDDYSTONE 2	354	1960	TANGENT	10,351	49.8%	Delaware	10%	Biomass Cofiring Dedicated Feed System	$400.00	$ 14.00	45.30
MITCHELL (PA) 3	299	1963	TANGENT	9,513	53.1%	Washington	10%	Biomass Cofiring Dedicated Feed System	$400.00	$ 14.00	42.01
PORTLAND (PA) 2	255	1962	TANGENT	10,122	45.9%	Northampton	10%	Biomass Cofiring Dedicated Feed System	$400.00	$ 14.00	46.53
ARMSTRONG 2	163	1959	FRONT	9,269	78.0%	Armstrong	10%	Biomass Cofiring Dedicated Feed System	$400.00	$ 14.00	35.18
NEW CASTLE 5	136	1964	FRONT	10,929	54.5%	Lawrence	10%	Biomass Cofiring Dedicated Feed System	$400.00	$ 14.00	44.84
SUNBURY 2	75	1949	OPPOSED	8,189	85.9%	Snyder	10%	Biomass Cofiring Dedicated Feed System	$400.00	$ 14.00	31.41
CROMBY 1	188	1954	FRONT	10,754	48.6%	Chester	10%	Biomass Cofiring Dedicated Feed System	$400.00	$ 14.00	46.78
MARTINS CREEK 1	156	1954	FRONT	11,409	44.4%	Northampton	10%	Biomass Cofiring Dedicated Feed System	$400.00	$ 14.00	50.36
SEWARD 5	156	1957	TANGENT	10,398	56.5%	Indiana	10%	Biomass Cofiring Dedicated Feed System	$400.00	$ 14.00	42.92
TITUS 3	75	1953	TANGENT	10,876	59.8%	Berks	25%	Biomass Cofiring Gasification	$700.00	$ 20.00	55.15
SUNBURY 1	75	1949	OPPOSED	9,773	74.1%	Snyder	10%	Biomass Cofiring Dedicated Feed System	$400.00	$ 14.00	37.08
HUNLOCK CREEK 3	50	1959	FRONT	14,349	75.2%	Luzerne	10%	Biomass Cofiring Dedicated Feed System	$400.00	$ 14.00	47.64

* Hypothetical scenario based on generic coal unit characteristics and cursory evaluation of suitable biomass cofiring technology and cofiring percent. No attempt has been made to verify biomass cofiring feasibility for individual units. When coal plant data was unknown (particularly heat rate and capacity factor data for ACFB units), it was estimated based on data from similar plants.

Appendix C.
LANDFILL GAS PROJECT CHARACTERISTICS

Landfill Name	County	Year Opened	Year Closed	Waste in Place, tons	Potential Capacity, kW	Capacity Factor	Capital Cost, $/kW	Variable O&M, $/MWh	Levelized Cost ($/MWh)
Adams Sanitation Company.	Adams	1970	1993	22,078,368	16,353	80.0%	1,275	15	28.01
Conestoga LF	Berks	1994		10,800,000	7,999	80.0%	1,325	15	28.01
Rolling Hills LF	Berks		1997	5,500,000	6,500	80.0%	1,340	15	27.79
Valley LF	Westmoreland	1990	2022	6,000,000	4,444	80.0%	1,369	15	28.01
Chrin Brothers LF	Northampton	1961	2010	4,600,000	3,407	80.0%	1,388	15	28.01
Seneca Landfill	Butler	1995	2002	3,000,001	2,700	80.0%	1,406	15	28.16
Shade LF (RCC LF)	Somerset	1992	2012	3,500,000	2,592	80.0%	1,409	15	27.69
Frey Farm LF	Lancaster	1986	2050	3,300,000	2,444	80.0%	1,414	15	28.01
Blue Ridge Landfill	Franklin			3,000,000	2,222	80.0%	1,421	15	28.44
Shade LF				3,000,000	2,222	80.0%	1,421	15	28.04
Rosencranse LF				1,000,000	2,000	80.0%	1,429	15	28.01
Commonwealth Environmental Systems	Schuylkill	1997	2007	2,500,000	1,852	80.0%	1,435	15	29.44
Pine Grove LF	Schuylkill		1998	2,000,000	1,481	80.0%	1,453	15	37.02
South Hills Landfill			2040	1,500,000	1,111	80.0%	1,476	15	34.27
Westmoreland Waste Landfill	Westmoreland			1,000,000	741	80.0%	1,509	15	33.43
Western Berks Refuse Auth.	Berks	1972	2004	943,550	699	80.0%	1,514	15	33.49
York County SLF	York	1974	1997	754,137	559	80.0%	1,532	15	35.80
Bethlehem LF	Northampton			498,051	369	80.0%	1,567	15	36.92
Sanitary LF	Westmoreland		2012	398,041	295	80.0%	1,587	15	37.42
Pellegrene LF	Indiana		2002	350,225	259	80.0%	1,598	15	32.94
Sandy Run LF	Bedford		2025	311,509	231	80.0%	1,608	15	37.90
Lanchester LF	Lancaster	1984	2005	10,003,394	7,409	80.0%	1,893	15	38.55
Kelly Run SLF	Allegheny		2023	7,187,741	5,324	80.0%	1,960	15	37.54
County LF	Clarion	1990	2007	929,812	3,000	80.0%	2,081	15	42.63
Cumberland County LF	Cumberland		2007	4,000,000	2,963	80.0%	2,084	15	51.23
Imperial LF	Allegheny		2013	3,968,151	2,939	80.0%	2,086	15	53.78
Arden LF	Washington	1920	2008	2,347,954	1,739	80.0%	2,204	15	45.30
Monroeville LF	Allegheny	1971	1998	2,000,000	1,481	80.0%	2,242	15	42.01
Northwest SLF	Butler	1991	2002	2,000,000	1,481	80.0%	2,242	15	46.53
Seccra LF	Chester	1986	2035	1,000,000	741	80.0%	2,411	15	35.18
Laurel Highlands LF	Cambria		2002	683,559	506	80.0%	2,509	15	44.84
McKean County LF	McKean	1972	2017	590,891	438	80.0%	2,548	15	31.41
Superior CBF, Inc. LF	Fayette	1985	2003	570,000	422	80.0%	2,558	15	46.78
Mifflin County SWA	Mifflin		2003	400,677	297	80.0%	2,654	15	50.36

Data Source: EPA Landfill Methane Outreach Program

Appendix D.
LOW IMPACT HYDRO PROJECT CHARACTERISTICS

Plant Name	River Basin	County	Project Capacity (MW)	Dam Status	Development Probability	Capacity Factor	Capital Cost ($/kW)	Fixed O&M ($/kW/yr)	Variable O&M (($/MWh)	Levelized Cost ($/MWh)
HOLTWOOD	SUSQUEHANNA RIVER BASIN	LANCASTER	162.00	Dam w/ Power	50%	49.9%	676	6.75	1.95	2.74
WALLENPAUPACK	DELAWARE RIVER BASIN	PIKE	40.00	Dam w/ Power	50%	49.9%	868	9.53	2.59	3.55
DASHIELDS L&D	OHIO MAIN STREAM	ALLEGHENY	25.00	Dam w/o Power	90%	49.9%	1,321	10.71	2.84	5.17
MONTGOMERY L&D	OHIO MAIN STREAM	BEAVER	20.00	Dam w/o Power	90%	49.9%	1,385	11.31	2.97	5.42
EMSWORTH L&D	OHIO MAIN STREAM	ALLEGHENY	20.00	Dam w/o Power	90%	49.9%	1,385	11.31	2.97	5.42
PATTERSON	BEAVER RIVER BASIN	BEAVER	2.70	Dam w/ Power	90%	49.9%	1,309	18.55	4.46	5.54
ALLEGHENY L&D 7	ALLEGHENY RIVER BASIN	ARMSTRONG	15.00	Dam w/o Power	90%	49.9%	1,472	12.15	3.15	5.76
DOCK STREET DAM	SUSQUEHANNA RIVER BASIN	DAUPHIN	34.40	Dam w/o Power	50%	49.9%	1,555	9.90	2.67	5.92
ALLEGHENY L&D 2	ALLEGHENY RIVER BASIN	ALLEGHENY	11.60	Dam w/o Power	90%	49.9%	1,556	12.94	3.32	6.09
YORK HAVEN	SUSQUEHANNA RIVER BASIN	YORK	2.20	Dam w/ Power	50%	49.9%	1,510	19.51	4.65	6.28
ALLEGHENY L&D 4	ALLEGHENY RIVER BASIN	ALLEGHENY	15.00	Dam w/o Power	50%	49.9%	1,649	12.15	3.15	6.37
ALLEGHENY L&D 3	ALLEGHENY RIVER BASIN	ALLEGHENY	12.00	Dam w/o Power	75%	49.9%	1,723	12.84	3.30	6.66
MAXWELL L&D	MONONGAHELA RIVER BASIN	WASHINGTON	10.00	Dam w/o Power	75%	49.9%	1,786	13.43	3.42	6.91
GEORGE B STEVENSON	SUSQUEHANNA RIVER BASIN	CAMERON	9.00	Dam w/o Power	50%	49.9%	1,800	13.78	3.50	6.97
MONONGAHELA L&D 4	MONONGAHELA RIVER BASIN	WASHINGTON	8.25	Dam w/o Power	50%	49.9%	1,856	14.08	3.56	7.18
POINT MARION	MONONGAHELA RIVER BASIN	FAYETTE	5.00	Dam w/o Power	90%	49.9%	1,869	15.93	3.94	7.32
GRAYS LANDING	MONONGAHELA RIVER BASIN	GREENE	6.70	Dam w/o Power	75%	49.9%	1,936	14.82	3.71	7.49
MONONGAHELA L&D 7	MONONGAHELA RIVER BASIN	FAYETTE	5.00	Dam w/o Power	75%	49.9%	2,054	15.93	3.94	7.95
PENN II	DELAWARE RIVER BASIN	PIKE	4.35	Dam w/o Power	50%	49.9%	2,087	16.49	4.05	8.10
PENN I	DELAWARE RIVER BASIN	PIKE	4.35	Dam w/o Power	50%	49.9%	2,087	16.49	4.05	8.10
ELLWOOD CITY	BEAVER RIVER BASIN	LAWRENCE	6.00	Dam w/o Power	75%	49.9%	2,137	15.23	3.80	8.20
MONONGAHELA L&D 3	MONONGAHELA RIVER BASIN	ALLEGHENY	2.25	Dam w/o Power	90%	49.9%	2,233	19.41	4.63	8.75
MONONGAHELA L&D 2	MONONGAHELA RIVER BASIN	ALLEGHENY	2.25	Dam w/o Power	90%	49.9%	2,233	19.41	4.63	8.75
CASTLE GARDEN	SUSQUEHANNA RIVER BASIN	CAMERON	50.00	Undeveloped	90%	49.9%	2,451	9.02	2.47	8.94
DAM 1	BEAVER RIVER BASIN	BEAVER	45.00	Undeveloped	90%	49.9%	2,483	9.26	2.52	9.07
FLAT ROCK	DELAWARE RIVER BASIN	PHILADELPHIA	2.50	Dam w/o Power	75%	49.9%	2,343	18.91	4.53	9.10
LOCK HAVEN	SUSQUEHANNA RIVER BASIN	CLINTON	3.12	Dam w/o Power	50%	49.9%	2,425	17.90	4.33	9.33
CHAIN DAM	DELAWARE RIVER BASIN	NORTHAMPTON	2.40	Dam w/o Power	50%	49.9%	2,554	19.10	4.57	9.83
QUEMAHONING	ALLEGHENY RIVER BASIN	SOMERSET	1.33	Dam w/o Power	90%	49.9%	2,518	22.10	5.15	9.86
HANOVER 7 DAM(ALLENTOWN)	DELAWARE RIVER BASIN	LEHIGH	1.76	Dam w/o Power	75%	49.9%	2,555	20.62	4.87	9.91
PLYMOUTH	DELAWARE RIVER BASIN	CHESTER	1.60	Dam w/o Power	75%	49.9%	2,578	21.11	4.96	10.02
FELIX DAM	DELAWARE RIVER BASIN	BERKS	1.50	Dam w/o Power	75%	49.9%	2,614	21.45	5.03	10.16
HAMILTON STREET	DELAWARE RIVER BASIN	LEHIGH	2.03	Dam w/o Power	50%	49.9%	2,642	19.90	4.73	10.17
FAIRMOUNT DAM	DELAWARE RIVER BASIN	PHILADELPHIA	2.00	Dam w/o Power	50%	49.9%	2,649	19.98	4.74	10.20
CYPHER STATION	SUSQUEHANNA RIVER BASIN	BEDFORD	16.00	Undeveloped	90%	49.9%	2,842	11.96	3.11	10.44
NORRISTOWN	DELAWARE RIVER BASIN	MONTGOMERY	1.80	Dam w/o Power	50%	49.9%	2,706	20.50	4.84	10.43
TREICHLERS(NO 4 DAM)	DELAWARE RIVER BASIN	NORTHAMPTON	1.43	Dam w/o Power	50%	49.9%	2,837	21.70	5.07	10.93
WISMER'S LOCKS	DELAWARE RIVER BASIN	MONTGOMERY	1.05	Dam w/o Power	90%	49.9%	2,826	23.42	5.40	10.98
AUBURN	DELAWARE RIVER BASIN	SCHUYLKILL	1.00	Dam w/o Power	75%	49.9%	2,857	23.71	5.46	11.10
VINCENT	DELAWARE RIVER BASIN	CHESTER	1.20	Dam w/o Power	50%	49.9%	2,941	22.66	5.26	11.34
TWO LICK CREEK	ALLEGHENY RIVER BASIN	INDIANA	1.22	Undeveloped	50%	49.9%	4,179	22.57	5.24	15.57
BEAVER RUN	ALLEGHENY RIVER BASIN	WESTMORELAND	1.10	Undeveloped	50%	49.9%	4,254	23.16	5.35	15.86

Data Source: INEEL, "Hydropower Equipment Refurbishment or Replacement: Generation Increases and Associated Costs," INEEL/EXT-03-00840, July 2003.

Economic Impact of Renewable Energy in Pennsylvania

E. ECONOMIC IMPACT ASSESSMENT

5 March 2004

building a world of difference™ BLACK & VEATCH

1. SUMMARY AND INTRODUCTION

The objective of this portion of the analysis is to determine the relative economic impacts of renewable energy development in Pennsylvania compared to the "business as usual" (BAU) development of fossil fuel resources.

1.1 INTRODUCTION

Evaluating the economics of renewable energy development requires estimation of the resulting economic costs and benefits to the state. The primary costs and benefits relevant to this analysis include (1) cost of electricity; (2) direct and indirect impacts on jobs, income, and economic output; and (3) fossil fuel price impacts, as introduced below:

1. **Cost of electricity –** the direct added electricity costs or savings which result from mandating an RPS and which are paid or realized by electricity consumers. This analysis is performed in Section E.2 which compares the 20-year costs of meeting a 10 percent RPS with the costs from a business as usual case (that is, fossil fuel development) in the state.

2. **Jobs, income, gross state output–** the socioeconomic impacts on the local economy arising from providing power through renewable resources instead of conventional generation technologies. These impacts include direct and indirect differences in the jobs, income, and gross state output associated with the alternative expansion plans. Section E.3 provides an estimate of these impacts, primarily through the use of the RIMS II regional input-output model developed by the US Bureau of Economic Analysis.

3. **Fossil fuel prices** – the potential for reduced costs of fuel and conservation of scarce fuel resources which could arise if the RPS results in significant reductions in fuel usage. This is discussed in Section E.4.

In addition to these economic benefits, development of renewable resources will have environmental, health, safety and other benefits. Many studies have tried to value these "externalities" and are the subject of much uncertainty and considerable controversy. An RPS will provide value to the citizens of Pennsylvania in terms of improved environmental, health, and safety aspects. However, no effort is made to quantify these benefits in this study.

1.2 SUMMARY RESULTS

This economic impact analysis relies directly on the renewable energy technology and resource characteristics developed in the previous sections. Assumptions were also developed to characterize the BAU case. Based on these inputs, various estimates were made of economic impacts, as summarized below.

Cost of Electricity

To estimate the direct impact that an RPS would have on electricity costs, an economic model was constructed to measure the 20-year (2006-2025) costs of providing 10 percent of the electricity consumed in Pennsylvania from renewable energy sources. This cost was compared to the cost of providing the same energy from a mix of coal and natural gas resources (Business As Usual scenario).

The initial RPS portfolio selection assumes a capacity mix consisting of approximately 65 percent wind, 2 percent landfill gas, 1 percent digester gas, 21 percent biomass cofiring, 11 percent hydro, and a minimal amount of solar photovoltaic (0.1 percent). This mix is based on the resource supply curve analysis described in Section D. The BAU portfolio consists of 50 percent coal, 40 percent gas-fired combined cycle, and 10 percent of gas-fired simple cycle capacity.

Annual cost estimates were calculated and compared for the portfolio mixes. In terms of cumulative present value costs over a 20-year period, the RPS portfolio cost of $4.68 billion is nearly $1.23 billion, or 36 percent higher than the $3.44 billion cumulative present value cost of the BAU case.

Taken in context, the RPS premium is small. By comparison, one advocacy group estimated consumer savings from the start of deregulation in 1999 to 2001 totaled $4 billion from rate cuts and shopping savings.[1] Further, on a statewide energy consumption basis, $1.23 billion equates to a premium of only 0.036 cents/kWh or a 0.46 percent increase over the average 2001 Pennsylvania retail electricity price of 7.86 cents/kWh. Based on an average household monthly electricity consumption of 800 kWh, the RPS would increase electricity costs per household by about 29 cents per month versus the BAU scenario.

Jobs, Income, and Economic Output

It has long been recognized that there can be significant socioeconomic impacts associated with new power plant investment. Foremost among these are the associated increases in employment, output, and income which arise in a local or regional economy. Increases in these categories occur as labor is directly employed in the construction and operation of a power plant, as local goods and services are purchased and utilized, and as those directly realizing added income from the project spend a portion of that income in the local economy. This process describes a "multiplier" effect in the economy.

For the study of the RPS, the intent is to estimate the multiplier impacts arising in Pennsylvania due to the construction and operation of a renewable portfolio, and to compare these impacts with those arising from a BAU expansion plan based on conventional technologies. The model chosen for use in the study is the Regional Input-Output Modeling System (RIMS II model), developed and maintained by the Bureau of Economic Analysis.

The RPS multiplier analysis involved evaluating impacts arising from construction and operation periods, then summing these impacts to arrive at a total impact for the RPS and BAU scenarios. The impacts are proportional to the percent of project expenditures made in Pennsylvania. For example, there is currently little wind turbine manufacturing capacity in Pennsylvania, so multiplier impacts associated with new wind farms are relatively modest. On the other hand, the presence of American Hydro and other companies indicates strong industrial capability for hydro, resulting in higher projected multiplier impacts.

The result of this process was the estimated output, earnings, and employment impact estimate for each RPS and BAU technology, compared in Figure E-1.

The cumulative impacts over the planning period are estimated by combining the impacts estimated on a unit basis with the total MW of capacity installed. Table E-1 compares the total impacts associated with the RPS and BAU portfolios. Figure E-2 shows the total estimated employment impact for each of the technologies.

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[1] J. Hanger, "2003 Mid-Course Review", Citizens for Pennsylvania's Future, available at www.eere.energy.gov/pro/pdfs/john_hanger.pdf.

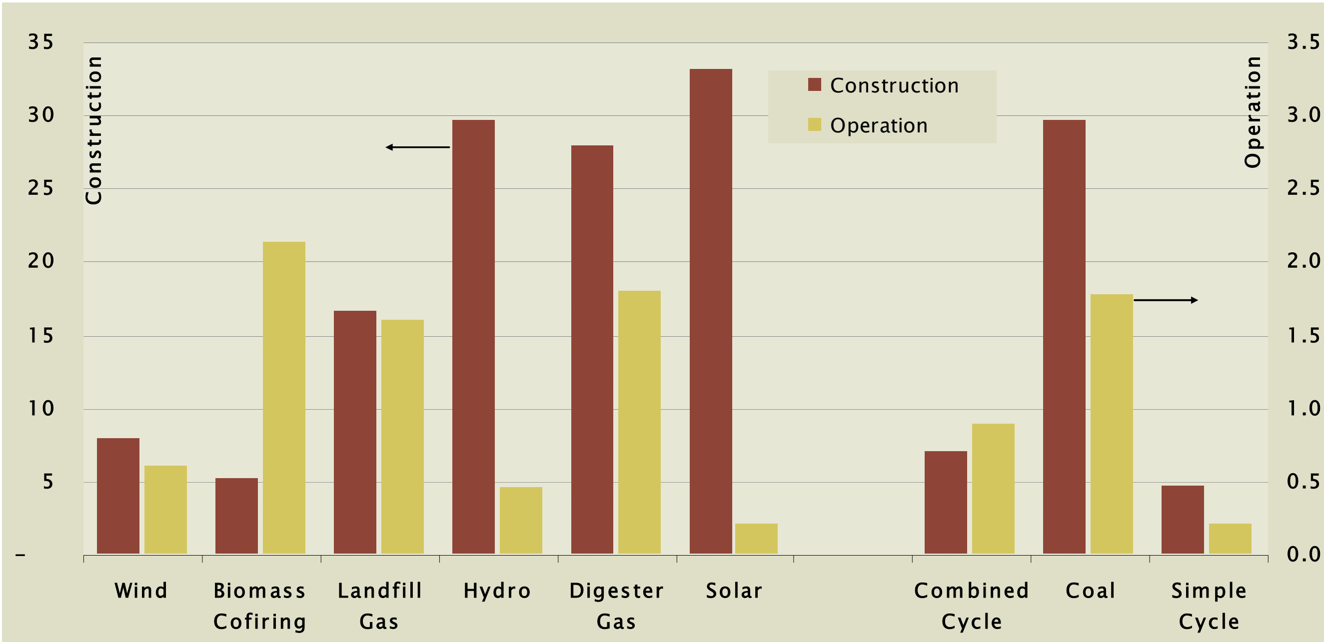

Figure E-1. Comparison of Pennsylvania Energy Employment Impacts per MW.

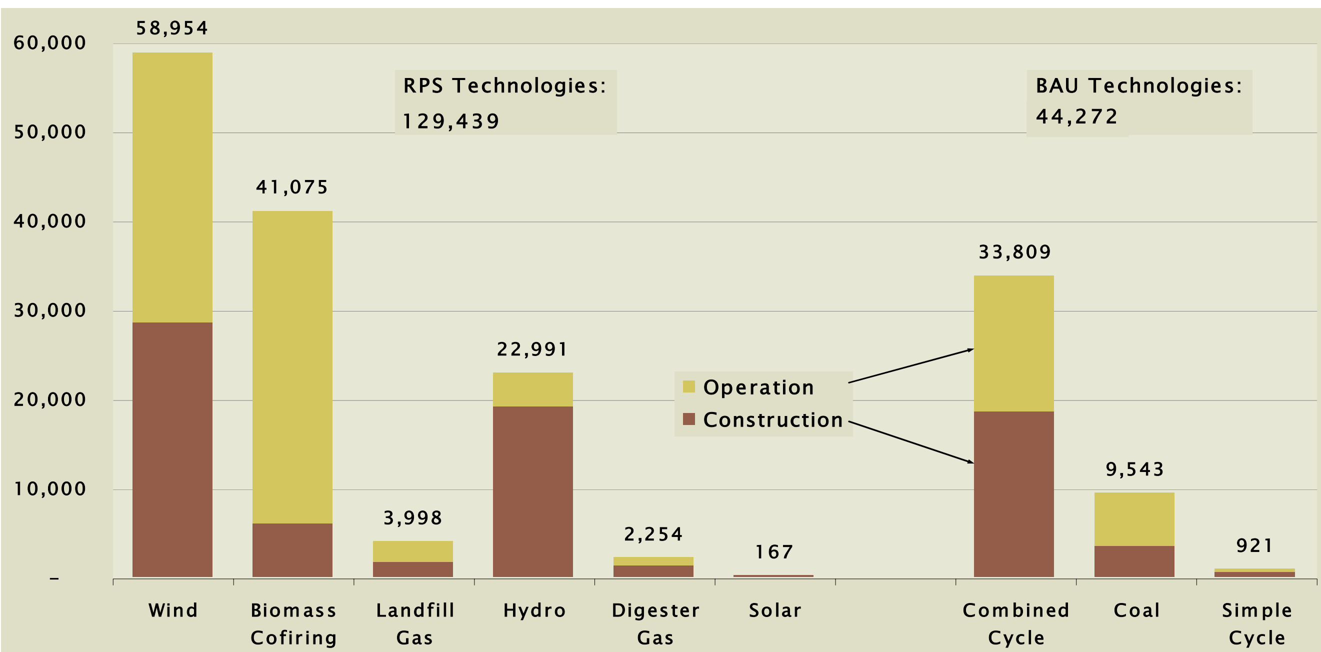

Figure E-2. Cumulative Employment Impacts for Construction and Operation Periods.

Table E-1. Cumulative Impacts For Construction and Operation Periods, RPS Versus BAU Portfolios.

	Output Impact	Earnings Impact	Employment Impact
RPS Portfolio	$15,468,918,425	$4,736,305,108	129,439
BAU Portfolio	$5,391,459,876	$1,897,570,828	44,272
Difference	$10,077,458,549	$2,838,734,279	85,167

Results indicate that the RPS portfolio has a significantly larger impact than does the BAU scenario. This includes an approximate $10.1 billion advantage in output, a $2.8 billion advantage in earnings, and approximately 85,000 more jobs (or "job-years") over the 20 year planning period. It is also useful to note that the RPS portfolio's added earnings multiplier impacts of approximately $2.8 billion would more than offset the BAU's cumulative present value direct electricity cost advantage of approximately $1.2 billion (see Section E.2). That is, the additional income earned by Pennsylvanians working in the renewable energy industry more than makes up for the small increase in electricity bills.

Fossil Fuel Prices

By decreasing the demand for fossil fuels, renewable energy resources may lower fuel prices and could potentially save consumers millions of dollars a year. Black & Veatch analyzed the potential impacts to fossil fuel prices and consumption as a result of the RPS in Pennsylvania by consulting four recent national and regional studies. Each of the studies reviewed assumed that natural gas fueled power generation is "on the margin" throughout the country, thus would be displaced by the installation of additional renewable energy generation.

The studies present strong evidence that suggest that there are natural gas price impacts as a result of the adoption of renewable energy policies. If the relationship between renewable energy and natural gas prices assumed by these studies holds true, a decrease in natural gas prices of up to perhaps 3 percent could be experienced. However, because the share of natural gas fueled power generation in Pennsylvania is relatively small (3 percent), the results of the analyses on these states are difficult to generally apply to Pennsylvania. Further, it is difficult to assert that relatively small changes in consumption by Pennsylvania would have significant impacts on the regional or national gas market.

Table E-2 shows the potential savings by assuming 1, 2, and 3 percent reductions in gas and coal prices. For example, if the RPS policy resulted in a reduction of 3 percent for natural gas and coal 2002 prices, the combined impact would be annual savings in excess of $400 million. By comparison, the expected cost premium in 2015 for the RPS portfolio over the BAU portfolio is only $295 million (see Table E-5). Even a 1 percent reduction would result in annual fuel savings of almost $140 million based on 2002 prices, roughly 50 percent of the projected 2015 RPS premium.

Table E-2. Potential Fossil Fuel Price Savings.

	Total Expenditures, $000s	Savings, $000s
2002 Natural Gas	12,191,026	
1% Price Reduction	12,069,116	121,910
2% Price Reduction	11,947,205	243,820
3% Price Reduction	11,825,295	365,730
2002 Coal	1,697,213	
1% Price Reduction	1,680,241	16,972
2% Price Reduction	1,663,269	33,944
3% Price Reduction	1,646,296	50,916

Conclusions

The following are the major findings of this economic impact analysis:

- **Electricity Costs** – the 20-year projected RPS portfolio electricity cost of $4.68 billion is nearly $1.23 billion, or 36 percent higher than the $3.44 billion estimate for the BAU scenario.
- **Electricity Costs –** the $1.23 billion higher cost equates to a premium of 0.036 cents/kWh over all electricity sold in the state. This is a 0.46 percent increase over the average 2001 Pennsylvania retail electricity price of 7.86 cents/kWh.
- **Electricity Costs** – Based on an average household monthly electricity consumption of 800 kWh, the RPS would increase electricity costs per household by about 29 cents per month versus the BAU scenario.

- **Economic Impacts:** the RPS portfolio has a significantly better economic impact than does the BAU scenario including an approximate $10.1 billion advantage in output, a $2.8 billion advantage in earnings, and approximately 85,000 more job-years over the 20 year planning period.
- **Fuel Savings –** Although not directly modeled in this study, other studies indicate that establishment of an RPS would result in gas and coal cost savings due to decreased demand. A 1 percent reduction in prices would result in annual fuel savings of almost $140 million based on 2002 prices, roughly 50 percent of the projected 2015 RPS premium.

2. COST OF ELECTRICITY

To estimate the direct impact that an RPS would have on electricity costs, an economic model was constructed to measure the 20-year (2006-2025) cost of providing 10 percent of the electricity consumed in Pennsylvania from renewable energy sources. This involved comparing the cost of generating electricity under the RPS with the costs that would be avoided (avoided fuel, O&M costs, and capacity costs) due to the RPS. In essence these avoided costs represent the benefit or value of the RPS. Ignoring secondary costs and benefits, the avoided costs represent the maximum that consumers could pay for electricity and be no worse off than in the BAU case. Stated differently, if the costs of the RPS are below the BAU avoided costs resulting from the program, it is an indication that the RPS would have direct cost of power benefits to consumers compared to a BAU case. Conversely, should the RPS costs be higher than the BAU avoided costs, it is an indication that the direct cost of the RPS does not result in direct electricity savings to consumers, although the RPS program may still be beneficial when secondary costs and benefits are considered (Section E.3 and E.4).

2.1 RPS ECONOMIC MODEL ASSUMPTIONS

To construct the economic model, assumptions about the future policy regime, generation mix, and generation technology costs were made. The assumptions are explained below and summarized in Table E-3. (All tables for Section E.2 are provided at the end of the section.)

RPS Study Period and Energy Targets

The RPS is based on the premise that 10 percent of the energy consumption in Pennsylvania would be provided by renewable energy over a long-term horizon. The study period was established for a 20-year period beginning in 2006 and extending through 2025.

A forecast of total energy consumption for the study period was required. The forecast was based on actual 2002 energy consumption for the state reported by EIA, and was increased at an assumed annual average growth rate of 1.5 percent, based on the forecast for the region by PJM. It is assumed that 1 percent of energy consumption would be met by new renewable energy generation in 2006, with an increase of 1 percent annually until the 10 percent program target is reached in 2015. The target would remain at 10 percent until the end of the study period. Due to load growth, this requires the addition of new renewable capacity after the RPS ramp up period. Table E-3 indicates that the 2006 energy requirements to be met from the RPS would be 1,485 GWh. This would increase to 16,985 by 2015 (the end of the ramp period) and 19,712 GWh by 2025.

Unit Cost and Performance Assumptions

The average cost and performance assumptions for each technology developed as part of the RPS supply curve analysis are presented in Table E-3. To keep the number of alternatives evaluated at a workable level, a representative cost and performance figure was developed for each technology. The representative numbers are based on the average cost determined from the renewable resource supply curve developed in Section D. As such, they include consideration for economies of scale, higher cost resources, transmission constraints, etc. For example, the costs of wind represent the average of class 3 through class 6 wind farms, with a large portion lower speed resources and/or requiring additional costs for transmission system upgrades.

Cost and performance categories for each technology include installed cost per kW, which range from $346/kW for biomass cofiring, to $7,245/kW for solar photovoltaic technology. In general, these estimates are conservative. The capital cost information is followed in the table by the assumed capacity factor, fixed and variable O&M costs, fuel costs (if applicable), tax credits, the levelized fixed charge rate, and the capital recovery period. Also listed is the present value discount rate, general inflation rate, fuel price escalation, and wind capital cost escalation rate (assumed to be zero in the base case).

Selected RPS Capacity Mix

Working down Table E-3, a key input to the model is the "Selected Capacity Mix to Meet the RPS Target". The model is set up to allow the user to specify what percent of the RPS capacity portfolio will be met by wind, biomass cofiring, low-impact hydro, etc. The capacity mix determines the cost and performance characteristics for the entire RPS portfolio, and can be used to perform sensitivity analyses. The initial portfolio selection assumes a capacity mix consisting of approximately 65 percent wind, 2 percent landfill gas, 1 percent digester gas, 21 percent biomass cofiring, 11 percent hydro, and a minimal amount of solar photovoltaic (0.1 percent). This mix was determined by the supply curve analysis described in Section D.

The same portfolio mix is assumed to be employed each year to meet the RPS. Assuming the same average mix of technologies is used each year is a simplifying, but conservative, assumption. In reality, the least cost technologies from the supply curve would be employed first, followed by higher cost technologies in latter years. Table E-6 shows the projected mix of technologies to meet the RPS.

Annual cost and performance estimates were calculated from the selected RPS portfolio mix. The weighted average fixed O&M, variable O&M, and fuel costs were calculated to estimate the total annual portfolio costs. The percent of energy generation contributed by each technology, which will differ from that in the capacity mix, was calculated from technology specific weighted average capacity factors.

Yearly Cost Estimates

The inputs and user specified assumptions in the top half of Table E-3 determine the year-by-year costs of meeting the RPS energy production target. In the bottom portion of the table, the cost columns are organized as follows:

- Column A is the Year
- Column B is the amount of renewable energy (GWh) required to be placed into service to meet the RPS target.
- Column C is the amount of renewable capacity (MW) needed each year to meet the RPS target, and is determined based on the selected capacity mix, and the annual production per MW of the selected RPS portfolio mix. Thus, to meet the 2006 RPS target of 1,485 GWh, a total of 423 MW of renewable capacity would be required in the first year of the analysis based on the selected capacity mix that produces 3,510 MWh per MW.
- Column D indicates the capacity cost of the RPS portfolio in a given year, and is based on the escalated installed cost of each technology and the levelized fixed charge rate. The capacity cost of the portfolio increases gradually from 2006 through 2020, then decreases due to three technologies (digester gas, landfill, and biomass cofiring) that are assumed to have a 10 year capital recovery period, but an operational life extending through the end of the study period.
- Column E is the fixed O&M costs of the RPS portfolio. This figure increases over time due to inflationary impacts and additional generating capacity coming into service.
- Column F is the variable O&M costs of the RPS portfolio. This figure increases over time due to inflationary impacts and additional generating capacity coming into service.
- Column G indicates the fuel cost of the portfolio, which consists of the cost of biomass fuel for cofiring.

- Column H indicates the tax credit value, which is assumed to be renewed for wind generation. The tax credit is assumed to be 1.97 cents/kWh in 2006.
- Column I is a sum of the previous cost components
- Column J is the cumulative present value cost of the RPS which is calculated by computing the present value of each annual total cost (Column H), and adding the present value to the previous years' present values.
- Column K is the annual busbar cost calculation, which represents the total cost of generating electricity with the portfolio in a given year on a cents/kWh basis.
- Column M is the busbar cost in present value terms. The levelized cost is provided at he bottom of the column. This is stated as both a net levelized bus bar cost (6.14 cents/kWh) and as a net levelized annual cost ($665 million).

The levelized busbar cost, levelized annual cost, and cumulative present value cost of the RPS portfolio shown in Table E-3 will be compared to the corresponding costs of the BAU avoided cost calculations made in the next section.

2.2 BAU AVOIDED COSTS (VALUE CALCULATION OF THE RPS

Given the estimated cost of the 10 percent RPS, it is important to determine whether the RPS portfolio cost is more or less than a BAU scenario in which no RPS is established. This can be done by comparing the cost of the RPS against the BAU costs avoided if an RPS is established. Costs avoided due to the adoption of the RPS include fuel, variable O&M, and fixed O&M costs that would have been incurred by pulverized coal, combined cycle gas, and simple cycle gas alternatives assumed to be built in the BAU case. Some capacity costs are also avoided, as discussed in further detail later.

Avoided costs that are lower than the RPS costs indicate that the RPS is not strictly cost-effective when looking only at direct costs; conversely, avoided costs higher than the RPS costs indicate that the RPS portfolio is cost-effectively replacing energy that would have otherwise been generated by conventional sources. For example, assume that in the absence of an RPS portfolio, consumers would pay $100 million in present value costs to provide 10 percent of energy consumption over a 20-year period. This implies that, ignoring indirect benefits, an RPS portfolio costing less than $100 million would generate a direct economic benefit. A BAU portfolio costing less than the RPS portfolio would mean that additional costs would be incurred by ratepayers under the RPS portfolio, though it may still be preferred once indirect benefits are considered.

The assumptions for the BAU scenario are presented in Table E-4 and explained below.

Unit Cost and Performance Assumptions

The top section of Table E-4 includes unit cost and performance characteristics including capital cost, net plant heat rate, O&M cost, and fuel cost. Estimates for these values are based on Black & Veatch power plant engineering and construction experience.

Economic Assumptions and Capacity Credits

The top of Table E-4 also lists a number of factors used to calculate the present value costs of the BAU case. The general inflation rate and present value discount rate are the same as in the RPS case. The levelized fixed charge rates for the conventional technologies are based on current utility cost of financing assumptions.

An additional input in this case is the "RPS Capacity Credit". This input specifies the percentage of capacity which can be avoided due to the adoption of the RPS portfolio. This could theoretically range from a 1-to-1 credit, meaning that for each MW of renewable capacity installed 1 MW of conventional capacity is avoided, to no credit. There has been much discussion in the industry as to whether renewables which are intermittent producers of energy, particularly wind and solar generation, will actually allow the avoidance of capacity. The argument against crediting such technologies with avoiding capacity-related costs is that a utility needs to plan its system to have sufficient capacity to meet its peak load plus an adequate reserve. For example, many utilities have not counted installed wind capacity towards the capacity requirements because the availability of wind generation is largely dependent on factors outside the utility's control (wind speed, weather patterns, etc.).

The alternative argument, dating back to the implementing language of the Public Utilities Regulatory Policy Act of 1978, is that if a renewable and intermittent resource produces a generation profile such that even a portion of the installed capacity can be relied upon as being available, especially during peak periods, then it is appropriate to take this reliable level of capacity into account during planning. Therefore a portion of the capacity can be used to avoid incremental capacity costs.

Along these lines, PJM Interconnection recently established a capacity credit methodology for wind generators.[2] Effective June 1, 2003, capacity credits are granted based on a wind facility's actual performance during PJM's peak-use hours (June, July and August, 3 to 6 PM). For wind farms with less than three years' operating experience, a capacity credit equal to 20 percent of the rated capacity applies. The 20 percent figure is based on the actual performance of existing Pennsylvania wind farms and will be used as the basis for this study.

For technologies other than wind, the base case assumption is that a renewable technology receives a capacity credit based on the expected long term capacity factor relative to that expected for conventional pulverized coal technology (85 percent). For example, a hydro plant which is expected to achieve a long-term capacity factor of 50 percent is assumed to receive a capacity credit of 59 percent (.50/.85). An exception is biomass cofiring at existing coal plants which does not increase MW output and, therefore, receives no incremental capacity credit. Further, solar is granted a capacity credit of 50 percent due to its favorable output correlation with peak usage periods. Based on the assumptions seen at the top of Table E-4, the weighted average capacity credit for the portfolio mix specified in Table E-3 is approximately 22 percent. This low number indicates that the renewable technologies are largely contributing energy, but not capacity.

BAU Capacity Mix

Another key input assumption into the BAU model concerns the capacity mix that would be used to meet 10 percent of energy consumption in the absence of the RPS. The optimum mix of capacity in the BAU case would typically be determined through a least cost expansion planning study, in which an hourly production costing model would be used to simulate the operation of the entire system. Alternative plans that meet the capacity requirements would be developed and compared on an economic basis. However, while this approach produces the most accurate results, it was outside the scope of this study. Therefore, it was necessary to make reasonable assumptions about the future capacity mix and perform sensitivity analyses.

The base case assumptions for the BAU scenario are that 50 percent pulverized coal, 40 percent gas-fired combined cycle, and 10 percent gas-fired simple cycle capacity would be installed. This assumption is a driver in the BAU cost and is also subject to considerable uncertainty due to the increasingly tightening environmental regulations on coal fired

[2] PJM Interconnection, "PJM Rule Change Supports Wind Power," April 24, 2003, Available at: www.pjm.com

power plants and the volatile natural gas market. In general, coal power generation is lower cost than natural gas power generation based on the assumptions of this analysis. A coal-focused BAU portfolio will make the RPS portfolio look more expensive in comparison, making this a conservative assumption. Sensitivity evaluations are performed for zero and 25 percent coal mixes.

Further it is expected that some renewable energy development would likely occur in Pennsylvania regardless of the establishment of a state RPS. This is due to growing consumer preference for renewable energy as well as strong renewable energy mandates in surrounding states, particularly New Jersey and New York. However, it was decided to not include any renewable energy development in the BAU scenario in order to allow direct comparisons to be made.

Based on the selected capacity mix, the final rows in the top half of Table E-4 calculate the weighted average capacity cost per MW of the BAU capacity mix, the weighted average fixed and variable O&M costs, and the MWh produced per MW of the selected capacity mix.

Yearly Cost Estimates

The bottom portion of Table E-4 calculates the annual BAU avoided costs. The calculations are made and organized in a similar manner as those in Table E-3:

- Column A is the Year
- Column B lists the energy that can be avoided if the RPS is in place.
- Column C lists the conventional capacity (MW) that can be avoided due to the installation of renewable energy. The avoided capacity is based on a 22 percent capacity credit.
- Column D lists the avoided conventional capacity cost based on the BAU capacity mix and conventional technology fixed charge rate.
- Columns E and F list the avoided conventional technology fixed and variable O&M, respectively.
- Column G lists the avoided fuel costs from conventional technologies due to the energy produced from the RPS portfolio mix. This represents direct avoidance of incremental fuel usage.
- Column H is the total avoided cost, consisting of avoided capacity, fixed O&M, and variable O&M costs.
- Column I calculates the cumulative present value avoided costs, which is equal to $3.44 billion.
- Columns J and K provide annual busbar costs and calculate the net levelized busbar avoided cost (4.30 cents/kWh) and net levelized annual cost $490 million.

2.3 RESULTS

The net economic cost or benefit of the 10 percent RPS is calculated by comparing the key results contained in Table E-3 and Table E-4. Table E-5 directly compares the year-by-year and cumulative present value RPS cost with the BAU avoided cost (RPS value). In terms of cumulative present value costs over a 20-year period, the RPS portfolio cost of $4.68 billion is nearly $1.23 billion, or 36 percent higher than the $3.44 billion BAU avoided cost. This means that, under the base assumptions made in the analysis, the state of Pennsylvania would pay approximately 36 percent more ($1.23 billion) in present value costs for the new energy associated with the RPS portfolio versus the BAU scenario over the 20 year evaluation term.

Taken in context, the RPS premium is small. By comparison, one advocacy group estimated consumer savings from the start of deregulation in 1999 to 2001 to be $4 billion from rate cuts and shopping savings.[3] Further, on a statewide energy consumption basis, $1.23 billion equates to a premium of only 0.036 cents/kWh or a 0.46 percent increase over the average 2001 Pennsylvania retail

[3] J. Hanger, “2003 Mid-Course Review”, Citizens for Pennsylvania’s Future, available at www.eere.energy.gov/pro/pdfs/john_hanger.pdf.

electricity price of 7.86 cents/kWh. Based on an average household monthly electricity consumption of 800 kWh, the RPS would increase electricity costs per household by about 29 cents per month versus the BAU scenario. The magnitude of industrial and commercial increases would be larger, but still relatively small in comparison to the monthly bill amount.

The levelized bus-bar cost and levelized annual cost results produce identical conclusions as the cumulative present value cost comparison. The levelized busbar cost for the BAU scenario is below that of the RPS scenario (4.3 cents/kWh versus 6.12 cents/kWh). Similarly, the levelized annual cost of the BAU scenario is approximately $175 million below the RPS levelized annual cost. Again, while this is a noticeable cost difference in relation to the 10 percent RPS portfolio, it is relatively minor when spread among all energy consumption in the state.

2.4 ECONOMIC SENSITIVITY EVALUATIONS

The assumptions for the base case economic analysis are subject to uncertainty and have the potential to significantly impact the results. To quantify the potential impact that these variables may have, several sensitivity evaluations were performed, including the following:

- **Capacity Credits** – 20 percent reduction / increase in RPS capacity credits for each RPS technology. For example, the wind capacity credit is changed from 20 percent to zero and 40 percent.
- **Natural Gas Prices** – 4, 3, and 0 percent natural gas fuel price escalation rate. The base case gas price is $4.50/MBtu at 3.5 percent annual escalation. A sensitivity case of natural gas prices $0.50/MBtu higher than the base case was also performed to simulate the cost of hedging natural gas costs to match the security of fixed-price renewables.[4]
- **Restrictive Renewable Energy Definition** – (1) More restrictive renewable energy definition excluding biomass cofiring. It is assumed that direct biomass combustion replaces cofiring. (2) More restrictive renewable energy definition excluding hydro. It is assumed that additional wind resources replace hydro. (3) Combination of the above two scenarios.
- **Lower Wind Capital Costs –** Reduction of the average wind capital cost from $1,550/kW to $1,300/kW and $1,000/kW. The weighted average wind capital cost was determined from the supply curve analysis (Section D) which identified a wide spectrum of wind projects ranging in capital cost from $1,193/kW to $2000/kW. There are a limited number of sites near the lower end of this range in Pennsylvania, many of which are currently being developed. The highest cost sites in this study are Class 3 and 4 sites requiring substantial transmission and distribution upgrades as they are generally located further from existing infrastructure. Although these sites are not currently being developed, it is expected that they may need to be developed to meet the full requirements of the RPS. This increases the average wind capital cost above typical values seen today. This sensitivity scenario investigates the impact of lower wind capital cost assumptions.
- **Production Tax Credit** – (1) No production tax credit for wind (or any other technologies) and (2) production tax credit for all renewable energy technologies.
- **Coal** – Lower coal capacity scenarios assuming that 20 percent and zero percent of BAU capacity is pulverized coal. The base case assumed 50 percent.

The results of these sensitivity analyses are presented in Table E-7. The results are summarized in terms of (1) the cumulative present value cost of the RPS versus BAU portfolios and (2) the projected monthly RPS premium per household. Across all

[4] M. Bolinger, R. Wiser, W. Golove, "Accounting for Fuel Price Risk: Using Forward Natural Gas Prices Instead of Gas Price Forecasts to Compare Renewable to Natural Gas-Fired Generation," August 2003.

scenarios, the RPS portfolio was between 6 percent and 120 percent more costly than the BAU case. The best RPS cases include lowering of average wind capital cost to $1,000/kW (sometimes reported for larger wind projects outside the Northeast), elimination of new coal capacity from the BAU case, and expansion of the production tax credit to cover all renewables (similar to proposals included as part of the federal energy bill). These sensitivity cases resulted in monthly household RPS premiums of 10 and 6 cents, respectively (versus 29 cents in the base case).

In terms of negative impacts, the largest appears to be an RPS renewable energy definition that does not include biomass cofiring at existing coal plants. The sensitivity scenario assumed that this biomass would instead be burned in new, higher cost dedicated biomass plants. It is estimated that using this biomass in new dedicated plants would triple the RPS cost premium versus the base case. In reality, some of the replacement energy might come from other resources, particularly wind.

Not allowing hydro to count towards the RPS would only have slight impact, raising costs 7 percent.

Elimination of the production tax credit for wind resources would raise the RPS cost premium by about 50 percent over the base case.

Changes in capacity credits and natural gas prices have relatively small impacts. The exception is the elimination of natural gas price escalation, which would increase the RPS cost premium by over 40 percent. For this to happen, large new gas supplies would have to be introduced to the market and/or demand would have to be substantially reduced. The RPS itself may result in reduced demand for natural gas; this is explored further in Section E.4.

When examining the combined results of the sensitivity investigations, it seems plausible that there are scenarios where implementing an RPS would actually result in lower direct electricity costs. For example, if average wind capital costs were decreased to $1300/kW and the production tax credit was extended to all technologies, the model predicts that the RPS would result in virtual no additional costs on consumers.

None of the savings or cost calculations presented in this section consider secondary economic benefits such as job creation. These are described further in the next section.

Table E-3. RPS Cost Calculation.

Unit Cost & Performance Data *(weighted averages from supply curve analysis)*		**Wind**	**Landfill Gas**	**Digester Gas**	**Biomass Cofiring**	**Hydro**	**Solar PV**	
Installed Cost/kW, 2003		$1,550	$1,590	$2,510	$346	$1,502	$7,245	
Full Load Heat Rate, Btu/kWh (HHV)		0	0	0	11,146	0	0	
Achievable Capacity Factor		28.4%	80%	80%	66%	50%	14%	
Fixed O&M ($/kW-yr), 2003		$20.48	$0.00	$0.00	$12.12	$10.30	$0.01	
Variable O&M ($/MWh), 2003		$7.20	$15.00	$15.00	$0.00	$2.73	$0.00	
Fuel Cost ($/MBtu), 2003		$0.00	$0.00	$0.00	$2.05	$0.00	$0.00	
Fuel Cost per MWh, 2003		$0.00	$0.00	$0.00	$22.86	$0.00	$0.00	
Fuel Escalation		0.0%	0.0%	0.0%	3.0%	0.0%	0.0%	
10-Year Production Tax Credit, $/MWh, 2006$		$19.7	$0.0	$0.0	$0.0	$0.0	$0.0	
Levelized Fixed Charge Rate		11.0%	17.8%	18.9%	18.9%	15.0%	9.9%	
Capital Recovery Period		15	10	10	10	20	20	
General Inflation	3.0%							
Present Value Discount Rate	10.0%							
Wind Capital Cost Escalation	0.0%							
RPS PortfolioMix								**Total**
Selected Capacity Mix to Meet RPS Target		64.8%	1.8%	0.8%	21.1%	11.4%	0.08%	100.0%
RPS Weighted Avg. Capacity Cost, $/kW, 2003								1,304
Annual MWh Produced Per MW of Portfolio		1610.8	128.9	53.2	1216.0	499.7	1.0	3,510
Energy Production by Technology, % of Total		45.9%	3.7%	1.5%	34.6%	14.2%	0.0%	100%
RPS Weighted Avg. FOM Cost, $/kW-yr, 2003								17.01
RPS Weighted Avg. VOM Costs, $/MWh, 2003								5.37
Percent of Total Energy Requirements Met by RPS Portfolio								10.0%

(A) Year	(B) RPS Energy Target GWh	(C) Incremental MW to Meet RPS Portfolio MW	(D) Capacity Cost of RPS Portfolio ($ 1,000)	(E) FOM Costs with RPS Portfolio ($ 1,000)	(F) VOM Costs with RPS Portfolio ($ 1,000)	(G) Fuel Costs with RPS Portfolio ($ 1,000)	(H) Value of Production Tax Credit ($ 1,000)	(I) Total Cost of RPS Portfolio ($ 1,000)	(J) Cumulative PV Cost of RPS Portfolio ($ 1,000)	(K) Busbar Cost of RPS Portfolio (c/kWh)	(M) Pres.Value Busbar Cost (c/kWh)
2006	1,485	423.3	$69,419	$7,865	$8,714	$12,857	$13,410	$85,445	$64,196	5.75	4.32
2007	3,016	436.0	$141,619	$16,202	$18,221	$26,882	$28,040	$174,885	$183,645	5.80	3.96
2008	4,591	448.9	$216,712	$25,281	$28,574	$42,156	$43,971	$268,751	$350,518	5.85	3.63
2009	6,213	462.2	$294,811	$35,152	$39,830	$58,762	$61,293	$367,263	$557,828	5.91	3.34
2010	7,883	475.8	$376,038	$45,867	$52,050	$76,791	$80,098	$470,649	$799,346	5.97	3.06
2011	9,602	489.7	$460,517	$57,484	$65,299	$96,338	$100,486	$579,153	$1,069,525	6.03	2.81
2012	11,370	503.9	$548,381	$70,063	$79,645	$117,502	$122,562	$693,029	$1,363,437	6.10	2.58
2013	13,189	518.4	$639,766	$83,666	$95,160	$140,392	$146,437	$812,547	$1,676,709	6.16	2.38
2014	15,060	533.2	$734,816	$98,361	$111,921	$165,119	$172,229	$937,987	$2,005,468	6.23	2.18
2015	16,985	548.3	$833,680	$114,219	$130,008	$191,804	$200,063	$1,069,648	**$2,346,291**	6.30	2.01
2016	17,240	72.6	$836,465	$119,406	$135,917	$200,522	$191,134	$1,101,175	$2,665,262	6.39	1.85
2017	17,498	73.7	$838,969	$124,828	$142,095	$209,635	$180,979	$1,134,548	$2,964,024	6.48	1.71
2018	17,761	74.8	$841,171	$130,496	$148,553	$219,163	$169,507	$1,169,876	$3,244,083	6.59	1.58
2019	18,027	75.9	$843,045	$136,422	$155,305	$229,124	$156,618	$1,207,277	$3,506,822	6.70	1.46
2020	18,298	77.0	$844,563	$142,617	$162,363	$239,538	$142,208	$1,246,874	$3,753,509	6.81	1.35
2021	18,572	78.2	$798,910	$149,094	$169,743	$250,425	$126,163	$1,242,008	$3,976,895	6.69	1.20
2022	18,851	79.4	$751,440	$155,865	$177,457	$261,807	$108,367	$1,238,202	$4,179,351	6.57	1.07
2023	19,133	80.6	$702,089	$162,943	$185,523	$273,706	$88,693	$1,235,569	$4,363,010	6.46	0.96
2024	19,420	81.8	$650,792	$170,343	$193,955	$286,146	$67,006	$1,234,230	$4,529,792	6.36	0.86
2025	19,712	83.0	$597,480	$178,079	$202,770	$299,151	$43,164	$1,234,316	**$4,681,423**	6.26	0.77
								Net Levelized Cost (c/kWh)			**6.124**
Total:	273,906	5,617						Net Levelized Annual Cost ($000s)			**665,353**

Table E-4. Calculation of the BAU Avoided Costs (Value) of the RPS Portfolio.

Unit Cost & Performance Data	Pulverized Coal	Combined Cycle Gas	Simple Cycle Gas
Installed Cost/kW, 2003	$1,700	$650	$500
Full Load Heat Rate, Btu/kWh (HHV)	9,800	7,000	9,700
Assumed Capacity Factor	85.0%	75.0%	10.0%
Fixed O&M ($/kW-yr), 2003	$18.00	$6.30	$3.00
Variable O&M ($/MWh), 2003	$2.60	$2.30	$2.80
Fuel Cost ($/MBtu), 2003	$1.25	$4.50	$4.50
Fuel Cost per MWh, 2003	$12.25	$31.50	$43.65
Fuel Escalation	2.5%	3.5%	3.5%
Levelized Fixed Charge Rate	12.4%	12.4%	12.4%
Capital Recovery Period	30	30	25

	Wind	Landfill Gas	Digester Gas	Biomass Cofiring	Hydro	Solar PV
Achievable Capacity Factor	28%	80%	80%	66%	50%	14%
Capacity Credit	20%	94%	94%	0%	59%	50%

Weighted Average Capacity Credit: 22.2%

General Inflation	3.0%
Present Value Discount Rate	10.0%

BAU Capacity Mix

	Pulverized Coal	Combined Cycle Gas	Simple Cycle Gas	
Selected Capacity Mix	50.0%	40.0%	10.0%	
Weighted Avg. Capacity Cost, $/kW, 2003				1,160
Annual MWh Produced Per MW of Capacity Mix	3723.0	2628.0	87.6	6,439
Energy Production by Technology, % Total	57.8%	40.8%	1.4%	100.0%
BAU Weighted Avg. FOM Cost, $/kW-yr, 2003				11.82
BAU Weighted Avg. VOM Costs, $/MWh, 2003				2.50
Weighted Avg. Capacity Credit with RPS Mix				22%

(A) Year	(B) Avoided Energy with RPS Target GWh	(C) Avoided MW with RPS Capacity Credit	(D) Avoided Capacity Cost ($ 1,000)	(E) Avoided FOM Costs with RPS ($ 1,000)	(F) Avoided VOM Costs with RPS ($ 1,000)	(G) Avoided Fuel Cost with RPS ($ 1,000)	(H) Total Avoided Cost Value ($ 1,000)	(I) Cumulative Present Value of RPS Portfolio ($ 1,000)	(J) Busbar Value of RPS (c/kWh)	(K) PV Busbar Value (c/kWh)
2006	1,485	93.8	$14,742	$1,211	$4,058	$33,485	$53,497	$40,193	3.60	2.71
2007	3,016	96.6	$29,927	$2,496	$8,485	$70,123	$111,031	$116,028	3.68	2.51
2008	4,591	99.5	$46,033	$3,894	$13,306	$110,140	$173,373	$223,680	3.78	2.34
2009	6,213	102.4	$63,113	$5,414	$18,548	$153,775	$240,850	$359,633	3.88	2.19
2010	7,883	105.4	$81,221	$7,065	$24,238	$201,284	$313,808	$520,666	3.98	2.04
2011	9,602	108.5	$100,417	$8,854	$30,408	$252,936	$392,615	$703,824	4.09	1.91
2012	11,370	111.7	$120,762	$10,792	$37,088	$309,020	$477,662	$906,400	4.20	1.78
2013	13,189	114.9	$142,320	$12,887	$44,313	$369,843	$569,362	$1,125,913	4.32	1.66
2014	15,060	118.2	$165,159	$15,150	$52,118	$435,730	$668,157	$1,360,098	4.44	1.55
2015	16,985	121.5	$189,352	$17,593	$60,541	$507,027	$774,513	**$1,606,882**	4.56	1.45
2016	17,240	16.1	$192,651	$18,392	$63,292	$531,002	$805,338	$1,840,160	4.67	1.35
2017	17,498	16.3	$196,100	$19,227	$66,169	$556,122	$837,619	$2,060,731	4.79	1.26
2018	17,761	16.6	$199,706	$20,100	$69,176	$582,443	$871,425	$2,269,343	4.91	1.17
2019	18,027	16.8	$203,476	$21,013	$72,320	$610,021	$906,830	$2,466,696	5.03	1.09
2020	18,298	17.1	$207,417	$21,967	$75,607	$638,919	$943,910	$2,653,443	5.16	1.02
2021	18,572	17.3	$211,537	$22,965	$79,044	$669,198	$982,743	$2,830,198	5.29	0.95
2022	18,851	17.6	$215,844	$24,007	$82,636	$700,927	$1,023,415	$2,997,535	5.43	0.89
2023	19,133	17.9	$220,347	$25,098	$86,392	$734,175	$1,066,012	$3,155,991	5.57	0.83
2024	19,420	18.1	$225,055	$26,238	$90,319	$769,015	$1,110,626	$3,306,070	5.72	0.77
2025	19,712	18.4	$229,977	$27,429	$94,424	$805,524	$1,157,354	**$3,448,246**	5.87	0.72
							Net Levelized Cost (c/kWh)			**4.295**
Total	273,906	1,245					Net Levelized Annual Cost ($000s)			**490,086**

Table E-5. Projected Base Case RPS Economics (Nominal $).

Year	Total Electric Supply, GWh	RPS Electric Supply, GWh	Cost of RPS, million $	BAU Avoided Cost, million $	RPS Premium		
					million $	Per RPS kWh, $/kWh	Per All kWh, $/kWh
Yearly RPS Costs							
2006	148,548	1,485	$85	$53	$32	$0.0215	$0.0002
2007	150,776	3,016	$175	$111	$64	$0.0212	$0.0004
2008	153,038	4,591	$269	$173	$95	$0.0208	$0.0006
2009	155,334	6,213	$367	$241	$126	$0.0203	$0.0008
2010	157,664	7,883	$471	$314	$157	$0.0199	$0.0010
2011	160,029	9,602	$579	$393	$187	$0.0194	$0.0012
2012	162,429	11,370	$693	$478	$215	$0.0189	$0.0013
2013	164,865	13,189	$813	$569	$243	$0.0184	$0.0015
2014	167,338	15,060	$938	$668	$270	$0.0179	$0.0016
2015	169,848	16,985	$1,070	$775	$295	$0.0174	$0.0017
2016	172,396	17,240	$1,101	$805	$296	$0.0172	$0.0017
2017	174,982	17,498	$1,135	$838	$297	$0.0170	$0.0017
2018	177,607	17,761	$1,170	$871	$298	$0.0168	$0.0017
2019	180,271	18,027	$1,207	$907	$300	$0.0167	$0.0017
2020	182,975	18,298	$1,247	$944	$303	$0.0166	$0.0017
2021	185,720	18,572	$1,242	$983	$259	$0.0140	$0.0014
2022	188,505	18,851	$1,238	$1,023	$215	$0.0114	$0.0011
2023	191,333	19,133	$1,236	$1,066	$170	$0.0089	$0.0009
2024	194,203	19,420	$1,234	$1,111	$124	$0.0064	$0.0006
2025	197,116	19,712	$1,234	$1,157	$77	$0.0039	$0.0004
Cumulative Present Value Costs (10 percent discount rate)							
2006	148,548	1,485	$64	$40	$24	$0.0162	$0.00016
2007	150,776	3,016	$184	$116	$68	$0.0150	$0.00023
2008	153,038	4,591	$351	$224	$127	$0.0140	$0.00028
2009	155,334	6,213	$558	$360	$198	$0.0129	$0.00033
2010	157,664	7,883	$799	$521	$279	$0.0120	$0.00036
2011	160,029	9,602	$1,070	$704	$366	$0.0112	$0.00040
2012	162,429	11,370	$1,363	$906	$457	$0.0103	$0.00042
2013	164,865	13,189	$1,677	$1,126	$551	$0.0096	$0.00044
2014	167,338	15,060	$2,005	$1,360	$645	$0.0089	$0.00045
2015	169,848	16,985	$2,346	$1,607	$739	$0.0083	$0.00047
2016	172,396	17,240	$2,665	$1,840	$825	$0.0077	$0.00047
2017	174,982	17,498	$2,964	$2,061	$903	$0.0073	$0.00047
2018	177,607	17,761	$3,244	$2,269	$975	$0.0069	$0.00046
2019	180,271	18,027	$3,507	$2,467	$1,040	$0.0065	$0.00045
2020	182,975	18,298	$3,754	$2,653	$1,100	$0.0062	$0.00044
2021	185,720	18,572	$3,977	$2,830	$1,147	$0.0058	$0.00043
2022	188,505	18,851	$4,179	$2,998	$1,182	$0.0055	$0.00041
2023	191,333	19,133	$4,363	$3,156	$1,207	$0.0051	$0.00040
2024	194,203	19,420	$4,530	$3,306	$1,224	$0.0048	$0.00038
2025	197,116	19,712	$4,681	$3,448	$1,233	$0.0045	$0.00036

Table E-6. Projected RPS Technology Mix.

Year	Wind	Landfill Gas	Digester Gas	Biomass Cofiring	Hydro	Solar PV	Total
Cumulative Capacity, MW							
2006	274	8	3	89	48	0.3	423
2007	557	16	7	181	98	0.7	859
2008	848	24	10	276	149	1.1	1,308
2009	1,147	33	13	373	202	1.5	1,770
2010	1,456	41	17	474	257	1.9	2,246
2011	1,773	50	21	577	312	2.3	2,736
2012	2,100	60	25	683	370	2.7	3,240
2013	2,436	69	29	792	429	3.1	3,758
2014	2,781	79	33	905	490	3.5	4,291
2015	3,137	89	37	1,020	553	4.0	4,840
2016	3,184	90	37	1,036	561	4.0	4,912
2017	3,232	92	38	1,051	569	4.1	4,986
2018	3,280	93	38	1,067	578	4.2	5,061
2019	3,329	94	39	1,083	587	4.2	5,137
2020	3,379	96	40	1,099	595	4.3	5,214
2021	3,430	97	40	1,116	604	4.4	5,292
2022	3,481	99	41	1,133	613	4.4	5,371
2023	3,533	100	41	1,150	623	4.5	5,452
2024	3,586	102	42	1,167	632	4.6	5,534
2025	3,640	103	43	1,184	641	4.6	5,617
Cumulative Energy, GWh							
2006	682	55	23	515	212	0.4	1,485
2007	1,384	111	46	1,045	429	0.9	3,016
2008	2,107	169	70	1,591	654	1.3	4,591
2009	2,852	228	94	2,153	885	1.8	6,213
2010	3,618	289	119	2,731	1,122	2.2	7,883
2011	4,407	353	145	3,327	1,367	2.7	9,602
2012	5,219	418	172	3,940	1,619	3.2	11,370
2013	6,053	484	200	4,570	1,878	3.8	13,189
2014	6,912	553	228	5,218	2,144	4.3	15,060
2015	**7,796**	**624**	**257**	**5,885**	**2,418**	**4.8**	**16,985**
2016	7,913	633	261	5,973	2,455	4.9	17,240
2017	8,031	643	265	6,063	2,491	5.0	17,498
2018	8,152	652	269	6,154	2,529	5.1	17,761
2019	8,274	662	273	6,246	2,567	5.1	18,027
2020	8,398	672	277	6,340	2,605	5.2	18,298
2021	8,524	682	281	6,435	2,644	5.3	18,572
2022	8,652	692	286	6,532	2,684	5.4	18,851
2023	8,782	703	290	6,630	2,724	5.4	19,133
2024	8,913	713	294	6,729	2,765	5.5	19,420
2025	9,047	724	299	6,830	2,807	5.6	19,712

Table E-7. Sensitivity Results: 20-Year Cumulative Present Value Cost Comparisons.

Case	RPS (Millions)	BAU (Millions)	RPS Premium (Millions)	RPS Premium, percent	Premium, Per Household $/mo	Change from Base Case $/mo, percent
Base Case	$4,681	$3,448	$1,233	35.76%	$0.29	
RPS Capacity Credits						
20% Reduction	$4,681	$3,270	$1,412	43.20%	$0.33	14%
20% Increase	$4,681	$3,616	$1,066	29.50%	$0.25	-14%
Natural Gas Prices						
4 Percent Escalation	$4,681	$3,552	$1,129	31.78%	$0.27	-8%
3 Percent Escalation	$4,681	$3,351	$1,330	39.71%	$0.31	8%
No Escalation	$4,681	$2,888	$1,793	62.10%	$0.42	45%
+ $0.50/MBtu	$4,681	$3,622	$1,060	29.26%	$0.25	-14%
Restrictive Renewable Energy Definition						
No Cofiring	$7,072	$3,386	$3,685	108.80%	$0.87	200%
No Hydro	$4,783	$3,467	$1,316	38.00%	$0.31	7%
No Cofiring + No Hydro	$7,149	$3,261	$3,889	119.30%	$0.91	214%
Lower Wind Capital Costs						
$1,300/kW	$4,320	$3,448	$871	25.30%	$0.20	-31%
$1,000/kW	$3,886	$3,448	$438	12.70%	$0.10	-66%
Production Tax Credit (PTC)						
No PTC	$5,367	$3,448	$1,919	55.60%	$0.45	55%
PTC for All Renewables	$3,852	$3,342	$510	15.2%	$0.12	-59%
Coal						
25 percent of BAU Capacity	$4,681	$3,881	$800	20.63%	$0.19	-35%
0 percent of BAU Capacity	$4,681	$4,434	$248	5.58%	$0.06	-80%

3. INDIRECT AND SECONDARY ECONOMIC IMPACTS

This section discusses the indirect and secondary economic costs and benefits not included in the direct economic analysis of Section E.2. The additional impact categories evaluated include the multiplier impacts on output, earnings, and employment. These impacts are compared for the RPS and BAU cases.

3.1 MULTIPLIER IMPACTS

Historically, utilities were charged with planning utility systems to obtain a safe, adequate, and reliable supply of electricity at the lowest reasonable cost and in an environmentally acceptable manner. Practically, this objective has translated into selecting the expansion plan having the lowest cumulative present value cost, which consists of incremental system fuel and variable O&M costs, plus the capital and fixed O&M costs of new unit additions. Even so, it has long been recognized that there can be significant socioeconomic impacts associated with new power plant investment that are not directly accounted for in an expansion planning study. It is also possible that two competing expansion plans may generate very different socioeconomic benefits even if the direct costs are comparable. For this reason, it is important to consider the socioeconomic costs and benefits of implementing an RPS.

Foremost among the indirect socioeconomic benefits associated with the construction and operation of a power plant are increases in employment, output, and income which arise in a local or regional economy. Increases in these categories occur as labor is directly employed in the construction and operation, as local goods and services are purchased and utilized, and as those directly realizing added income from the project spend a portion of that income in the local economy. As income is spent and re-spent, the total economic impact becomes a multiple of the original income, employment, and output originated by the project. This process describes a "multiplier" effect in the economy. Other things being equal, the multiplier effect is increased by the following:

- Larger initial plant expenditures
- Larger input contributions from the local economy
- Larger percentage spending within the local economy in successive rounds (fewer leakages)

3.2 RIMS II INPUT-OUTPUT MODEL

One means of estimating multiplier impacts is through the use of a regional input-output (I-O) model. Generally, I-O models measure the interdependency of the various sectors of an economy through the establishment of an accounting matrix which shows the change in output, earnings, or employment in each industry due to a change in final demand. For the study of the RPS, the intent is to estimate the multiplier impacts arising in Pennsylvania due to the construction and operation of a renewable portfolio, and to compare these impacts with those arising from a BAU expansion plan involving conventional technologies. In addition, distributed renewable resources, which are not explicitly built as a response to the RPS, will also have impacts additive to the RPS technologies.

The model chosen for this study is the Regional Input-Output Modeling System (RIMS II model), developed and maintained by the Bureau of Economic Analysis. It is well suited for the needs of this study because it can estimate economic impacts for any county or combination of counties in the US, and includes multipliers for nearly 500 industry classifications. For this analysis, the region of study was established as the state of Pennsylvania.

The RPS multiplier analysis included the evaluation of impacts arising from construction and operation periods. The results for each period were then summed to arrive at the total impact for the RPS and BAU scenarios. The multi-step "bill of goods" method was used to estimate the potential impacts in the construction and operation periods.

For the construction period of a project, the purchases of goods and services that directly result from the investment are converted into regional purchases in producers' prices. The regional purchases are then multiplied by demand multipliers for output, earnings, and employment. For the RPS and BAU cases, the total capital cost was divided into major equipment and labor cost categories. The percent of expenditures in each category that would occur in Pennsylvania was then estimated. Table E-8 shows a summary of this analysis performed for the RPS and BAU technologies.

Table E-8. Estimated Percent of Expenditures Made in Pennsylvania.

	Construction	Operation
RPS Technologies		
Hydro	55%	71%
Biomass Cofiring	50%	57%
Landfill Gas	34%	57%
Digester Gas	33%	65%
Wind	17%	66%
Solar	10%	60%
BAU Technologies		
Coal	45%	82%
Combined Cycle Gas	33%	24%
Simple Cycle Gas	32%	7%

For industries such as wind, it is expected that only a small amount of the project capital cost would actually be sourced from the Pennsylvania area. This is because there are no wind turbine manufacturers in Pennsylvania (although there are a few component suppliers). On the other hand, the presence of American Hydro and other companies indicates strong industrial capability for hydro projects.

Among the renewable technologies, biomass cofiring has the largest ongoing operational expenses due to the collection and transportation of the biomass fuel. Based on the resource assessment, it is projected that, conservatively, 50 percent of the expenditures for collecting, processing, and transporting the biomass occurs within Pennsylvania. By comparison, it is assumed that 90 percent of the coal and 20 percent of the natural gas is sourced from within Pennsylvania.

The study area expenditures were converted to producers' prices and the final demand multipliers for the respective industries were applied. This impact estimate was then combined with the initial change due to the investment, and earnings and output estimates were deflated to 1999 as this is the basis for the national I-O tables on which the RIMS II model is based. All estimates during construction were performed on a per MW basis. A similar process was followed for the operation period, based on the annual expenditures made per MW of installed capacity. This estimate included expenditures for plant staff, consumables and supplies, land rent, and other cost items.

The results of this process were the output, earnings, and employment impact estimates for each RPS and BAU technology, summarized in Table E-9. On a per MW basis, the RPS technologies are projected to produce a higher output impact than the BAU case. The RPS technologies are also generally higher in terms of earnings and employment impacts. Biomass cofiring has the lowest construction phase impact due to its very low capital cost. Conversely, solar has very high impacts. Of the conventional technologies, a MW of coal investment produces more than two times the impact as does combined cycle or simple cycle capacity.

Table E-9. Multiplier Impacts per MW of Capacity.

Construction Phase	Output	Earnings	Employment
RPS Technologies			
Wind	$1,792,428	$298,992	7.84
Biomass Cofiring	$589,811	$192,718	5.08
Landfill Gas	$2,295,310	$637,456	16.60
Hydro	$3,024,518	$1,077,181	29.66
Digester Gas	$3,576,834	$1,106,010	27.96
Solar	$7,498,268	$1,390,461	33.12
BAU Technologies			
Combined Cycle Gas	$1,018,968	$291,155	6.93
Pulverized Coal	$2,792,565	$1,353,517	29.68
Simple Cycle Gas	$813,991	$176,541	4.65
Operation Phase	**Output**	**Earnings**	**Employment**
RPS Technologies			
Wind	$71,294	$22,054	0.60
Biomass Cofiring	$92,221	$74,354	2.13
Landfill Gas	$178,999	$58,602	1.59
Hydro	$42,736	$16,571	0.44
Digester Gas	$199,479	$63,820	1.79
Solar	$20,087	$7,593	0.20
BAU Technologies			
Combined Cycle Gas	$119,793	$35,574	0.88
Pulverized Coal	$251,318	$72,573	1.77
Simple Cycle Gas	$24,925	$8,496	0.20

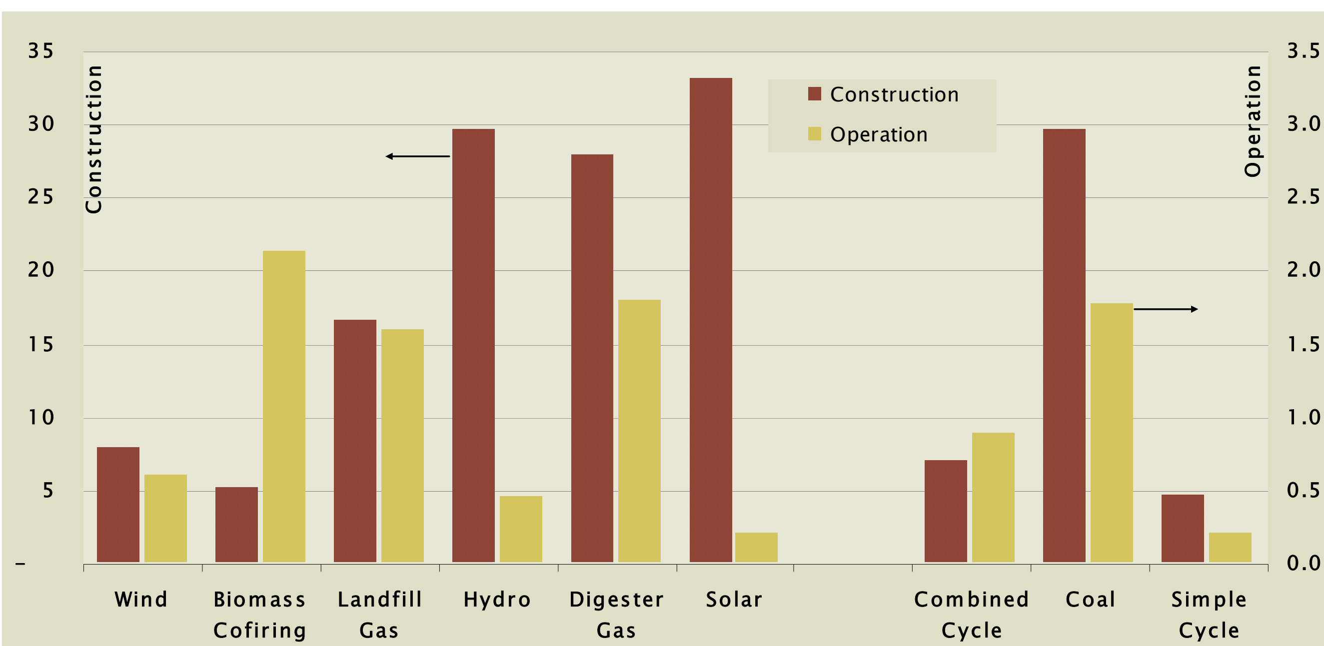

Figure E-3. Comparison of Pennsylvania Energy Employment Impacts per MW.

The impacts during operation are based on the yearly cost of operating a facility. As with the impacts during construction, the results vary significantly between technologies. Biomass cofiring is projected to have the largest multiplier impact, due to the significant labor and material requirements for collection and transportation of the biomass fuel. Digester gas, landfill gas, and pulverized coal are below the impact of biomass cofiring, but well above the remaining technologies.

The impacts from the construction and operation periods were then combined and applied to the RPS and BAU scenarios over the study period. This enabled a comparison of the total impacts of the RPS and BAU portfolios. Table E-10 indicates the total multiplier impact due to the construction of all renewable capacity during the 20-year evaluation period. The entries for each technology are calculated by multiplying the impact per MW by the total capacity (MW) installed during the evaluation period.

The results indicate that the total output impact from renewable technology construction in the state is approximately $9.6 billion, with an earnings impact of $2.1 billion, and approximately 56,600 jobs. Within the RPS group, wind capacity accounts for the largest portion of the impacts, followed by hydro.

Table E-11 shows the cumulative multiplier impacts of the RPS technologies during the 20-year operating period assumed in the study. The portfolio is estimated to have an output impact of approximately $5.9 billion, and earnings impacts of nearly $2.6 billion. The employment impact is projected to be about 73,000 jobs. As with all multiplier results in this analysis, these output and earnings impacts have been deflated to 1999 dollars.

The potential impacts during the construction and operation periods were estimated and are presented in Table E-12 and Table E-13, respectively. Table E-12 indicates that the cumulative impact of the BAU is 1,245 MW with a total output impact of approximately $2.3 billion, an earnings impact of $1.0 billion, and an employment impact of more than 22,500 jobs. During the operational phase, the BAU case would have cumulative impacts during the 20-year study phase of approximately $3.0 billion in output, $890 million of earnings, and more than 21,800 jobs.

Table E-14 and Figure E-4 show a comparison of the construction and output impacts for the RPS and BAU cases. The results indicate that the RPS portfolio has a significantly larger economic impact than the BAU scenario. The RPS Scenario has an approximate $10.1 billion advantage in output, a $2.8 billion advantage in earnings, and approximately 85,000 more jobs over the 20 year study period. It is also useful to note that, while the impact figures are in 1999 dollars and the cumulative present value costs in the economic analysis are discounted back to 2003, the RPS portfolio's added earnings multiplier impacts of approximately $2.8 billion would more than offset the BAU's cumulative present value direct electricity cost advantage of approximately $1.2 billion (see Section E.2). That is, the additional income earned by Pennsylvanians working in the renewable energy industry more than makes up for the small increase in electricity bills.

Table E-10. Cumulative Construction Multiplier Impacts, RPS Technologies.

Construction Phase	Total MW	Output Impact	Earnings Impact	Employment Impact
Wind	3,640	$6,524,928,858	$1,088,411,368	28,523
Biomass Cofiring	1,184	$698,513,295	$228,235,434	6,019
Landfill Gas	103	$237,068,910	$65,839,017	1,715
Hydro	641	$1,940,046,565	$690,947,089	19,025
Digester Gas	43	$152,430,096	$47,133,652	1,191
Solar	5	$34,721,347	$6,438,645	153
TOTAL	5,617	$9,587,709,072	$2,127,005,206	56,627

Table E-11. Cumulative Operation Multiplier Impacts, RPS Technologies.

Operation Phase	Total MW-Years in Planning Period	Output Impact	Earnings Impact	Employment Impact
Wind	50,584	$3,606,331,719	$1,115,598,406	30,431
Biomass Cofiring	16,457	$1,517,646,955	$1,223,610,045	35,057
Landfill Gas	1,435	$256,899,557	$84,105,352	2,283
Hydro	8,913	$380,911,623	$147,704,510	3,965
Digester Gas	592	$118,126,979	$37,792,989	1,063
Solar	64	$1,292,520	$488,600	13
TOTAL	78,046	$5,881,209,353	$2,609,299,902	72,812

Table E-12. Cumulative Construction Multiplier Impacts, BAU Technologies.

Construction Phase	Total MW	Output Impact	Earnings Impact	Employment Impact
Pulverized Coal	622	$1,737,820,788	$842,297,300	18,472
Combined Cycle Gas	498	$507,285,158	$144,949,372	3,449
Simple Cycle Gas	124	$101,309,720	$21,972,419	579
TOTAL	1,245	$2,346,415,667	$1,009,219,091	22,500

Table E-13. Cumulative Operation Multiplier Impacts, BAU Technologies.

Operation Phase	Total MW-Years in Planning Period	Output Impact	Earnings Impact	Employment Impact
Pulverized Coal	8,647	$2,173,225,816	$627,560,339	15,336
Combined Cycle Gas	6,918	$828,711,761	$246,097,753	6,094
Simple Cycle Gas	1,729	$43,106,632	$14,693,644	342
TOTAL	17,295	$3,045,044,209	$888,351,737	21,772

Table E-14. Cumulative Impacts For Construction and Operation Periods, RPS Versus BAU Portfolios.

	Output Impact	Earnings Impact	Employment Impact
RPS Portfolio	$15,468,918,425	$4,736,305,108	129,439
BAU Portfolio	$5,391,459,876	$1,897,570,828	44,272
Difference	$10,077,458,549	$2,838,734,279	85,167

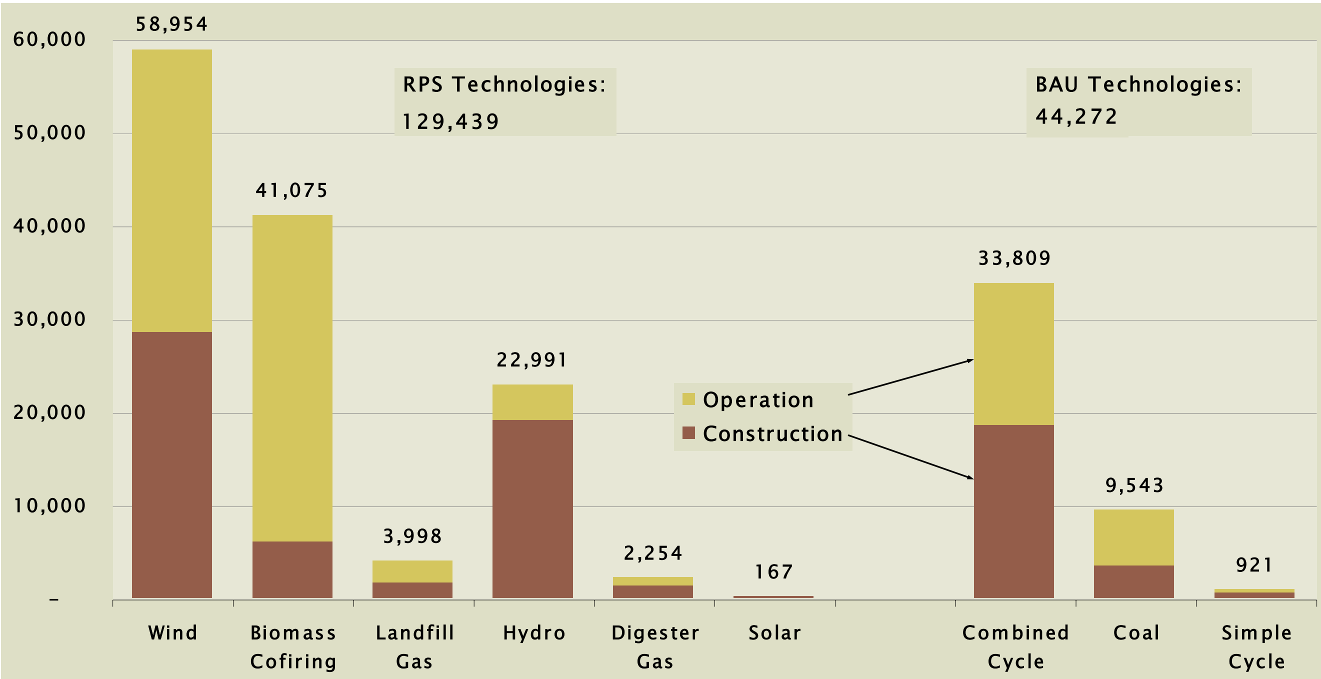

Figure E-4. Cumulative Employment Impacts (Jobs) for Construction and Operation Periods.

4. FOSSIL FUEL PRICES

By decreasing the demand for fossil fuels, renewable energy resources may lower fuel prices and could potentially save consumers millions of dollars a year. This section explores this potential positive impact of the RPS on fossil fuel prices.

4.1 PENNSYLVANIA NATURAL GAS MARKET

The volatility and rising price of fossil fuels, particularly natural gas, has become an increasing national concern over the past three years. However, in the same time period, about 200 GW of new natural gas fueled power plants have been built across the country. There is legitimate concern that the increasing reliance of new power generation plants on natural gas will have negative effects on the overall natural gas market, raising costs for all users, including residential home heating and industrial users.

Pennsylvania is one of the largest consumers of natural gas in the country, with gas serving a broad mix of residential, commercial and industrial customers. A relatively small portion of natural gas is used for electricity production, but this amount has increased about 60 percent in the past five years, see Figure E-5.

As with the rest of the country, Pennsylvania has been subjected to large increases in natural gas prices over the past few years (Figure E-6).

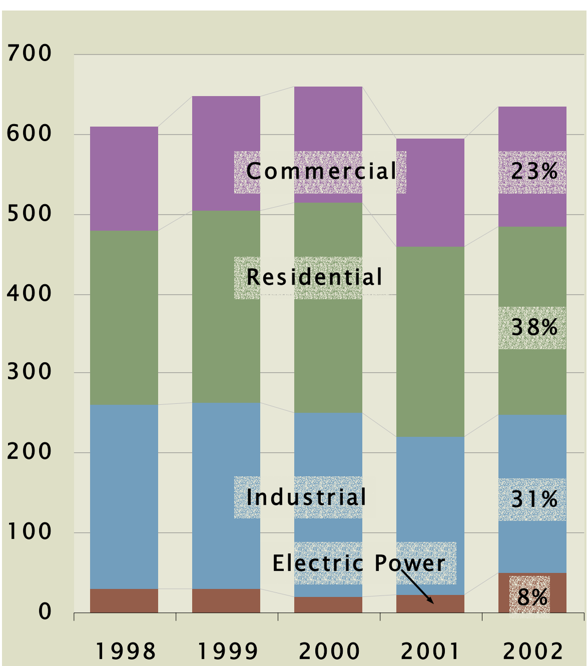

Figure E-5. Pennsylvania Natural Gas Consumption, Billion Cubic Feet (EIA).

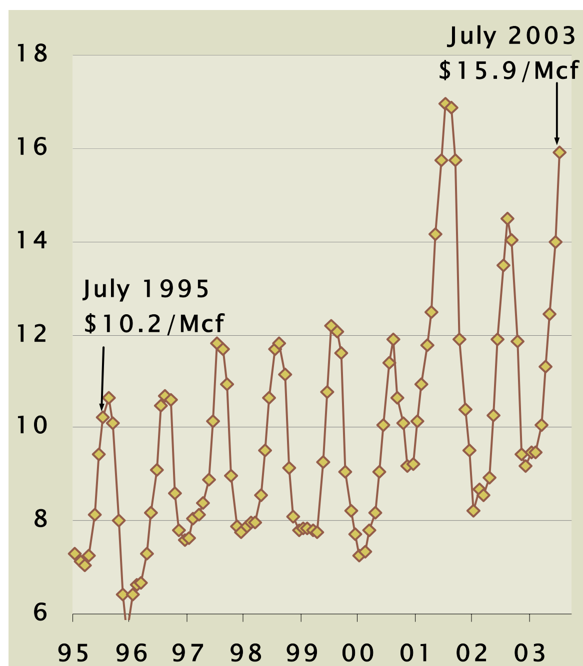

Figure E-6. Pennsylvania Residential Natural Gas Price, $ per Thousand Cubic Feet (EIA).

In 2001, Pennsylvania imported approximately 75 percent of the natural gas used in the state. Natural gas production in the state is moderate and generally declining – although production has increased in recent years in response to elevated prices. Production peaked in 1989 at 192 billion cubic feet. Figure E-7 shows natural gas production statistics for the state over the past 30 years.

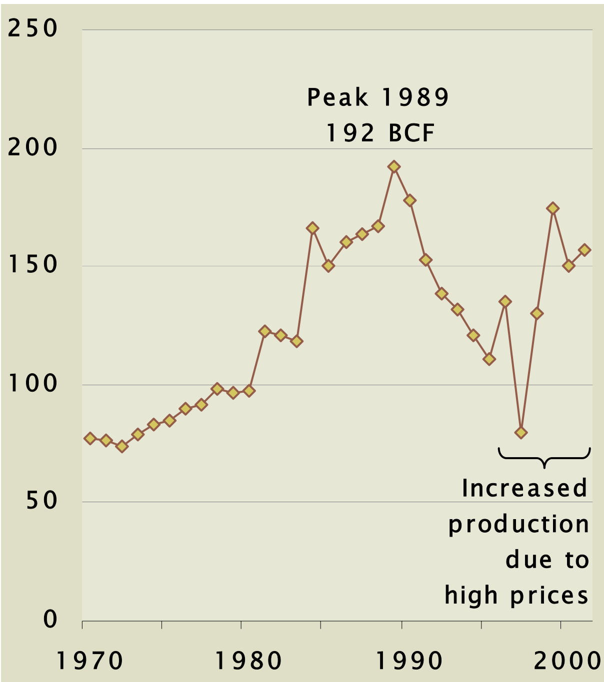

Figure E-7. Pennsylvania Natural Gas Production, Billion Cubic Feet (EIA).

With a limited resource base and increasing demand for natural gas from the power generation sector, the outlook for natural gas prices is not positive. There have been many proposals to address this situation including increased domestic production, LNG imports, and energy efficiency. Using renewable resources is another possible solution that has attracted attention lately. The results of several studies of this issue are summarized in the next section.

4.2 EFFECT OF RENEWABLE ENERGY ON FOSSIL FUEL PRICES

Black & Veatch analyzed the potential impacts to fossil fuel prices and consumption as a result of the RPS in Pennsylvania by consulting recent national and regional studies. Four studies were consulted for the analysis: (1) a study performed by Synapse Energy Economics on the potential benefits of a New York RPS;[5] (2) a recent study performed by the Department of Energy, Energy Information Administration (EIA) on the potential impacts of a national RPS on gas and coal prices;[6] (3) a Tellus Institute study that analyzed the potential impacts to natural gas prices in Rhode Island as a result of an RPS;[7] and (4) an American Council for an Energy-Efficient Economy (ACEEE) study on the effects of energy efficiency and renewable energy on natural gas and electricity consumption and prices.[8]

Each of the studies reviewed assumed that natural gas fueled power generation is "on the margin" throughout the country. Natural gas power generation is considered to be "on the margin" because these resources typically generate electricity at a higher marginal cost than baseload resources such as coal and nuclear. Consequently they are used to cover intermediate to peak levels of electric consumption. New renewable energy generation is typically more expensive than base load resources,

The EIA analyzed a national RPS requiring that 2.5 percent of sales come from new renewable energy generation in 2005, escalating to 10 percent by

[5] Synapse Energy Economics, Inc., "Cleaner Air, Fuel Diversity and High-Quality Jobs: Reviewing Selected Potential Benefits of an RPS in New York State," 2003.
[6] Energy Information Administration, "Impacts of a 10-Percent Renewable Portfolio Standard," 2002.
[7] Tellus Institute, "Rhode Island RPS Modeling," 2002.
[8] American Council for an Energy-Efficient Economy, "Natural Gas Price Effects of Energy Efficiency and Renewable Energy Practices and Policies," 2003.

2020. The National Energy Modeling System was used to estimate the fuel price impacts of an RPS policy. The model estimated that in 2010 natural gas and coal prices would fall by 4.6 percent and 3.2 percent, respectively. By 2020, the model predicted that prices would fall by 3.7 percent and 0.6 percent, respectively. EIA noted that if the RPS were not ended in 2020, the price impacts would be more profound. The study found that decreases in fuel prices as a result of the policy would be nearly sufficient to offset the higher electricity cost of installing new renewable energy generation.

The Tellus Institute analyzed the potential natural gas price impacts of an RPS in Rhode Island that stipulates that 3 percent of generation come from renewable sources in 2005 and rises to 10, 15, or 20 percent in 2020. This policy would require an estimated 2,060 GWh of new renewable energy generation by 2013, about 12 percent of the proposed Pennsylvania RPS. The study concluded that the average annual reduction in natural gas prices for the electric sector would be 0.36 percent from 2005 through 2010, and 0.45 percent from 2011 through 2020 for a 20 percent requirement in 2020.

ACEEE analyzed the potential electric and natural gas consumption and expenditure savings as a result of the adoption of energy efficiency and renewable energy policies on a national and regional level. They used results of recent studies on the potential for energy savings from implementing energy efficiency practices and studies conducted on the potential impacts to fossil fuel consumption and prices from new renewable energy generation. The study assumed that the following energy efficiency and renewable energy policies would be adopted in the PJM region.

- Energy efficiency performance targets
- Expanded federal funding for energy efficiency and renewable energy
- Appliance efficiency standards at the state and federal level
- Ensuring more efficient buildings through codes
- Support of clean and efficient distributed generation technologies
- Renewable Portfolio Standards
- Public awareness campaigns

The study concluded that the large-scale adoption of energy efficiency and renewable energy technologies, leading to 7.74 GWh of new renewable generation, would decrease natural gas consumption in the region by over 100 billion cubic feet. Natural gas prices were projected to decrease by between 1 and 5 percent from 2004 through 2008. It was estimated that as a result of decreased consumption and price reductions, expenditures on natural gas would fall by over $2.5 billion.

The ACEEE study also estimated the potential impacts to regional natural gas prices. The study specifically examined the impacts of an increase in renewable energy generation in New York from the current share of generation of 5.9 percent to 8.7 percent in 2008. This increase was estimated to result in a reduction of natural gas consumption of 19 billion cubic feet and a 2 percent decrease in the wholesale price of natural gas.

Although the approach of each of these studies varies, the result is consistent – the development of renewable energy generation will decrease the consumption and price of natural gas.

4.3 PENNSYLVANIA FOSSIL FUEL PRICE IMPACTS

Strong evidence has been presented by numerous studies that suggest that there are natural gas price impacts as a result of the adoption of renewable energy policies. However, because the share of natural gas fueled power generation in Pennsylvania (3 percent) is much smaller than that in New York (32 percent) and Rhode Island (60 percent), the results of the analyses on these states are difficult to generally apply to Pennsylvania. Further, it is difficult to assert that relatively small changes in consumption by Pennsylvania would have significant impacts on the national gas market.

If the relationship between renewable energy and natural gas prices assumed by these studies holds true, a decrease in natural gas prices of up to perhaps 3 percent could be experienced, without considering the policies of the surrounding states that are also considering/implementing RPS policies. Further, considerable natural gas savings could be realized (over 100 billion cubic feet per year) depending on the level of energy efficiency measures adopted in Pennsylvania.

To calculate the range of potential savings in fossil fuel expenditures as a result of the proposed RPS, information was obtained from the EIA for coal and natural gas consumption and prices for 2002. The total expenditures were calculated by multiplying the average price by the consumption for each respective sector (residential, commercial, and industrial).

Table E-15 shows the potential savings by assuming 1, 2, and 3 percent reductions in gas and coal prices. For example, if the RPS policy resulted in a reduction of 3 percent for natural gas and coal 2002 prices, the combined impact would be annual savings in excess of $400 million. By comparison, the expected cost premium in 2015 for the RPS portfolio over the BAU portfolio is only $295 million (see Table E-5). Even a 1 percent reduction would result in annual fuel savings of almost $140 million based on 2002 prices, roughly 50 percent of the projected 2015 RPS premium.

While further analysis is needed to determine specific impacts of the RPS on fossil fuel prices, it can be generally concluded that there appears to be real potential to recoup a substantial portion of the higher costs of implementing a state RPS through lower fossil fuel prices.

Table E-15. Potential Fossil Fuel Price Savings.

	Total Expenditures, $000s	Savings, $000s
2002 Natural Gas	12,191,026	
1% Price Reduction	12,069,116	121,910
2% Price Reduction	11,947,205	243,820
3% Price Reduction	11,825,295	365,730
2002 Coal	1,697,213	
1% Price Reduction	1,680,241	16,972
2% Price Reduction	1,663,269	33,944
3% Price Reduction	1,646,296	50,916