ENERGY EFFICIENCY AND RENEWABLE ENERGY RESOURCE DEVELOPMENT POTENTIAL IN NEW YORK STATE

Final Report

VOLUME FOUR:
RENEWABLE SUPPLY TECHNICAL REPORT

Prepared for

NEW YORK STATE ENERGY RESEARCH AND DEVELOPMENT AUTHORITY

Lawrence J. Pakenas, Project Manager

Prepared by

OPTIMAL ENERGY, INC. • BRISTOL, VT
John Plunkett, Project Leader

AMERICAN COUNCIL FOR AN ENERGY-EFFICIENT ECONOMY • WASHINGTON, D.C.
Anna Shipley, Senior Analyst

VERMONT ENERGY INVESTMENT CORPORATION • BURLINGTON, VT
David Hill, Renewables Co-Leader

CHRISTINE T. DONOVAN ASSOCIATES • STOWE, VT
Christine Donovan, Renewables Co-Leader

AUGUST 2003

NOTICE

TABLE OF CONTENTS

LIST OF TABLES

SECTION 4: HYDROPOWER

SECTION 5: LANDFILL GAS TO ELECTRICITY

SECTION 6: MUNICIPAL SOLID WASTE TO ELECTRICITY

SECTION 7: PHOTOVOLTAICS

SECTION 8: SOLAR THERMAL

SECTION 9: WIND ENERGY

LIST OF FIGURES

Section 1:
ELECTRICITY FROM RENEWABLE RESOURCES — AN OVERVIEW

SUMMARY RESULTS

Renewable energy resources and technologies are available to provide a large share of New York State's electric power supply within the next two decades. This study has examined the new contributions that can be expected from eight specific renewable energy resources and 30 renewable energy technologies. These technologies and resources are expected to have the greatest potential impact in New York State during the next 20 years. However, it is important to note that not all renewable technologies or resources are represented, and therefore the study results represent a subset of the total renewable potential. The scope of this study is also limited to new renewable resource potential; therefore for example, the results presented here do not include existing hydropower resources that are not scheduled for re-licensing during the study's time horizon. Assessments of the total (existing plus new) renewable resource available in New York State should be adjusted accordingly.

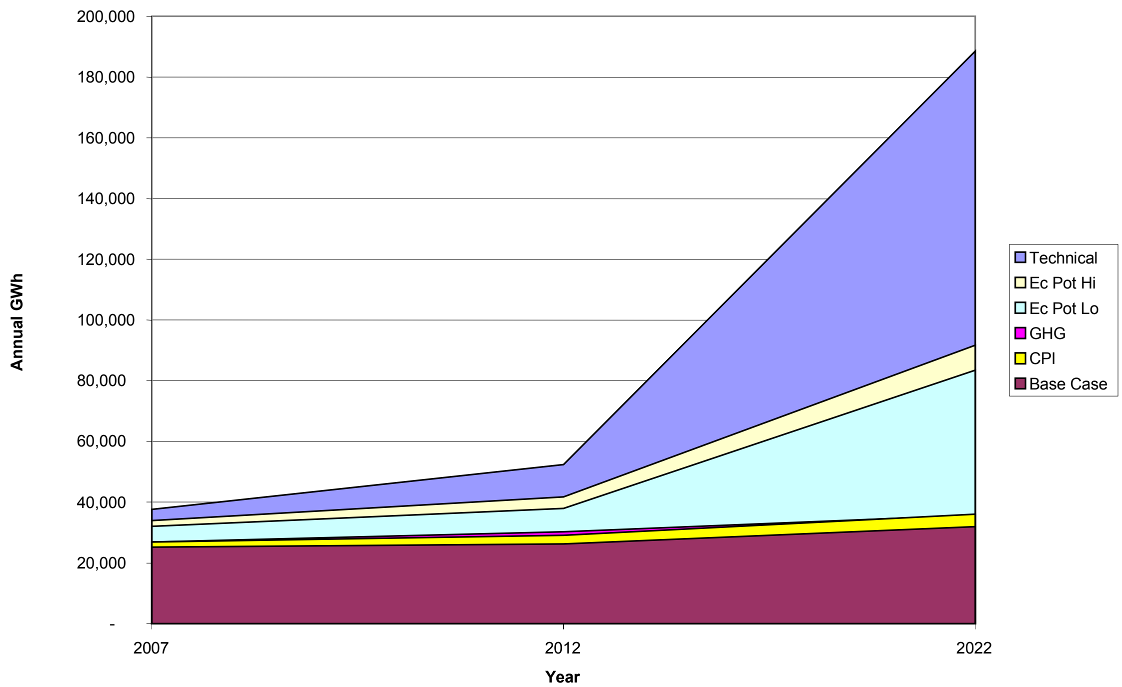
The results identify the energy and capacity impacts and costs associated with renewable energy resource deployment in 2007, 2012, and 2022. The analysis of the renewable resource potential is consistent with the overarching study design, as described in Volumes 1 and 2 of this study. A summary definition of the potential analysis scenarios is presented in Table 4.1.1.

Table 4.1.1 Potential Estimate Definitions

Potential Estimate	Description
Technical Potential	Upper limit available considering resource and technology capacities, without regard to costs, market acceptability, or other market barriers.
Economic Potential	The subset of technical potential that is societally cost-effective compared to the electric supply it would avoid. The study includes examination of high and low statewide avoided costs, and five zonal avoided costs.
Achievable Potentials	
Base Case	Represents the impacts of renewable projects that are already on-line, already permitted, or well along in planning as of 2002.
Currently Planned Initiatives (CPI)	Future impacts from initiatives included in New York State's latest State Energy Plan.
Contribution to Greenhouse Gas (GHG) Reduction Targets	The analysis identifies the achievable potential available from each resource under an expanded set of policy and program supports for renewable energy. These policy and program supports explicitly exclude the consideration of a renewable portfolio standard (RPS). The Greenhouse Gas (GHG) reduction scenario results indicate the contribution of each resource to the integrated (efficiency and renewables) least-cost portfolio to meet targets in 2012 and 2022. In addition, each renewable narrative provides a stand-alone (not integrated into efficiency or renewable) estimate of the achievable potential for each renewable resource in 2012 and 2022.

The projected potential for electric generation from renewable resources under the study scenarios and time horizon encompasses a large range between 25,000 and 188,000 GWh per year (Figure 4.1.1).

Figure 4.1.1 New York State Renewable Potential Summary



These results, and the data compiled to conduct the analysis, provide fertile ground for the consideration and development of renewable energy policy and programs. Detailed results and analysis for each renewable resource are presented in the following sections of this report. The study notes the following five observations as among the significant overarching findings from the renewable portion of the study:

- The potentials for renewable resources increase dramatically during the second decade of the analysis horizon. While significant new renewable resources are available by 2012, it is the complementary growth in technology manufacturing and delivery capacity that generates the acceleration of growth after 2012. This finding is consistent with current and anticipated industry exponential growth trends for several of the resources analyzed, including photovoltaics, fuel cells, and wind. This finding highlights the point that the resource potentials identified in this study are not instantaneous, and reflect the complementary availability of the renewable energy resource base (e.g., wind or solar insulation) and the manufacturing and delivery infrastructure needed to capture these resources.
- Significant shares of the available technical potential in each time period are societally cost-effective. Many of the renewable resources and technologies examined pass societal economic screening and can be expected to provide electric supply at lower costs than the conventional supply they would avoid. The largest contributors to the cost-effective portions of the renewable potential include biomass, hydropower, and wind power. Wind power is particularly important as a contributor to the cost-effective potential after 2012. However, the cost-effective results, by themselves, should not be misinterpreted to represent expected or "business as usual" development, since there may be significant market or other barriers to the

full deployment of the cost-effective resource. For example, siting and licensing issues may prevent wind and hydropower resources that pass economic screening from being developed. Policy and program supports, including those examined in this study under the currently planned initiatives (CPI) and greenhouse gas (GHG) reduction scenarios, as well as others (such as a Renewable Portfolio Standard), may be required to capture the economically cost-effective levels of renewable potential identified by this study.

- The CPI scenario results indicate that by 2022, 4,000 to 5,000 GWh per year of incremental (over base case) new renewable resources are expected to be in place due to existing policy and program supports. This represents an increase of roughly 13% above the base case. At the same time, this is a relatively small portion of both the economic and technical potentials in 2022. The incremental impact of the CPI is the greatest for emergent renewable technologies, including photovoltaics, and particularly fuel cells.
- The distributions of technical and economic potential by resource and time period are illustrated in Figures 4.1.2 and 4.1.3 respectively. These further highlight the potential importance of fuel cells, photovoltaics, and wind resources by 2022 (combining to account for more than 80% of the technical potential by 2022), and of hydropower, biomass, and wind in the economic potential scenario (these three combined represent approximately 97% of the economic potential in 2022).
- Renewable resources contribute approximately 19% of the total to the integrated (efficiency and renewable) least-cost portfolio needed to achieve reductions of 21,000 GWh by 2012, and 14% of the necessary resource needed to achieve total reductions of 27,000 GWh in 2022. Biomass, hydropower, municipal solid waste, and solar thermal are the resources that contribute to the integrated GHG-reduction portfolio in both 2012 and 2022.

Figure 4.1.2 Renewable Technical Potential by Resource & Year

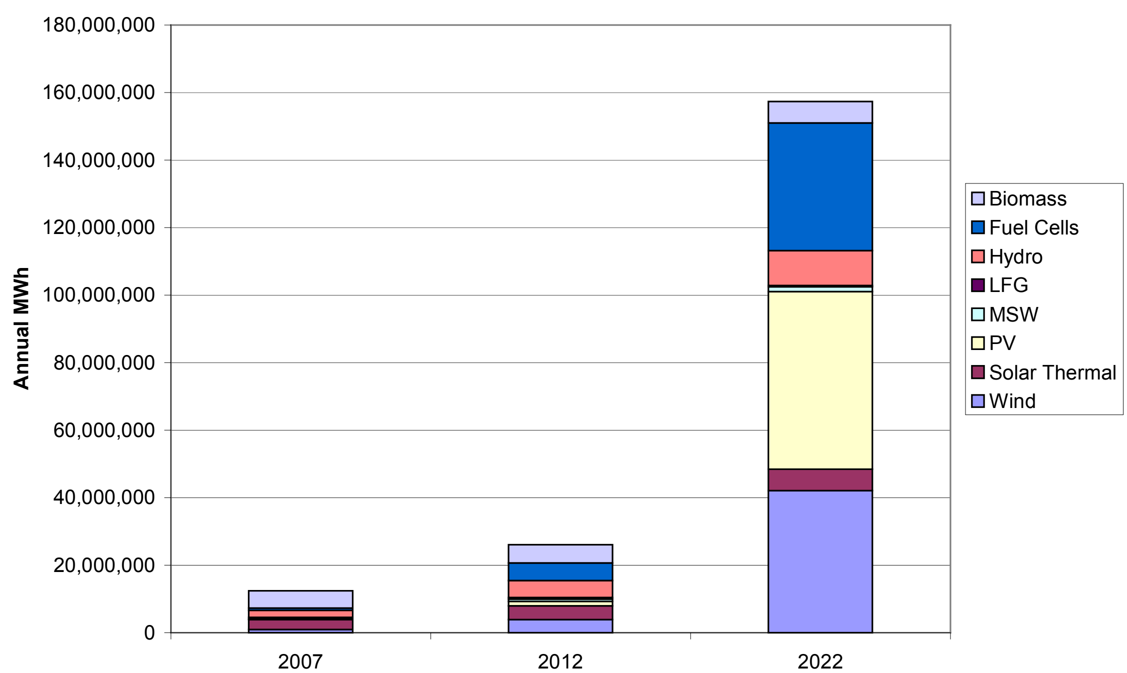
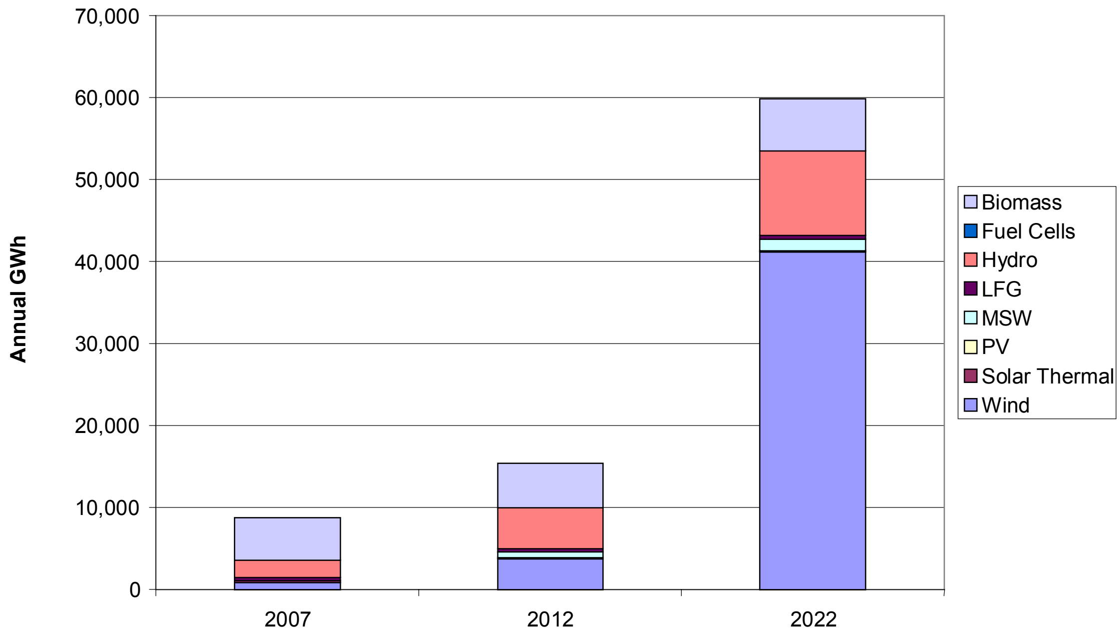


Figure 4.1.3 Renewable Economic Potential by Resource & Year (Statewide High Avoided Costs)



The remainder of this section provides an overview of the approach taken to assess New York State's renewable energy potential. Following this is a narrative section devoted to the details of the analysis conducted for each renewable resource, including a description of the resource and technologies, a review of commercialization status and costs, environmental and other regulatory barriers, and detailed presentation of the inputs used for the renewable resource assessment.

OVERVIEW OF APPROACH

The renewable energy analysis is a resource-by-resource assessment of the current and future potential for electricity generation. Experts in each field have undertaken individual resource assessments (Table 4.1.2). In each case, the study started by reviewing each renewable resource in New York State and selecting the appropriate technology and scale combinations for full analysis in this report.

Table 4.1.2 Contributing Renewable Energy Experts

Renewable Resource	Resource Experts and Affiliation	Lead Coordinator
Biopower	Barclay Gibbs and Kevin Comer; Antares Group Incorporated	Christine Donovan
Fuel Cells	Anna Shipley; American Council for an Energy Efficient Economy	David Hill
Hydropower	George Lagassa; Mainstream Associates	David Hill
Landfill Gas	Peter Kuniholm; SCS Engineers, PC	Christine Donovan
Municipal Solid Waste	Peter Kuniholm; SCS Engineers, PC	Christine Donovan
Photovoltaics	Richard Perez; University of Albany, Scott Sklar; The Stella Group	David Hill
Solar Thermal	Richard Perez; University of Albany, Scott Sklar, The Stella Group, and Andy Shapiro	David Hill
Wind Energy	Greg Strong and Jamie Chapman, OEM Development Corporation	Christine Donovan

The 30 technology and scale combinations recommended by the resource experts and chosen in collaboration with NYSERDA (Table 4.1.3) are expected to have the greatest potential for providing renewable-based electricity in New York State in the next 20 years. It is important to clearly recognize that this study is restricted to the analysis of these technologies and therefore represents a subset of all potential renewable resources that may be tapped in the future.

Table 4.1.3 Renewable Technology and Scale Combinations

Renewable Resource	Technology	Scale Analyzed
Biomass	Co-firing w/ Coal	10 MW
	Gasification / Advanced Gasification after 2010	15 MW
	Customer-Sited Combined Heat and Power (CHP)	1-5 MW
Fuel Cells	Proton Exchange Membrane (PEM)	5-10 kW
	Phosphoric Acid (PAFC)	200 kW
	Solid Oxide (SOFC)	200-250 kW
	Molten Carbonate (MCFC)	250-2000 kW
Hydroelectricity	Repowering/Efficiency Improvements at Existing Sites	5 MW+
	Additional Capacity at Existing Hydroelectric Site	5 MW+
	Creation of new hydroelectric capacity at existing dams (without hydro in place)	Mini (10kW – 100kW) Small (100 kW-5000 kW) Medium (5MW - 50 MW) Large (50 MW +)
	Construction of entirely new dam sites	Mini (10kW – 100kW) Small (100 kW-5000 kW) Medium (5MW - 50 MW) Large (50 MW +)
Landfill Gas	Combustion Turbines	3-15 MW
	Internal Combustion Engines	400 kW –5 MW
	Microturbines	30-800 kW
Municipal Solid Waste	Large Mass Burn/RDF Steam Generators	> 250 TPD
	Small Mass Burn/RDF Steam Generators	< 250 TPD
	Anaerobic Digestion	250 TPD units
Photovoltaics	Grid-connected residential PV retrofit and new constructions	3 kW
	Energy/Capacity-maximizing, grid-connected, user-sited commercial/industrial PV, including systems with solar load control	200 kW
	Envelope cost tradeoff-maximizing grid-connected, user-owned commercial/industrial PV	50 kW
Solar Thermal	Solar water heating residential	32 – 128 sq. ft.
	Solar water heating commercial	320 – 2,000 sq. ft.
	Solar pre-heating of ventilation air	10,000 – 50,000 sq. ft.
	Solar Absorption Cooling	4,000 – 50,000 sq. ft.
Wind	** * SEE NEXT PAGE * **	

Wind	Horizontal axis, grid-connected wind turbines designed for use in wind farm arrays	10 – 50 wind turbines rated at 600kW – 1.5MW output per machine.
	Horizontal axis, grid-connected wind turbines designed for use in small cluster installations	2 – 10 wind turbines rated at 600kW – 1.5MW output per machine.
	Small-scale wind turbines designed for use on residences, farms, villages, and remote sites. These systems can also serve small commercial and industrial facilities.	Stand-alone wind turbines rated at 1kW – 300kW output per machine.
	Horizontal axis, grid-connected wind turbines designed for use in offshore installations	1-20 wind turbines rated at 1-3 MW output per machine

Each renewable resource assessment begins with a technology description; a discussion of manufacturing and commercialization status; and a review of regulatory, permitting, and siting issues.

The first analytic step was to characterize the key features of each renewable technology included in the study. The appropriate resource expert for each of the 30 renewable resource technologies completed these characterizations, which include measure lifetime, annual kilowatt per hour (kWh) production, distribution of energy production to avoided cost periods, summer and winter peak coincidence factors, and fossil fuel offsets (where applicable).

The measure characterization also included the estimation of the installed and annual operation and maintenance costs for each technology. To provide consistency across technology scales, all cost estimates were normalized to $/kW of installed capacity (maximum potential output), and $/kW-yr for operations and maintenance.[1] The technology-performance and cost measure characterizations and other inputs used in the analysis (e.g., market potential under each scenario) are documented in Renewable Technical Appendices Section 6.3. Any expected changes in technology performance or costs over time — for example, more efficient wind turbine designs that generate more annual kWh for each installed kW of capacity — are incorporated in the measure characterization data.

The third step was to estimate the technical potential statewide and for five zones in 2007, 2012, and 2022. By definition, for the renewable energy analysis, the technical potential for each technology comprises the new resources that can be brought on-line in each time period considering resource availability, manufacturing capacity, and installation infrastructure. Thus, for example, the technical potential for photovoltaic (PV) electricity is based on a combination of solar resource, suitable roof space, and growth in PV manufacturing output. The technically feasible potential includes technology applications that are plausible and practical. Cost, market barriers, or market acceptability do not restrict the technical potential

estimates. Zonal variations in renewable resources are reflected in the technical potential results. Note that in the following renewable resource narratives, potential estimates are provided in terms of installed capacity and annual energy output at the meter. The analysis results present coincident summer and winter peak capacity, as well as energy at the generator.

For renewable resources, the base case represents the impacts of electricity projects that are already on-line, already permitted, or well along in planning as of 2002. The impacts of the technical-potential scenario were calculated by multiplying the measure characterization data on energy and capacity performance for each technology by the estimate of installed capacity (above base case) in each time period. The assumptions and results of the technical potential for each renewable technology are presented individually in each of the renewable resource sections that follow. A summary of technical potential results for renewable resources is presented in the Volume 1.

The fourth step of the analysis was to identify the economic portion of the technical potential by applying the program screening tool developed by Optimal Energy Inc., using energy and capacity avoided costs provided by NYSERDA. The renewable technologies were screened using both high and low statewide avoided costs, and for five individual zonal avoided cost levels.

The fifth step in the renewable analyses was to estimate the market penetration in each time period for the currently planned initiatives (CPI) and greenhouse-gas reduction (GHG) scenarios. Each renewable resource expert was provided with a guidance document outlining the policy and program supports to consider for both scenarios, and asked to forecast the resulting development levels for each renewable technology under these conditions.

For the CPI scenario, the policy and program supports include NYSERDA's expected funding through June 2006, and the funding of New York Power Authority (NYPA) and Long Island Power Authority (LIPA) programs through June 2004. NYSERDA funding for renewable energy is expected to be at least $77 million.[2] LIPA's funding for renewable energy in currently planned initiatives is approximately $14 million.[3] NYPA plans include more than $560 million of renewable funding through 2013. The majority of the NYPA funding will be used to extend the life and modernize the St. Lawrence and Niagara hydropower projects. The re-licensing of these two major hydro power projects is considered to be well

---

1 Technology performance and market estimates are also normalized using 1kW of installed capacity as the base unit.

2 "Table 4.1.3: 2001-2006 New York Systems Benefits Charge (SBC) Funding for Renewable Energy," New York State Energy Plan. Page 3-49. Note however, that many renewable technologies are eligible for support through other SBC initiatives (e.g., green buildings, secure generation, combined heat and power). Assuming that modest shares (ranging from 10% to 25%) of funding from other selected SBC programs will go to support renewable energy increases the total renewable funding to ~ $105 million, or an average of $21 million/year.

3 Including spending on the Solar Pioneer, and renewable R&D projects through June 2004.

along in planning and therefore is represented in the base case scenario. Additional NYPA programs considered in the CPI scenario include plans to support fuel cells, landfill gas generation, photovoltaics and wind development. Table 3.5.4.1 in the Renewable Technical Appendix summarizes the policy and program supports considered during the development of the CPI scenario market-penetration estimates.

To develop GHG scenario market-penetration estimates, the renewable resource experts were asked to consider a set of additional incremental policies and program supports to further promote the development of renewable energy resources (Table 6.4.3 and 6.4.3). At NYSERDA's request, the GHG scenario did not include a statewide Renewable Portfolio Standard or the implementation of an emissions cap and trading strategy. Examples of the incremental policy and program support mechanisms included in the GHG scenario are:

- *Green Power Marketing:* Require all electric service providers to develop and offer (by 2005) customers green-power purchase options — consisting of 25%, 50%, and 100% green mix options. Starting in 2007 require that green-power products consist of >50% new and in-state renewable resources;
- *Wind Development:* Power purchase agreements (5 to 10 years) for ~ 200 MW of off-shore or wind farm installations;
- *Photovoltaic and Fuel Cell Development:* Extend incentive and market-development programs, extend and expand green building tax credits and state personal-income tax credits; and
- *State Purchasing Requirements:* Make renewable purchase requirements for state entities (established under Executive Order 111) mandatory as opposed to targets.

When estimating the market-penetration rates for both the CPI and GHG scenarios, the renewable experts were instructed to consider the impact of the policy and program supports as a portfolio, rather than the individual impacts of each policy and program support by technology.

The sixth step was to estimate the administrative "cost adders" associated with the programs in each scenario that would be necessary to achieve the projected market impacts. Using available data from NYSERDA, LIPA, and NYPA, the Vermont Energy Investment Corporation (VEIC) estimated these adders, which are stated as a percentage of installed measure cost in both the CPI and GHG scenarios. The level of administrative adder varies by resource and is influenced by the share of non-incentive program costs (including administration, but also market-development activities such as training and marketing). The percentage adder is also impacted by the magnitude of total measure costs installed for each technology. In cases where an initiative is expected to impact numerous renewable energy technologies and resources (e.g., green power market development), the study allocated the cost-adders across resources based on the study's estimation of expected programmatic impacts.

Section 2:
BIOPOWER

SUMMARY RESULTS

Biomass is an abundant renewable resource in New York State that has been used for many years to produce electricity and heat. With the fifth highest state-level potential for low-cost biomass supplies in the U.S., New York State is well-positioned to stimulate new growth in bioenergy applications. This study analyzed biopower capacity in New York State in two ways:

First, the total amount of biomass feedstock potentially available for biopower was estimated. Overall, by 2022, more than 38,000 GWh from more than 5,500 MW of biopower capacity could be supported by approximately 400 trillion BTU/yr of clean waste wood and agricultural residues, energy crops, and sustainably managed forest resources.

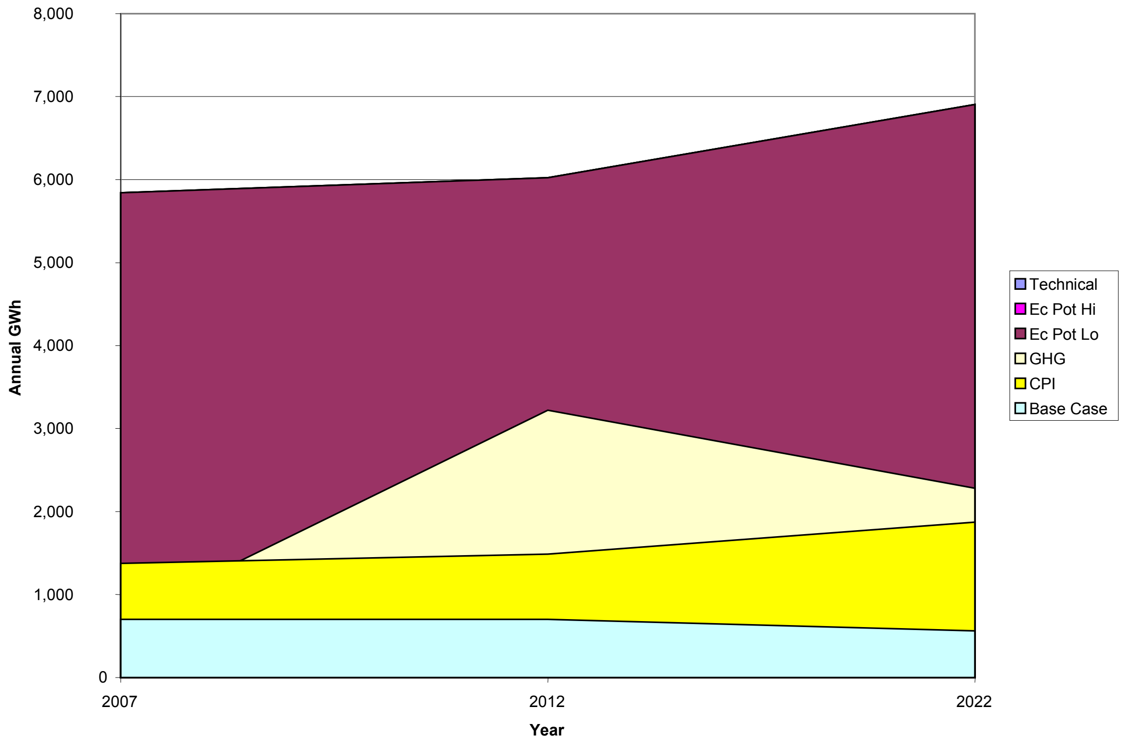
Second, the amount of biopower capacity and generation was projected through 2022 under six cases: technical potential, economic potential (assuming high statewide avoided costs), economic potential (assuming low statewide avoided costs), currently planned initiatives (CPI), greenhouse gas (GHG) reduction targets, and the base case.

Technical potential is defined as the upper limit for biopower capacity and generation theoretically possible from the resource base in New York State without regard to cost, market barriers, or market acceptability. For biopower, technical potential is driven by the availability of clean biomass resources, technical performance (e.g., heat rates) of the conversion technology, and existing and future coal plant capacity (for biomass co-firing with coal). Economic potential is the subset of technical potential that is cost-effective from a societal perspective compared to the cost of electricity that biopower would replace. Economic potential is assessed separately for both high and low statewide avoided costs (provided by NYSERDA). The CPI case is defined as future impacts expected from currently planned initiatives included in the 2002 New York State Energy Plan. The GHG-reduction targets case is defined as the least-cost combination of efficiency and renewable resources (above those expected from currently planned initiatives) that can be used to meet GHG-reduction targets established by the State for 2012 and 2022. The base case is defined as biopower capacity and generation already on-line, already permitted, or well along in planning as of late 2002.

In each case, biopower capacity and generation were determined based both on the amount of the biomass feedstock resource potentially available for fuel and the ability of four conversion technologies to utilize the feedstocks. Feedstocks were matched to conversion technologies in order to avoid double-counting fuel supply. The projected potential for electric generation from biomass co-firing, biomass combined heat and power (CHP), biomass gasification, and direct-fire biopower under the study scenarios ranges from 600

GWh to 6,900 GWh per year (Figure 4.2.1). The high end of this range (6,900 GWh) represents only 18% of the resource-limited biopower technical potential.

Figure 4.2.1 Biopower Potential Summary in New York State



The base case represents between 8% and 12% of the technical potential depicted in Figure 4.2.1. (Note that technical potential and both economic potential cases are essentially the same for biopower). The CPI case represents 27% of the technical and economic potential by 2022. Under the CPI case, biopower generation grows from 1,400 GWh to 1,900 GWh over the 2007-2022 timeframe. The projected growth in generation from biomass gasification and biomass CHP resulting from CPI during 2007-2022 more than offsets the small projected decline in biomass co-firing over the same period. For the GHG-reduction scenario, biopower generation peaks at 53% of technical and economic potential in 2012 due to the federal production tax credit that is slated to expire after 2012.

All biopower technical potential over and above what is projected as a result of currently planned initiatives and greenhouse-gas reduction strategies passes societal economic screening using both high and low statewide avoided costs.

The study suggests that, depending on the scenario and timeframe, biopower will represent between 4% and 15% of renewable generation in New York State. While there is technical and economic potential to

increase biopower penetration by a factor of two to four times that projected under currently planned initiatives and greenhouse-gas reduction strategies, a combination of environmental, siting, financial, and regulatory barriers could constrain penetration.

Over the next 20 years, the biopower technology that *could* achieve the highest market penetration and experience the highest net growth in capacity is biomass co-firing (at coal-fired facilities).[4] Biomass gasification technology may also experience moderate growth under likely policy conditions. It is unlikely that, in terms of installed capacity, biomass gasification will overtake co-firing before late into the next decade. Because biomass gasification is a relatively new and unproven technology, it is unlikely that many projects will be put in place quickly. Biomass CHP is a relatively mature technology that will be chosen by certain wood-products industries under existing policy conditions. The growth of biomass CHP will likely be driven by the growth of power and heat demand by the industries for which biomass CHP is a natural fit. Although direct-fired biopower accounts for about 40 MW of existing capacity in New York State, altered economics under a deregulated electricity market — in conjunction with tighter emissions standards — suggest that it is unlikely that major new direct-fire capacity will go on-line during the next 20 years.

TECHNOLOGY DESCRIPTION AND COMMERCIALIZATION STATUS

Biomass Resource Description

The term *biomass* includes a wide variety of closed-loop and open-loop organic energy resources. Closed-loop resources are those that are grown exclusively for the purpose of being consumed as an energy feedstock. Closed-loop resources can be either woody (e.g., hybrid poplar or willow) or herbaceous (e.g., switchgrass). Open-loop resources are typically either woody residues produced as byproducts in the wood- processing industry or are clean woody waste materials intercepted from the municipal solid waste stream. The list of biomass resources included in this study is given in Table 4.2.1.

4 This statement is based upon technical potential only. Under the currently planned initiatives scenario, biomass CHP would likely achieve the greatest penetration, and biomass gasification would likely experience the highest net growth.

Table 4.2.1 Biomass Energy Resources Included in Study

Biomass Resource Class	Definition
Mill Residues	Wood residues produced in the primary and secondary wood products industries.
Silviculture Residues	Wood residues produced from commercial logging and silvicultural activities.
Site Conversion Residues	Wood residues produced when forested lands are converted for other uses (e.g., for agriculture, roads, etc.).
Silviculture (other than residues)	Wood, other than residues, from silvicultural activities that could potentially be used for biopower (e.g., net annual growth).
Woody Yard Trimmings	Woody materials from yard trimming activities that can be separated from the MSW stream.
Construction & Demolition Residues	The clean and available wood portion of the C&D waste stream.
Pallets and Other Waste Wood	Pallets, containers, discarded wood consumer products, scrap lumber (other than from construction and demolition), etc. that can be separated from the MSW stream.
Agricultural Residues	Corn stover and wheat straw residues.
Bio-energy Crops	Woody or herbaceous crops grown specifically for the solar energy stored during photosynthesis.
Cattle Manure, Poultry Litter, Hog Manure *	Various on-farm animal manures that could be collected to reduce greenhouse gas emissions and to reduce pollution from agricultural runoff.
Wastewater Methane *	Methane collected during the digestion of wastewater under methanogenic conditions.

* These resources are included in this report because they can be used to produce power from biomass. Estimates of the amount of electricity produced from these resources are provided for the base year (2003) but are not projected into the future.

It should be noted that many of the above resources can be converted to bio-liquids for the purpose of providing fuel for automobiles or for power generation.

Introduction to Biopower Technologies

A variety of technology types and scales can be used to produce electricity from biomass. In some cases, a particular biomass resource is more suitable for conversion to electricity using a particular technology. The main types of biopower technologies, their corresponding market applicability, and the types of feedstocks most frequently used with the technology are presented in Table 4.2.2.

Table 4.2.2 Biopower Technologies Selected for Initial Screening

Biopower Technology	Electricity Markets	Potential Feedstocks
Customer-Sited Biomass Combined Heat and Power (CHP)	Primarily end-use, could involve sale into wholesale markets	Mill residues
Co-firing w/ Coal	Wholesale	All, except manures and wastewater methane
Gasification	Wholesale or end-use	All, except wastewater methane. Most-likely to use C&D wood (Gasification assumed to use primarily C&D wood in this study).
Direct-Fire, Stand-Alone	Wholesale	All, except manures and wastewater methane
Co-firing Gasified Biomass with Natural Gas or Coal	Wholesale	All, except manures
Small, Modular Biopower	End-use, could involve sale to wholesale markets	All
Bioliquids-to-Power	Wholesale or end-use	All, except manures and wastewater methane
Animal Manure Digesters	End-use, could involve sale to wholesale markets	Only manures
Wastewater Methane Combustion	Primarily end-use, could involve sale to wholesale markets	Wastewater methane only

Biopower Technologies Selected for This Study

A subset of six technologies from Table 4.2.2 was selected for consideration in this study. Three of the technologies are considered in the full analysis (customer-sited combined heat and power (CHP), co-firing with coal, and gasification). Three other technologies (bioliquids-to-power, manure digesters, and wastewater methane combustors) are discussed in the technology descriptions but are not considered in the full analysis. Current state-level technical potentials are presented for (cow) manure digesters and wastewater methane combustion.

The guiding principle used when selecting which technologies to focus on during this study was whether or not a given technology could have a significant impact on wholesale or end-use electricity markets over the next 20 years. Market experience and knowledge, along with best professional judgment, were used to make these determinations.

Co-firing Biomass with Coal.

- *Typical Scale of Technology:* up to 15% of coal plant capacity.
- *Scale of Technology Chosen for this Study:* 10 MW (e.g., 67 MW coal plant at 15% biomass heat input).
- *Use of Technology:* Biomass is combusted in a coal boiler, directly displacing a portion of the coal fed to the boiler. Typical application is central-station electricity production. Biomass can be blended with coal on the coal-pile (mixed feed) or injected via a separate biomass transfer system.
- *Customer or Market:* Wholesale markets.
- *Overall RD&D and Commercialization Status:* Well-developed and proven technology.
- *Extent of Existing Use and Markets in New York State:* Limited existing use. Load Zone C has 10.7 MW of active co-firing capacity (at Greenidge Station) along with an additional (previously active but currently unused) 11 MW of co-firing capacity (at two other plants, Hickling and Jennison Stations). The active 10.7 MW of co-firing capacity is not always fully exploited, but the plant recently invested in upgrading its biomass handling equipment, suggesting that co-firing will continue. Another commercially viable system has been installed in Load Zone A at Dunkirk Station. This system is capable of producing 10 MW of biopower and has just completed pre-commercial demonstration testing.
- *Major Markets Expected During Next 20 Years in New York State:* Potential exists for considerable growth. The technical potential is 15% of the coal-fired electric generation capacity in any given year (subject to the biomass resource constraint).
- *Considered in Full Analysis?* Yes

Biomass Gasification.

- *Typical Scale of Technology:* 5 MW to 40 MW
- *Scale of Technology Chosen for this Study:* 15 MW
- *Use of Technology:* Biomass is gasified prior to combustion. This improves the emissions characteristics of biomass combustion (relative to solid fuel direct-fire technology and CHP). Efficiency improves with considerable increase in capital cost (relative to solid fuel direct-fired technology). Advanced systems employing gas turbines and combined-cycles have potential to make gasification more economically competitive once they have been proven to a degree suitable to attract commercial investment.
- *Customer or Market:* Wholesale markets or end use. For wholesale markets, gasification systems are likely to be sited near C&D landfills. End-use customers could be in the wood-processing industry (especially pulp and paper at potentially large scales).
- *Overall RD&D and Commercialization Status:* An emerging technology. Only a few gasifiers are in operation in the US.
- *Extent of Existing Use and Markets in New York State:* No gasifiers in New York State currently.
- *Major Markets Expected During Next 20 Years in New York State:* Given the proper combination of renewable energy, environmental, and waste-management policies, a few biomass gasifier projects could be developed in New York State.
- *Considered in Full Analysis?* Yes

Customer-Sited Biomass Combined Heat and Power (CHP).

- *Typical Scale of Technology:* 1-30 MW
- *Scale of Technology Chosen for this Study:* 3 MW
- *Use of Technology:* To produce both heat (for steam) and electricity from biomass residues. Production of heat and electricity (together) makes efficient use of the biomass resource.
- *Customer or Market:* Typically wood-processing facilities (especially in the pulp and paper industry) that have large electricity and steam needs and a captive supply of biomass residues. Opportunities also exist in some food-products manufacturing facilities. Biomass CHP is often an end-use market application, but electricity can be sold back into wholesale markets.
- *Overall RD&D and Commercialization Status:* Well-developed and proven technology.
- *Extent of Existing Use and Markets in New Yor State:* In Load Zone F, there are currently two mills that employ biomass CHP. Together, these two mills represent 67.6 MW of CHP electric generation capacity.
- *Major Markets Expected During Next 20 Years in New York State:* Wood-processing facilities, particularly especially in the pulp and paper industry. Biomass CHP is a technology that can often be economical without additional incentives or mandates.
- *Considered in Full Analysis?* Yes

Direct-Fire, Stand-Alone Wood-Fired Power Plants.

- *Typical Scale of Technology:* 1-50 MW
- *Use of Technology:* Combust wood fuel directly to produce power using steam turbines, typically at low efficiency (17 to 24%) relative to most other types of power plants.
- *Customer or Market:* Wholesale markets.
- *Overall RD&D and Commercialization Status:* Technology in widespread use in the US. Efficiency improvements are still required and possible.
- *Extent of Existing Use and Markets in New York State:* About five direct-fire, stand-alone wood-fired power plants were constructed in New York State from the the late 1970s to the early 1990s. These five plants total 41.8 MW of capacity. In 2001, only two direct-fire biomass plants were operated — one plant is 18 MW, located in Load Zone D, and the other plant is 21 MW, located in Load Zone E.
- *Major Markets Expected During Next 20 Years in New York State:* Due to a variety of environmental and market factors, this technology is not expected to significantly increase penetration in New York State.
- *Considered in Full Analysis?* For the purpose of estimating the resource-limited potential for all biopower technologies, the biomass resource currently consumed by direct-fire biopower is accounted for. Direct-fire biopower is included in the technical potential estimates for 2003. A simplifying assumption was made at the beginning of the study (at the direction of NYSERDA) that direct-fire biopower is not likely to increase significantly in the future.

Bioliquids-to-Power.

- *Typical Scale of Technology:* A wide range of biofuels is blended with conventional liquid fuels for use in stationary engines or turbines for power generation.
- *Scale of Technology Chosen for this Study:* NA
- *Use of Technology:* Through various processes (depending on the solid feedstock used), solid biomass is converted to a liquid that can be used as a fuel or fuel additive in electric gen-sets whose prime movers are industrial gasoline or diesel engines, or gas turbines. At least initially, these would probably be smaller, distributed generation systems.
- *Customer or Market:* End-use (industrial or commercial) or central-station.
- *Overall RD&D and Commercialization Status:* An emerging technology, soon to be commercialized. A pilot project exists in Vancouver. The early market is likely to be in the UK. The U.S. Department of Energy recently announced a research effort to determine the technical and commercial viability of integrated pyrolysis/combined-cycle biomass power systems.
- *Extent of Existing Use and Markets in New York State:* None
- *Major Markets Expected During Next 20 Years in New York State:* It is too early to comment on the likely penetration of this technology.
- *Considered in Full Analysis?* No, but included in technology description because markets for this technology are emerging.

Animal Manure Digesters.

- *Typical Scale of Technology:* 0.05-0.3 MW
- *Scale of Technology Chosen for this Study:* 0.08 MW
- *Use of Technology:* Anaerobic manure digesters produce methane, which can be used to produce electricity or useful heat.
- *Customer or Market:* End use. End-use customers would be dairy farms, hog farms, or poultry farms.
- *Overall RD&D and Commercialization Status*: An emerging technology.
- *Extent of Existing Use and Markets in New York State:* There is 1.9 MW of planned or existing dairy-farm manure digester capacity in New York State.
- *Major Markets Expected During Next 20 Years in New York State:* On farm. Can be implemented in combination with food-processing wastes.
- *Considered in Full Analysis?* Included in the technology description because federal and state farm methane initiatives are under way. The current state-level technical potential for combustion of digested cow manure is reported as well.

Wastewater Methane Combustion.

- *Typical Scale of Technology:* 0.09-10 MW
- *Scale of Technology Chosen for this Study:* 1 MW
- *Use of Technology:* Anaerobic treatment of wastewater produces methane, which can be used to produce electricity or useful heat.
- *Customer or Market:* Primarily end use. End-use customers would be wastewater-treatment facilities or federal facilities that might buy power from the wastewater-treatment facilities. Can also sell electricity into wholesale markets.
- *Overall RD&D and Commercialization Status:* An existing technology.
- *Extent of Existing Use and Markets in New York State:* Five operating units totaling about 6 MW of generation capacity at three separate sites. Nearly all of the New York State-based operating capacity as of 1999 was in Brooklyn (Load Zone J).
- *Major Markets Expected During Next 20 Years in New York State:* Wastewater-treatment facilities or federal facilities.
- *Considered in Full Analysis?* Included in the technology description. The current state-level technical potential for wastewater methane combustion also is reported.

Biopower Technologies NOT Selected for This Study

The following technologies were considered but not selected for this study. The guiding principle used when selecting the technologies for focus in this study was whether the technology could be expected to have a significant impact on wholesale or end-use electricity markets over the next 20 years. Market experience and knowledge, along with best professional judgment, were used to determine that the following technologies have significantly lower potential in New York State over the next 20 years, and therefore would not be assessed in detail in this study.

Co-firing Gasified Biomass with Natural Gas or Coal.

- *Typical Scale of Technology:* 10-50 MW of biopower. (Up to 40% of the total natural gas or coal plant capacity.)
- *Use of Technology:* Gasified biomass is co-fired with natural gas, typically in central-station power plants. Gasified biomass can also be co-fired with coal.
- *Customer or Market:* Wholesale markets.
- *Overall RD&D and Commercialization Status:* There are a few demonstration projects in the US.
- *Extent of Existing Use and Markets in New York State:* Gasified biomass is not currently co-fired with coal or natural gas in the State.
- *Major Markets Not Expected During the Next 20 Years in New York State:* This technology is still in R&D. However, this technology could offer two key benefits in the future: 1) overall environmentally superior performance in comparison to co-firing solid biomass with coal, and 2) fuel-flexibility/natural gas price-hedge benefits.

Small Modular Biopower.

- *Typical Scale of Technology:* 0.001-5.0 MW
- *Use of Technology:* Niche, small-scale applications.
- *Customer or Market:* End-use markets.
- *Overall RD&D and Commercialization Status:* A few demonstration projects exist in the US.
- *Extent of Existing Use and Markets in New York State:* Modular biomass demonstration projects do not currently exist in the State (except for animal-manure digesters).
- *Major Markets Not Expected During Next 20 Years in New York State:* High unit costs and small application size suggest low market penetration (in terms of MW) in the next 20 years.

MANUFACTURING AND SERVICE INFRASTRUCTURE

Co-firing

Co-firing installations involve a combination of traditional wood-handling and processing equipment that is assembled together for a fairly new application for power generation. Depending on site-specific conditions, this equipment could include a wood storage facility or silo, hammer mills and/or grinders, bucket conveyors, blowers for pneumatic conveyance of processed biomass, and miscellaneous other components that are familiar to power generators. While each co-firing system needs to be engineered to suit site-specific conditions, the individual components that comprise a co-firing system are off-the-shelf items. This is due to demand for these components in other applications that require handling and processing of either coal or wood, such as wood recycling and processing operations (e.g., mulching and composting), wood products and pulp and paper manufacturers, agriculture and associated industries, biomass fueled heating and/or power plants, and coal-fired power plants.

Two operating base-load power plants in New York State — Greenidge and Dunkirk — have already been modified to allow co-firing biomass with coal. The Greenidge co-firing system was assembled primarily from salvaged parts from mothballed power plants, while the Dunkirk system was engineered and constructed using off-the-shelf equipment and systems. While co-firing is just a minor activity in New York State today, most of the pieces are in place from associated industries and service companies for greatly expanded biomass co-firing activity. The manufacturing and service infrastructure in the U.S. and the region surrounding New York State does not represent an obstacle to increased co-firing in the State. Permitting and economics are the largest hurdles.

Gasification

A few companies are capable of supplying biomass gasification systems in the near term on a commercial scale. Near -term applications most likely would involve generating power using steam turbines in stand-alone operations, or providing supplemental steam or combustion gas at an existing power plant. These

companies would be able to service and install systems in New York State if market conditions encouraged gasification installations; however, advanced applications involving the use of gas turbines and eventually combined-cycle plant designs would be undertaken with higher risk than more traditional power plant designs because these systems have limited commercial experience. Performance guarantees and warranties for gas turbine applications will be needed before any advanced gasification systems are installed. To date, no companies have been willing to provide these critical performance assurances, although several are working toward it. Gas-cleanup systems may be a technology-related area in need of additional commercial-scale demonstration prior to installation of gas turbine and combined-cycle systems.

Combined Heat and Power

Combined heat and power (CHP) applications using biomass alone or in combination with other fuels utilize off-the-shelf equipment from established companies with long operating histories. Manufacturing, service, and design infrastructures for these systems are well-established and would be capable of responding rapidly to increased business opportunities in New York State. It should be noted that most biomass CHP and stand-alone power installations are at scales well above 10 MW for a number of very practical reasons. Stimulating increased demand for installation of large- and small-scale (<10 MW) biomass CHP systems will require new policies and incentives.

Bioliquids-to-Power

Technologies capable of producing bioliquids such as ethanol, biodiesel, and levulinic acid that could be used for stationary power generation are available, although the most promising markets for these products are in the transportation and/or chemicals markets. Stationary power-generation applications could provide a supplemental market for these bioliquids in the future if the economics become more favorable.

Manure Digesters and Wastewater Methane Combustion

Although anaerobic digestion with power generation has been implemented only on a limited basis to date, nine companies throughout the Northeast manufacture or design either manure-digestion systems or components for such systems. Consulting and design services are also available in the region. According to BioCycle's *2002 Directory of Equipment and Systems*, 33 companies in the U.S. and Canada offer products and services associated with anaerobic digestion systems. If demand for anaerobic digestion power-generation systems increases, these suppliers likely will be able to meet that demand even in the near term. The most pressing issue facing increased use of anaerobic digestion systems with power generation capabilities is cost. The primary drivers for installing an anaerobic digestion system are odor control, waste management, and nutrient management. Policies and incentives that provide more value for the electricity produced from these systems could play a key role in improving the economics associated with digestion systems.

According to McGraw-Hill's *1999 World Electric Power Plants Database*, there were 59 operating wastewater methane power-generation units in the U.S. These units are capable of generating a combined 61 MW of electricity. Five of the units totaling about 6 MW of generation capacity are in New York State, with nearly all of that capacity in Brooklyn. Most operating units in the U.S. were installed prior to 1993. For the limited potential for additional installations of this technology for power generation in New York State, sufficient equipment and design expertise would be available to implement new projects.

Market Factors Related to Biomass Fuel Distribution

The ability of a biopower project to acquire a steady biomass supply depends on site-specific conditions of the project (including the biopower technology and the biomass resource class). For customer-sited CHP projects, part of the motivation for the project is usually the need to avoid disposal costs; thus, acquisition of biomass supply does not typically present a problem. Similarly, for manure digesters and wastewater methane combustion, the origin of the biomass resource also is on site, so supply acquisition is not an issue.

In contrast, for central station biopower applications (co-firing, gasification, direct-fire, etc.), acquisition of a steady and affordable biomass supply depends on the biomass resource class being utilized, the proximity of the resources to the biopower plant, the cost of disposal alternatives (tipping fees), and competing demands for the biomass. The last factor — competing demands — is critical; often a wood recycler can obtain higher prices for its products in other markets (e.g., mulch markets). When the demand for recycled wood in other markets is strong, biopower applications often will be priced out of the biomass residue market.

As an example of an operating biopower plant, the Chateaugay direct-fire biopower plant in Load Zone D prefers construction and demolition wood as its biomass resource class. The Chateaugay plant is permitted to burn only clean construction and demolition wood. Typically, the Chateaugay plant prefers a three-inch minus chip that is clean — that is, free of dirt, drywall, sand, metals and plastic, which adversely affect boiler operation, performance, and lifetime.

Transportation costs are important to biopower economics because biomass is typically low density compared to coal; thus, more trucks are needed per MMBTU of fuel transported. Fifty miles is often viewed as the practical maximum distance for biomass transport to a biopower plant. The company that operates the Chateaugay plant believes that backhauling of its ash by recyclers (after delivering the wood residues) is a key to managing its company-wide transportation costs.

In general, a small amount of paint on wood chips is not viewed as a problem, but paint levels need to be low enough to prevent emissions in excess of permitted levels. In some cases, companies that operate

biopower plants use magnets to remove metals at the boiler site, but they typically prefer that wood-residue suppliers (recyclers) remove the metals. Cardboard contamination is acceptable to biopower plants as long as there is no wax. Usually, paper contamination is kept to a minimum.

Biopower plants typically buy their wood residues from recyclers or brokers, employing wood-residue supply contracts. The company that operates the Chateaugay plant uses wood-residue supply contracts lasting between six months and 15 years. Recyclers typically intercept wood residues from the construction and demolition stream or the municipal solid waste (MSW) stream during or before delivery to a transfer station. There are more than 300 major transfer stations in New York State, of which more than 200 handle construction and demolition waste. The recyclers are private entities that are typically paid a tipping fee (reduced relative to landfill tipping fees) to accept the materials that they then separate and sell to various markets.

REGULATORY, PERMITTING AND SITING ISSUES

Potential Environmental Impacts of Biopower Technologies

The potential environmental impacts of biopower depend both on the conversion technology employed and the class of biomass resource being utilized. The major environmental issues (air, ash, land use, noise, fisheries/avian, and visual) associated with biopower are discussed in simplified and general terms below. Technology-specific and biomass class-specific distinctions are made where important.

Air Emissions

Because biopower is a combustion technology, there are atmospheric emissions associated with it. The emissions vary across biopower technologies and depend in part upon the properties of the fuel combusted. In addition, atmospheric emissions are strongly impacted by the type and quality of emissions-control technologies used by biopower plants. Operating conditions, such as the air-to-fuel ratio, also matter.

Typically, when co-firing biomass with coal, all criteria pollutant emissions are reduced or not changed substantially relative to coal-only operation. This is not always the case, however; sometimes PM and NOx emissions are problematic and should be considered on a case-by-case basis depending on the facility's permitting situation.

Compared to criteria pollutant emissions from coal-fired power plants, co-firing applications, and direct-fire biopower applications, such emissions from biomass gasification are substantially reduced. Criteria pollutant emissions from biomass gasification plants are similar to those from conventional natural gas turbine facilities and slightly higher than those from natural gas combined-cycle applications.

Emissions of greenhouse gases from biopower technologies can be assessed meaningfully only in a life-cycle context. If the biomass that is combusted is exactly replaced by biomass growth (i.e., closed-loop), there are zero net CO_2 emissions in the lifecycle (exclusive of CO_2 emissions from farming, transportation, etc.).

CO_2 reduction benefits are not usually attributed to open-loop biomass applications. However, if the open-loop biomass that is combusted would otherwise end up in a landfill that does not practice methane capture (or would decay uncollected), combusting the open-loop biomass avoids the emission of methane because most of the carbon is instantaneously oxidized (such that the open-loop CO_2 emissions are more than offset by the methane emissions reductions). This leveraged emissions benefit can be up to 3 tons of CO_2(eq) emissions for every ton of biomass combusted.[5] The leveraged emissions benefit of combusting open-loop biomass does not exist if the biomass would otherwise go to a landfill that practices methane capture (in this case, the CO_2 emissions from combustion would not be offset by methane reductions).

As noted, atmospheric emissions from biopower depend not only on the biopower technology but also upon the biomass resource class being utilized and the emissions-control technologies employed. The topic of biopower emissions is complex and does not easily condense into a few paragraphs. For simplicity, biopower emissions are discussed below according to biopower technology. Emissions of SO_2, NOx, particulates, Hg, CO, and CO_2 are addressed.

Co-firing. Due to the nearly zero sulfur content of most biomass, co-firing biomass with coal typically reduces SO_2 emissions (relative to coal-only operation) on a one-to-one basis according to the amount of overall heat provided by biomass. Using biomass to replace 10% of the heat input from coal typically reduces SO_2 emissions by 10%.

Due to the complexity of NOx-formation chemistry, a blanket statement cannot be made about the impacts of co-firing on NOx emissions (relative to coal-only operation). However, many co-firing emissions tests have resulted in reduced NOx emissions relative to coal-only operation. NOx increases have been observed in several cases.

Emissions of total particulates do not typically increase (relative to coal-only operation) during co-firing. However, emissions of PM_{10} and $PM_{2.5}$ have been observed to increase. Emissions of fine particulates during co-firing is an ongoing research issue that needs to be considered within the context of site-specific factors (biomass type, emissions control technologies, permitting restrictions, etc.).

---

5 Biomass and Bioenergy 19 (2000) 363-364.

Biomass typically has very low Hg concentrations; thus co-firing typically reduces Hg emissions relative to coal-only operation.

Biomass co-firing involves combustion of carbon-containing fuels; thus CO and CO_2 emissions are produced. Small but insignificant increases in CO emissions (relative to coal-only operation) during co-firing have been observed in some cases. On a lifecycle basis, co-firing biomass with coal reduces a coal plant's greenhouse gas emissions. Lifecycle greenhouse gas emissions for each kWh of biopower produced are either small or negative in many cases, depending upon the biomass resource utilized.

Gasification. Combustion of gasified biomass results in emissions of SO_2, NOx, particulates, Hg, CO, and CO_2. Compared to critera pollutant emissions from coal-fired power plants, co-firing applications, and direct-fire biopower applications; such emissions from biomass gasification are substantially reduced. Criteria pollutant emissions from biomass gasification plants are similar to those from conventional natural gas turbine facilities and are slightly higher than those from natural gas combined-cycle applications. Hg emissions from the combustion of gasified biomass are low compared to coal combustion. Lifecycle greenhouse gas emissions from the combustion of gasified biomass are either small or negative in many cases, depending upon the biomass resource utilized.

Combined Heat and Power. Biomass CHP results in emissions of SO_2, NOx, particulates, Hg, CO, and CO_2. Hg and SO_2 emissions from biomass CHP are low compared to coal combustion. Again, lifecycle greenhouse gas emissions from biomass CHP are either small or negative in many cases, depending upon the biomass resource utilized.

Bioliquids-to-Power. Combustion of bioliquids results in emissions of SO_2, NOx, particulates, Hg, CO, and CO_2. Hg, particulate, and SO_2 emissions from combusting bioliquids are low compared to coal combustion. Lifecycle greenhouse gas emissions from bioliquids-to-power are either small or negative in many cases, again depending upon the biomass resource utilized.

Manure Digesters and Wastewater Methane Combustion. Combustion of biogas captured from manure digesters, or wastewater processing, results in emissions of SO_2, NOx, particulates, Hg, CO, and CO_2. Hg and particulate emissions from combusting biogas are low compared to coal combustion. The combustion of biogas captured from manure digesters or wastewater processing avoids emissions of methane (a powerful greenhouse gas) to the atmosphere, converting the carbon to CO_2 (a much less powerful greenhouse gas).

Ash-Management Issues

Ash from biopower production needs to be disposed of as land spread or in a landfill. This is one of the reasons that biopower should mostly be obtained from clean biomass resources: If the wood is treated, often the concentration of hazardous materials during combustion can result in ash with higher associated disposal costs.

A major issue confronting co-firing is that an American Society for Testing and Materials (ASTM) standard precludes co-fired ash from being sold into concrete admixture markets. Since coal plants that co-fire have to pay to landfill their ash (instead of selling it into concrete admixture markets), the ASTM standard has a significant detrimental effect on the economics of co-firing. There are efforts under way to alter the ASTM standard so that co-fired ash can be sold into cement markets.

Land-Use Impacts

The major land-useimpacts are ash disposal (discussed above), landfill avoidance (for residues), and impacts on soil erosion and soil quality (including chemical runoff for bioenergy crop production). The landfill-avoidance benefit results from the diversion of biomass residues that otherwise would end up in landfills. This extends landfill lifetimes and reduces the need for landfill proliferation.

Soil-erosion problems are typically mitigated by bio-energy crop cultivation. The impacts of bio-energy crop cultivation on soil quality and chemical runoff is a site-specific and complicated topic. In general, bio-energy crop cultivation improves soil quality and mitigates chemical (and fertilizer) runoff relative to conventional crop cultivation, but it reduces soil quality and increases chemical (and fertilizer) runoff relative to fallow land use.

Noise Impacts

Biopower technologies do not create any unusual noise impacts.

Fisheries and Avian Impacts

Avian impacts are of concern only for bio-energy crop production. Avian impacts, along with more general studies of ecosystem health and habitat impacts, are being conducted in conjunction with bio-energy crop projects (e.g., the Chariton Valley Biomass Project in Iowa). The impacts of bio-energy crop cultivation depend upon the crop variety, the cropping techniques, and the avian species. In general, experimental evidence suggests that properly executed bio-energy crop cultivation is compatible with supporting a wide variety of avian species.

Visual Impacts

Biopower technologies do not create any unusual visual impacts.

Permitting Experience in New York State

Co-firing. The Greenidge plant in Load Zone C acquired the necessary permits to co-fire wood residues. A coal power plant in Load Zone A (Dunkirk Station) has conducted preliminary co-firing operations using wood as the supplementary biomass fuel. Proceeding to full co-firing emissions tests (including willow crops and wood), has presented some permitting challenges. The challenges include agreeing upon which pollutants to monitor (under co-firing and coal-only operation) and the exact testing protocols to be implemented. Particulate monitoring issues have presented the greatest permitting challenges.

Gasification. No biomass gasification facilities have been permitted in New York State. If a biomass gasification facility were to be permitted, it is expected that the process would be simpler than permitting a coal plant or other biopower technologies due to the desirable emissions profile of biomass gasification.

Combined-Heat and Power. A few biomass CHP facilities have been successfully permitted in New York State.

Bioliquids-to-Power. No bioliquids-to-power facilities have been permitted in New York State. The permitting process would be similar to that for a stationary diesel genset, many of which have been permitted.

Manure Digesters. Several manure digesters have been permitted in New York State.

Wastewater Methane. Six wastewater methane electric-generation units have been permitted in New York State.

Cost and Related Information

Total installed costs of biomass CHP, biomass gasification, and biomass co-firing (with coal) are provided in Table 4.2.3. When interpreting the CHP installed costs, it should be recognized that much of the steam (about 80%) goes to supply heating needs. For co-firing, capital costs assume installation of a separate handling, processing, and injection system for biomass. This allows co-firing up to about 15% biomass on a heat-input basis in pulverized coal boilers. Lower-cost co-firing installations (as low as $50 to $100 per kW of *biomass* capacity) are possible in cyclone boilers, or at low co-firing rates (2% heat input from biomass) in pulverized coal boilers where biomass and coal are blended, co-pulverized by existing pulverizers, and injected into the boiler through existing coal burners. The separate injection system in

pulverized coal boilers was the basis of the capital cost estimate for biomass co-firing because the large majority of power plant boilers are pulverized coal units, and most co-firing projects would be expected to use equipment allowing separate processing and injection of biomass. Both existing utility-scale co-firing installations in New York State are this type of system.

Table 4.2.3 Biopower Installed Costs (2003 $ per kW)

Year	Biomass CHP+	Biomass* Gasification	Cofiring Biomass with Coal*
2003	3,960	1,750	243
2007	3,960	1,600	235
2012	3,960	1,464	220
2022	3,960	1,258	190

+ Based on analyst professional experience.
* EPRI's Renewable Energy Technology Characterizations (EPRI TR-109496, 1997).

The other major components of cost considered in the scenario analysis are fixed non-fuel O&M, variable non-fuel O&M, and fuel costs. Real levelized O&M costs, reflecting all three of the aforementioned O&M cost components, are provided with the Inputs Template in the Appendix. Fuel O&M is a function of penetration: Higher levels of penetration (e.g., in the Technical Potential scenario) result in higher fuel costs because of rightward movement along the upward sloping biomass supply curve. For biomass gasification, the levelized O&M costs are negative in some cases; this is a result of the assumed tipping fees associated with C&D residues exceeding non-fuel O&M costs.[6]

Projected biomass supply curves, along with consideration of technology/resource linkages, were used to determine average fuel costs in the cases (one component of levelized O&M). The biomass supply curves were adjusted for projected biomass consumption due to cellulosic ethanol production (the supply curves are for *available* biomass). Each year of analysis has its own corresponding biomass supply curve; the 2012 supply curve is shifted to the right of the earlier curves, and the 2022 supply curve is shifted to the right of the 2012 curve. Most of the shift in the 2012 and 2022 supply curves is due to the projected increase in the supply of energy crops (i.e., the top of the curve is shifting to the right).

---

6 Non-fuel O&M costs for biomass gasification are based on EPRI's Renewable Energy Technology Characterizations (EPRI TR-109496, 1997).

TECHNICAL POTENTIAL

The technical potentials (over time in some cases) of the following technologies are discussed below:

- Co-firing biomass with coal
- Biomass gasification
- Customer-sited biomass CHP
- Combustion of digested cow manure
- Wastewater methane combustion

The technical potential of a technology represents the upper limit for renewable electricity capacity (for that technology) and output theoretically possible from the resource base within New York State, without regard to cost, market barriers, or market acceptability. For biopower, the technical potential is driven by the *availability* of *clean* biomass resources; technical performance (e.g., heat rates); linkages between resources and technologies (e.g., mill residues are tied to CHP); and in the case of co-firing, coal plant capacity.

Biomass Resource Base State-Level Analysis

The state-level biomass resource analysis is based on the concept of *clean and available* biomass supplies (except for bio-energy crops, which are assessed hypothetically). In concept, a resource is *available* if it is not already put into productive use (e.g., for existing biopower, mulch production, particle-board production, etc.). The level of *clean and available* biomass resource quantities in New York State is based on a variety of previous studies:

- NREL (prepared by the Antares Group), *Biomass Residue Supply Curves for the United States*, NREL Task No. ACG-7-17078-07, 1999.
- Oak Ridge National Laboratory, Biomass Feedstock Availability in the United States: 1999 State-Level Analysis, 1999.
- Northeast Regional Biomass Program (prepared by C.T. Donovan Associates Inc.), *The Potential for Producing Ethanol from Biomass in the Northeast*, 1994.
- NTIS (prepared by C.T. Donovan Associates Inc.), *Waste Wood Resource Supply Assessment*, 1991.

For more detailed discussion of the concept of *clean* and *available* biomass supplies, refer to the Appendix.

Each biomass resource class was assessed over time in a different manner, as discussed below. The state level of *clean and available* biomass resource quantities were then adjusted downward to reflect the potential that ethanol production from cellulosic biomass would consume an increasing portion of the New York biomass resource stream in future years. It was assumed that ethanol production would consume biomass as indicated in Table 4.2.4. (The assumptions in the table represent the best professional

judgement of the authors and are reasonable for purposes of planning. However, it is important to note that minimal ethanol currently is produced from the biomass classes included in this study, and any projections of future use of biomass for ethanol are quite speculative.) The biomass consumed for ethanol production was assumed to be taken from the agricultural residue class first, and then in an equal fraction from all other resource classes, with the overall fraction as indicated in Table 4.2.4.

Table 4.2.4 Assumed Consumption of Biomass for Ethanol Production, as a Percentage of Total Clean and Available Biomass Resources

Year	2003	2007	2012	2022
% of Total, Clean and Available Biomass Resources Consumed for Ethanol Production	0.5%	2.0%	6.0%	8.0%

Mill Residues. The current state-level *clean and available* mill residue quantity is based upon the 1994 Northeast Regional Biomass Program report referenced above. The quantity increases over time because, as the pulp and paper and wood products industries in New York State grow, more mill residues will be generated.

Silviculture Residues. The current state-level *clean and available* silvicultural residue quantity is based upon the 1994 Northeast Regional Biomass Program report referenced above. The quantity increases over time because, as the wood products industry in New York grows, more silvicultural residues will be generated.

Site Conversion Residues. The current state-level *clean and available* site conversion residue quantity is based upon the 1994 Northeast Regional Biomass Program report referenced above. The quantity is assumed to be constant over time except for a small decrease due to an increase in ethanol production.

Silviculture (other than residues). The current state-level *clean and available* silviculture (other than residues) resource quantity is based upon the 1991 NTIS report referenced above. This quantity decreases over time because the New York State (and US) pulp, paper, and wood-products industries grow over time. Drawdown of the silviculture resource (other than residues) is based on the projected growth of New York State's pulp and paper industry. As the State's pulp, paper and wood-products industries grow, more wood is needed as an input (to be converted to product, for heat, and for electricity). It is reasonable to reduce New York State's silviculture resource (other than residues) according to the projected growth in these industries within the State because pulpwood net exports from New York are small relative to the State's pulpwood production.

Woody Yard Trimmings. The current state-level *clean and available* woody yard trimming residue quantity is based upon the 1999 NREL report referenced above. Some 27% of the total woody yard trimmings are assumed to be *clean* and *available* for biopower in the 1999 NREL report (refer to the Appendix for more detailed discussion of *clean* and *available* woody yard trimmings). The quantity is assumed to be constant over time except for a small decrease due to an increase in ethanol production.

Construction and Demolition Residues. The current state-level *clean and available* construction and demolition residue quantities are based upon the 1999 NREL report referenced above. Some 44% of the total construction and demolition wood residues is assumed to be *clean* and *available* for biopower in the 1999 NREL report (refer to the Appendix for more detailed discussion of this issue). The quantity is assumed to be constant over time, again except for small decrease due to an increase in ethanol production.

Pallets and Other Waste Wood. The current state-level *clean and available* waste wood (from the MSW stream) residue quantities are based upon the 1999 NREL report referenced above. 46% of the total waste wood (from the MSW stream) residues are assumed to be *clean* and *available* for biopower in the 1999 NREL report (refer to the Appendix for more detailed discussion of *clean* and *available* "pallets and other waste wood"). The quantity is assumed to be constant over , again except for small decrease due to an increase in ethanol production.

Agricultural Residues. The current state-level *clean and available* agricultural residue quantities are based upon the 1999 Oak Ridge National Laboratory report referenced above. The quantity is assumed to be constant over time but fully utilized by 2007 for ethanol production.

Bioenergy Crops. The current state-level available bio-energy crop quantities are based upon an estimate of the technically feasible bio-energy crop growth trajectory in New York State (i.e., the growth trajectory is based on biological constraints, not economic constraints). The quantity increases over time as the stands develop and mature. The assumed biological constraint translates into 5.2 M acres of land planted as bio-energy crops by 2022 (also assuming a yield of between 4.5 wet tons/acre/year and 5.5 wet tons/acre/year, depending upon the previous land-use). [7]

Cattle Manure. The current state-level available biogas (from cattle manure) quantity is based upon estimates provided by NYSERDA. Combusting the biogas from digested cattle manure represents a potential greenhouse-gas mitigation opportunity. Cattle manure does not represent a large biomass resource but is included nominally in this analysis in the event that NYSERDA should choose to further study this opportunity in the future.

---

7 As a comparison, New York State has about 30.2 M acres of land in its entirety.

Wastewater Methane. The current state-level available wastewater methane quantity is based upon per-capita wastewater methane-emissions calculations and the state population. Combusting wastewater methane represents a potential greenhouse-gas mitigation opportunity. Wastewater methane does not represent a large biomass resource but is included nominally in this analysis in the event that NYSERDA should choose to further study this opportunity in the future.

Table 4.2.5 summarizes the estimated *clean and available* biomass resource quantities in New York State that were assumed in computing the technical potentials for various biopower technologies (discussed below).

Table 4.2.5 Clean, Available Biomass Resource Quantities in New York State*
(Trillion BTU/yr)

Biomass Resource Class	2003	2007	2012	2022
Mill Residues	0.55	1.41	2.31	3.79
Silviculture Residues	12.86	15.88	21.03	30.71
Site Conversion Residues	26.45	26.17	25.07	24.46
**** Silviculture (other than residues)**	176.97	156.92	116.86	55.43
Woody Yard Trimmings	8.21	8.12	7.78	7.59
Construction Residues	3.37	3.34	3.20	3.12
Demolition Residues	7.37	7.29	6.98	6.81
Pallets and other Waste Wood (from MSW stream)	5.99	5.93	5.68	5.54
+ Agricultural Residues	1.02	0.00	0.00	0.00
Bioenergy Crops	0.03	6.89	68.89	260.61
TOTAL	**242.83**	**231.94**	**257.80**	**398.07**
# Biogas from Cow Manure	6.35	not estimated	not estimated	not estimated
# Methane from Wastewater Treatment	0.71	not estimated	not estimated	not estimated

* All biomass resource quantities in this table are available for *new* biopower and are exclusive of biomass residues that are put to other uses (e.g., for existing biopower, mulch production, particle-board production, etc.). In addition, these numbers have been reduced to account for biomass that will be consumed in producing ethanol in New York State.

** Silviculture (other than residues) resource quantities are projected to decline over time due to increased wood needs of the pulp and paper and wood products industries.

\+ Agricultural residue quantities decline to zero by 2007 because ethanol production is assumed to utilize agricultural residues before any other biomass resource class.

\# These biomass resources are not included in the total because they will not be included in the full analysis.

Apportionment of Biomass Resources into Load Zones

Estimated *clean and available* biomass resources in New York State (and their time evolutions) were presented in the previous section. The next step in the analysis involved apportioning these resources into the load zones in order to enable the technical potentials to be estimated for the various biopower technologies. The apportionment of the resources into the load zones was based on reasonable assumptions specific to each biomass resource class. For example, "pallets and other waste wood" (from the MSW stream) were apportioned into a particular load zone based on the fraction of statewide daily MSW intake (at transfer stations) that occurs in that load zone (based on Chartwell data). Another example: The 1996 U.S. Forest Service Timber Product Output Database was used to apportion mill residues and silvicultural resources into particular load zones. (Load-zone-specific tables of estimated clean and available biomass resources, analogous to the state-level Table 4.2.5 above, are available upon request.)

Major Potential Constraints on the Biomass Resource Base

A number of factors could potentially constrain the *clean* and *available* biomass resource base presented in Table 4.2.5 (recognizing that these quantities are rough estimates). These constraints are either economic or policy constraints and thus should not strictly affect estimates of technical potential. (In some cases, however, these constraints have been included for the sake of practicality, thus modifying the definitional intent of *technical potential*). Some of the more important constraints are:

- Waste-to-energy plants compete for biomass resources, largely for the waste wood in the MSW stream. This constraint is reflected in this analysis by assuming that only 46% of the MSW wood is available for biopower (see Appendix for further discussion). The ultimate availability of waste wood in the MSW stream depends upon market conditions and waste-management policies.
- Ethanol production from cellulosic biomass could compete for biomass resources in New York State in the future. This factor is reflected in this analysis according to the assumption outlined in Table 4.2.4. This assumption represents a large uncertainty that is dependent upon market conditions, fuel composition, and air-quality policies.
- The bio-energy crop resource, as presented in Table 4.2.5, is an estimate of what *could* happen (recognizing a biological constraint). Bio-energy crop production has not been demonstrated on this scale. The eventual scale of bio-energy crop production will depend upon agricultural market conditions, agricultural policies, and land-use policies.
- The silviculture resource (sustainable harvest) estimate is based on the net annual growth of the New York State forest (reduced over time to supply wood to the growing pulp and paper and wood products industries). Whether this resource will actually be available to biopower depends upon forestry-conservation policies.

Efforts have been made to define all of the biomass resource classes as *clean* and *available*. Due to data limitations, the assumed resource quantities may not actually fit this definition. In addition, non-biopower competing demands for these resources may increase in the future.

Biopower Resource-Limited Technical Potential

Using the *clean and available* biomass resource quantity estimates for each Load Zone (Table 4.2.5), the technical potential for new biopower (capacity and generation) was estimated over time. For these calculations, a generic technology was assumed to have a heat rate of 10,500 BTU/kWh and a capacity factor of 0.8. The capacity and generation of existing biopower (co-firing, CHP, and direct-fire) were then added back, yielding estimates of the total (new plus existing) resource-limited potential for biopower technologies in New York State. These estimates are presented in Table 4.2.6. (This table does not include the technical potential for wastewater methane combustion or animal-manure digestion.)

Table 4.2.6 Biopower Resource-Limited Technical Potential*

Load Zone		2003	2007	2012	2022
Zone A: West	Capacity (MW)	415.4	404.7	517.5	964.7
	Generation (GWh/year)	2,910.9	2,836.2	3,626.3	6,760.3
Zone F: Capitol	Capacity (MW)	823.8	776.7	760.9	910.1
	Generation (GWh/year)	5,802.7	5,472.4	5,362.4	6,407.9
Zone G: Hudson Valley	Capacity (MW)	105.9	101.3	116.4	189.4
	Generation (GWh/year)	742.1	709.9	815.3	1,327.1
Zone J: NYC	Capacity (MW)	90.2	89.2	85.3	82.9
	Generation (GWh/year)	631.8	624.5	597.5	581.5
Zone K: Long Island	Capacity (MW)	7.1	7.4	10.9	22.7
	Generation (GWh/year)	49.7	51.6	76.6	159.3
All other Load Zones	Capacity (MW)	1,975.1	1,890.2	2,129.9	3,357.1
	Generation (GWh/year)	13,797.1	13,205.8	14,887.2	23,488.8
NY Statewide	**Capacity (MW)**	**3,417.3**	**3,269.3**	**3,620.8**	**5,527.1**
	Generation (GWh/year)	**23,934.3**	**22,900.4**	**25,365.4**	**38,724.8**

* Technical potential estimates assume 100% of the *clean and available* biomass resources in New York State are consumed. They include existing biopower (co-firing, CHP, and direct-fire) as well as potential new biopower. Estimates do not include wastewater methane combustion or manure digestion. The generic biopower technology assumed for these estimates has a heat rate of 10,500 BTU/kWh and a capacity factor of 0.8.

The numbers at the bottom, right-hand corner of Table 4.2.6 (5,527.1 MW and 38,724.8 GWh/year) represent the technical potential (capacity and generation, respectively) for total biopower in New York State in 2022. These technical potentials are limited only by the *clean* and *available* biomass resource.

Technical Potential Estimating Methodology Overview

The next step in the analysis was to estimate the technical potential for the three technologies being assessed in the full analysis. Using the *clean and available* biomass resource quantity estimates for each load zone, the technical potential (capacities and generation) for new biomass combined heat and power, biomass gasification, and new coal/biomass co-firing were estimated. The existing capacities and generation for these three technologies were added back so that total technical potential (new plus existing) could be estimated. In order to estimate the technical potential of the various biopower technologies, capacity factors and heat rates were assumed. These assumptions are summarized in Table 4.2.7.

Table 4.2.7 Biopower Technical Potential Heat Rate and Capacity Factor Assumptions

Technology	Assumption	2003	2007	2012	2022
Biomass CHP	****Heat Rate (BTU / kWh)**	17,043	15,771	14,500	11,845
	***Capacity Factor**	0.85	0.85	0.85	0.85
Biomass Gasification	**#Heat Rate (BTU / kWh)**	9325	9230	9230	8224
	#Capacity Factor	0.8	0.8	0.8	0.8
Co-firing Biomass	**#Heat Rate (BTU / kWh)**	10,497	10,497	10,497	10,497
	+Capacity Factor	0.76	0.81	0.835	0.84

* Information provided by ACEEE.
\# EPRI, Renewable Energy Technology Characterizations, 1997.
\+ EIA AEO 2002, for U.S. coal plants.
** Analyst's judgment based on professional experience.

Using the heat rate and capacity-factor assumptions, along with quantity estimates of the biomass resource, the technical potential (capacity and generation) were estimated for CHP, co-firing, and gasification as follows:

- **New Biomass CHP:** Current *clean* and *available* mill residues were exhausted in estimating the technical potential for new combined heat and power. In addition, the growth in technical potential for biomass combined heat and power was assumed to be limited to the electrical capacity that will be required in the pulp, paper and wood-products industries over and above today's needs (in each load zone). The assumption is that all of the industry's growth in electrical capacity would be met by biomass CHP. The growth in New York State's pulp and paper industry's electrical capacity was assumed to be 1.8% per annum over the analysis period (increasing over 2002 capacity by a total of 42.8 MW by 2022).
- **New Biomass Gasification:** The technical potential for biomass gasification was constrained by the *clean and available* construction and demolition (C&D) residue quantities within each load zone. For the purposes of technical potential estimation, it was assumed that all of the *clean* and *available* C&D resource was exhausted solely by biomass gasification. The justification for linking biomass gasification to the C&D resource is that the utilization of C&D appears to offer the most favorable economics for biomass gasification, according to

gasification technology developers.[8] The likely business model for biomass gasification would be to locate the technology adjacent to a C&D landfill, splitting the tipping fee with the landfill, and therefore improving the economics of the gasification technology.

- **New Cofiring Biomass with Coal:** Mathematically, new co-firing could use all of the remaining *clean and available* biomass resources (i.e., exclusive of mill residues, construction and demolition residues, manure, wastewater methane, and most of the agricultural residues) in each load zone. However, it was assumed that only 15% of the available coal capacity in a given year could be used for co-firing (the coal capacity was assumed to increase over time at the rate of 0.4% per year — from 4,035,017 kW in 2003 to 4,352,973 kW in 2022). This coal-plant capacity constraint was found to be a binding constraint in all cases with the exceptions of years 2007 and 2012 in Load Zone G.
- **Adding-In Existing Capacity and Generation:** The existing capacity and generation for CHP and co-firing were added back in each load zone to yield the total (new plus existing) technical potential for each of the three technologies in each load zone (there is no existing gasification capacity in any of the load zones).
- **Summing Across the Load Zones:** To attain state-level technical potential estimates for each technology, the load zone capacities or generation numbers were summed across all of the load zones (including the load zones not itemized in this analysis).

The technical potentials (capacity and generation) for biomass CHP, cofiring, and gasification — by load zone and at the state level — are presented below.

The statewide technical potential for cow manure digesters was estimated by assuming that every 1000 cows can support 0.1 MW of power (there are 700,000 milking cows in New York State). This relationship is based on information provided by NYSERDA. The capacity factor for cow manure digesters was assumed to be 0.7, and the heat rate was assumed to be 14,800 BTU/kWh (based on biogas input). Only the current statewide technical potential for cow-manure digesters is estimated; future years could be estimated using a ratio based on the expected growth in the cow population. The current technical potential for cattle-manure digestion in New York State is about 0.43 billion kWh/yr from 70,000 kW of capacity. The energy-coincidence factors and capacity coincidence factors for cattle-manure digestion would be similar to those for biomass gasification (Table 4.2.15 and Table 4.2.18).

The statewide technical potential for wastewater methane combustion was estimated based on an estimate of wastewater methane emissions. The wastewater methane-emissions estimate was based upon the New York State population. The capacity factor for wastewater methane combustion was assumed to be 0.7, and the heat rate was assumed to be 12,000 BTU/kWh. Only the current statewide technical potential for wastewater methane combustion is estimated; future years could be estimated using a ratio based on the expected growth in human population. The current technical potential for wastewater methane combustion in New York State is about 0.06 billion kWh/yr from 9,700 kW of capacity. The energy-coincidence

---

[8] Although economics do not enter into the technical potential estimates for total biopower, it is necessary to make use of quasi-economic reasoning in order to apportion the biomass resource to specific biopower technologies.

factors and capacity coincidence factors for wastewater methane combustion would be similar to those for biomass gasification (see Tables 4.2.15 and 4.2.18).

Technical Potential by Biopower Technology

The capacity technical potentials for co-firing, gasification, and CHP are presented below. The existing capacities for these technologies are included. Statewide totals include capacity in all New York State load zones (i.e., not only the itemized load zones). The capacity estimates were not rounded off or made to be divisible by the single unit capacity.

The net effect of the five technical-potential estimation steps (detailed in the previous section) is that the sum of the technical potentials for CHP, gasification, and co-firing do not consume all of the *clean and available* biomass resources in New York State (because CHP and gasification are restricted to particular biomass resources, and the coal-capacity constraint binds in the co-firing capacity estimate). In fact, it is estimated that CHP, gasification, and co-firing are technically capable of consuming only about 16% of the total *clean and available* biomass resource in 2022 (based on the estimation methodology detailed in the previous section). Therefore, Tables 4.2.8 through 4.2.10 (and their corresponding generation tables) represent only a subset of the resource-limited technical potentials presented in Table 4.2.6.

Table 4.2.8 Biopower Technical Potential — Co-firing Biomass with Coal Capacity (15% co-firing)

	Technical Potential			
	Installed Capacity 2003 (MW)	Installed Capacity 2007 (MW)	Installed Capacity 2012 (MW)	Installed Capacity 2022 (MW)
Statewide	605.3	605.1	626.7	652.9
Zone A: West	325.9	331.2	337.9	351.6
Zone F: Capitol	0	0	0	0
Zone G: Hudson Valley	108.2	100.1	111.5	116.7
Zone J: NYC	0	0	0	0
Zone K: Long Island	0	0	0	0

Table 4.2.9 Biopower Technical Potential — Biomass Gasification Capacity

	Technical Potential			
	Installed Capacity 2003 (MW)	Installed Capacity 2007 (MW)	Installed Capacity 2012 (MW)	Installed Capacity 2022 (MW)
Statewide	164.3	164.3	157.4	172.3
Zone A: West	32.6	32.6	31.2	34.2
Zone F: Capitol	4.4	4.4	4.2	4.6
Zone G: Hudson Valley	0	0	0	0
Zone J: NYC	94.1	94.0	90.1	98.6
Zone K: Long Island	.168	.168	.161	.176

Table 4.2.10 Biopower Technical Potential — Customer-Sited Biomass, Combined Heat and Power Capacity

	Technical Potential			
	Installed Capacity 2003 (MW)	Installed Capacity 2007 (MW)	Installed Capacity 2012 (MW)	Installed Capacity 2022 (MW)
Statewide	71.9	79.6	88.9	110.6
Zone A: West	.546	1.5	2.7	5.4
Zone F: Capitol	67.8	68.1	68.5	69.4
Zone G: Hudson Valley	0	0	0	0
Zone J: NYC	0	0	0	0
Zone K: Long Island	0	0	0	0

The technical potential for biomass co-firing, gasification, and CHP generation are presented below. Statewide totals include generation in all New York load zones (i.e., not only the itemized load zones). For reasons discussed above, Tables 4.2.11-4.2.13 represent only a subset of the resource-limited technical potentials presented in Table 4.2.6.

Table 4.2.11 Biopower Technical Potential — Co-firing Biomass with Coal Generation

	Technical Potential			
	Energy Generation 2003 (GWh)	Energy Generation 2007 (GWh)	Energy Generation 2012 (GWh)	Energy Generation 2022 (GWh)
Statewide	4,029.5	4,293.6	4,584.2	4,804.6
Zone A: West	2,170.1	2,350.1	2,471.5	2,587.6
Zone F: Capitol	0	0	0	0
Zone G: Hudson Valley	720.5	710.1	815.6	859.0
Zone J: NYC	0	0	0	0
Zone K: Long Island	0	0	0	0

Table 4.2.12 Biopower Technical Potential — Biomass Gasification Generation

	Technical Potential			
	Energy Generation 2003 (GWh)	Energy Generation 2007 (GWh)	Energy Generation 2012 (GWh)	Energy Generation 2022 (GWh)
Statewide	1,151.7	1,151.0	1,102.8	1,207.4
Zone A: West	228.3	228.2	218.6	239.4
Zone F: Capitol	30.5	30.5	29.2	31.9
Zone G: Hudson Valley	0	0	0	0
Zone J: NYC	659.1	658.8	631.1	691.0
Zone K: Long Island	1.2	1.2	1.2	1.1

Table 4.2.13 Biopower Technical Potential — Customer-Sited Biomass, Combined Heat and Power Generation

	Technical Potential			
	Energy Generation 2003 (GWh)	Energy Generation 2007 (GWh)	Energy Generation 2012 (GWh)	Energy Generation 2022 (GWh)
Statewide	535.9	592.5	662.4	823.7
Zone A: West	4.1	11.1	19.9	40.0
Zone F: Capitol	504.7	507.1	509.9	516.7
Zone G: Hudson Valley	0	0	0	0
Zone J: NYC	0	0	0	0
Zone K: Long Island	0	0	0	0

Energy Coincidence Factors

The energy and capacity coincidence factors used in the analysis are presented in the following tables. Biomass resources are not intermittent, and therefore have a high peak-capacity coincidence as illustrated in Tables 4.2.17 through 4.2.19.

Table 4.2.14 Biopower Energy Coincidence Factors — Co-firing Biomass with Coal

	Energy Coincidence Factors					
	Summer On-Peak %	Summer Off-Peak %	Summer Shoulder %	Winter On-Peak %	Winter Off-Peak %	Winter Shoulder %
Statewide	4.5	38.4	7.5	5.9	37.8	5.9

Table 4.2.15 Biopower Energy Coincidence Factors — Biomass Gasification

	Energy Coincidence Factors					
	Summer On-Peak %	Summer Off-Peak %	Summer Shoulder %	Winter On-Peak %	Winter Off-Peak %	Winter Shoulder %
Statewide	4.5	38.4	7.5	5.9	37.8	5.9

Table 4.2.16 Biopower Energy Coincidence Factors — Customer-Sited Biomass, Combined Heat and Power

	Energy Coincidence Factors					
	Summer On-Peak %	Summer Off-Peak %	Summer Shoulder %	Winter On-Peak %	Winter Off-Peak %	Winter Shoulder %
Statewide	5.9	36.9	7.6	7.4	36.4	5.8

Capacity Coincidence Factors

Table 4.2.17 Biopower Capacity Coincidence Factors — Co-firing Biomass with Coal

	Capacity Coincidence Factors	
	Summer Generation Capacity % of Max Output	**Winter Generation Capacity % of Max Output**
Statewide	98.2	99.8

Table 4.2.18 Biopower Capacity Coincidence Factors — Biomass Gasification

	Capacity Coincidence Factors	
	Summer Generation Capacity % of Max Output	**Winter Generation Capacity % of Max Output**
Statewide	98.2	99.8

Table 4.2.19 Biopower Capacity Coincidence Factors — Customer-Sited Biomass, Combined Heat and Power

	Capacity Coincidence Factors	
	Summer Generation Capacity % of Max Output	**Winter Generation Capacity % of Max Output**
Statewide	98.2	99.8

ECONOMIC POTENTIAL

All of the biopower technical potential resources identified above (Table 4.2.13) pass the economic screening applied for this assessment and are cost effective under both high and low statewide avoided costs. Table 4.2.13 represents the technical potential including what is expected to be developed under the base-case scenario. The economic potential for incremental (over base case) energy production is projected to be 5,100 GWh in 2007, 5,300 GWh in 2012, and over 6,300 GWh in 2022. The economic summer peak coincident capacity resource grows from 833 MW in 2007 to 861 MW in 2012, and 1,022 MW in 2022.

ACHIEVABLE POTENTIAL

Base Case

For renewables, the base case represents the impact of renewable electricity projects already on-line, already permitted, or well along in planning as of late 2002. As discussed in "Biopower Technologies Selected for this Study," the base case includes 20.7 MW of co-firing capacity and 67.6 MW of CHP capacity. Since co-firing projects typically have a 10-year lifetime, the co-firing installed capacity in the base case is zero in 2022. There is no biomass gasification capacity in the base-case scenario. Although

not included in the full analysis, about 40 MW of direct-fire biopower capacity are currently installed in New York State.

Currently Planned Initiatives

Penetration of biomass co-firing (with coal) under the currently planned initiatives (CPI) case was projected based upon a comparison of the biomass supply curve(s) with projected coal prices. Mill residues and C&D wastes were assumed to not be available for co-firing. For biomass co-firing, the biomass cost had to be sufficiently low to compensate the facility for the capital expenditure necessary to co-fire. Professional judgment was also applied to the estimates. Under currently planned initiatives, there are projected to be 68 MW, 65 MW, and 43 MW of co-fired capacity by 2007, 2012, and 2022, respectively. The co-firing capacity is projected to decline after 2007 in part due to declining projected coal prices. In the CPI case, no policy or program initiatives specifically encourage biomass co-firing.

Penetration of biomass gasification under the CPI case was projected based on the competitiveness of biomass gasification with the grid-average cost of electricity. The business model for biomass gasification was based upon splitting the tipping fee for C&D wastes with an adjacent landfill. The supply curves for C&D wastes were used to determine the fuel cost at each level of penetration for biomass gasification. Under currently planned initiatives, there are projected to be 41 MW, 49 MW, and 97 MW of biomass gasification capacity by 2007, 2012, and 2022, respectively. Since green-power markets are projected to be dominated by wind and the federal production tax credit expires in 2003, only Executive Order 111 could potentially offer support for biomass gasification. However, Executive Order 111 applies only to sustainably managed biomass resources that are unlikely — when converted by costly gasification technology — to compete with other resources eligible under the Order. Therefore, no policy supports are assumed in the CPI case to explicitly encourage biomass gasification.

Penetration of biomass CHP under the CPI case was projected based primarily upon professional judgment. Again, since green-power markets are projected to be dominated by wind and the federal production tax credit expires in 2003, only Executive Order 111 could potentially stimulate biomass CHP. The Order could stimulate biomass CHP if biomass sustainability could be demonstrated; however, biomass CHP penetration is driven more by market forces. Under currently planned initiatives, 77 MW, 87 MW, and 110 MW of biomass CHP capacity are projected by 2007, 2012, and 2022, respectively. In the technical potential estimates for CHP, mill residues and CHP were exclusively linked. If forestry residues were also made available to CHP, it is reasonable to project that the technical potential for CHP could increase by an additional 25 MW, 35 MW, and 65 MW in 2007, 2012, and 2022, respectively. Some portion of these increases could be achieved in the CPI case (and in the greenhouse-gas reducation scenario discussed below). Forest residues are presently used as fuel for about 30% of New York State's biomass CHP

capacity, so it seems reasonable that a 32% increase in biomass CHP would result in 2007 if forest residues were considered in this analysis as a potential feedstock for such projects.

Potential Contributions to Greenhouse-Gas Reduction Targets

The greenhouse gas (GHG) reduction targets case for biomass co-firing was projected in a fashion similar to that for the CPI case. The major difference in the GHG case is that the federal production tax credit is extended to 2012 and is expanded to cover co-firing. In addition, it is assumed that a modest state-level policy is enacted to encourage biomass co-firing (but that the federal production tax incentive dominates). The GHG targets case projects 134 MW, 217 MW, and 72 MW of co-firing capacity by 2007, 2012, and 2022, respectively. Because the full federal Production Tax Credit applies to energy crops (instead of the one-third value applied to biomass residues), about 50% of the 2012 co-firing capacity is projected to be from energy crops. The decline in co-firing capacity between 2012 and 2022 is due primarily to the expiration of the federal production tax credit after 2012, and in part to declining coal prices.

The GHG case for biomass gasification was projected similarly to that for the CPI case. The major difference is that the federal production tax credit is extended to 2012 in the GHG case. Overall, 96 MW, 119 MW, and 119 MW of biomass gasification capacity are projected by 2007, 2012, and 2022, respectively, in the GHG case. The flat projection for biomass gasification capacity between 2012 and 2022 is due to expiration of the federal production tax credit after 2012.

The GHG case for biomass CHP was projected using professional judgment. Due to the application of the federal production tax credit to CHP under the GHG-reduction targets case, CHP is projected to achieve its technical potential in 2003, 2007 and 2012. The GHG case for biomass CHP involves 80 MW, 89 MW, and 110 MW in 2007, 2012, and 2022, respectively. As discussed under the CPI case, additional CHP capacity would be possible in the GHG-reduction targets case if the CHP technology/resource linkage was expanded to include forestry resources.

STRATEGIES FOR ACCELERATING MARKET DEVELOPMENT

The major barrier to market development of biopower technologies is the lack of incentives to increase biopower's competitiveness against the dominant generation technologies. Such incentives should be based upon quantitative estimation of the net environmental benefits associated with biopower and the benefits of energy-portfolio diversification.

Market development of biopower technologies would accelerate if the federal production tax credit were extended for 10 or 20 years and expanded to include biomass-residue feedstocks and co-firing technology, or an equivalent tax credit were made available at the State level. Favorable treatment of co-firing technology and biomass residue feedstocks under Executive Order 111 (or a similar policy) and by

consumer green markets, would accelerate biopower market development. A state-level or federal Renewable Portfolio Standard also would be beneficial if biopower technologies qualified for meeting the standards.

State-sponsored or co-sponsored feasibility studies could accelerate biopower development in New York State. Although it is difficult to quantify the market impact a feasibility study co-sponsoring program would have, it is important to point out that promising opportunities are neglected due to the up-front costs of feasibility assessments (with no guaranteed return on the investment). If a significant portion of these costs were offset by the State, new projects would most likely be developed. Perhaps a program similar to other cost-share programs in New York State would be appropriate — e.g., a 50% initial cost-share on the feasibility study up to a specified dollar amount cap, with a 100% cost share if the project is implemented. This type of program would encourage new feasibility studies *and* provide incentives to follow through to project development.

A State-sponsored biomass materials exchange would provide an opportunity to better match producers of clean residues with potential projects. Residue producers often operate in industries that are quite different from power producers, and transaction costs are high. Such an exchange would be an effective way for State funds to facilitate market development by matching buyers and sellers.

Public policies aimed at increasing biopower's penetration need to be evaluated critically to balance sometimes competing public-policy objectives, including sustainable-forestry objectives, local air-quality objectives, waste-management objectives, greenhouse-gas mitigation objectives, and portfolio-diversification objectives.

.

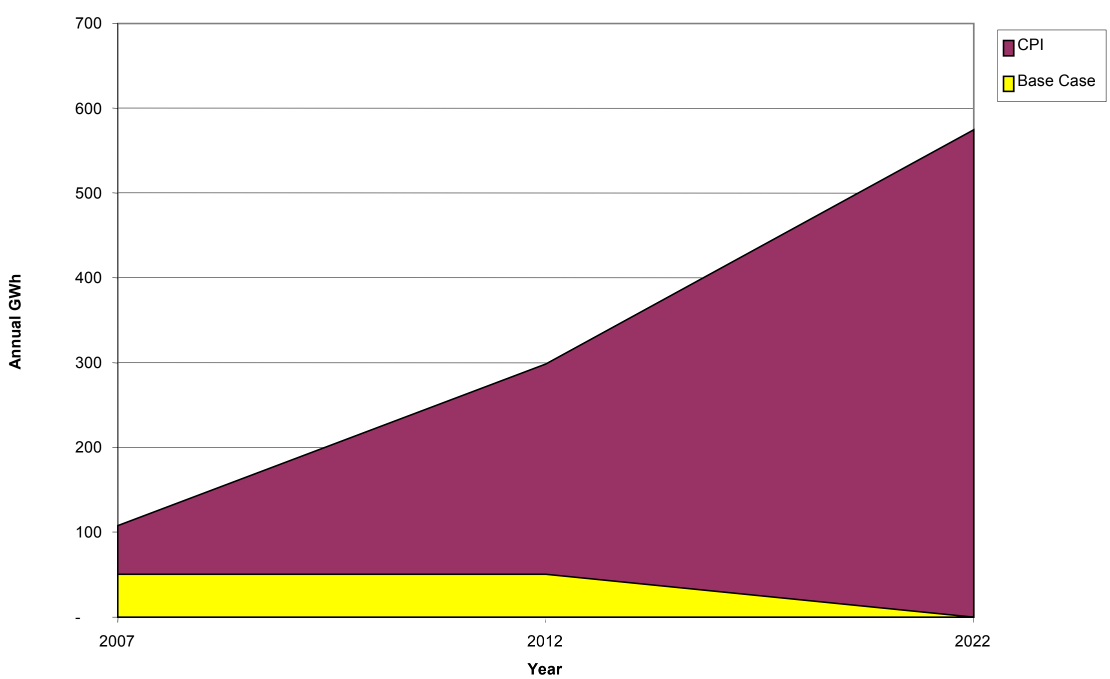
Section 3:
FUEL CELLS

SUMMARY RESULTS

Fuel cell technologies have the technical potential to provide large amounts of electric generation in New York State. By 2022, this study estimates a technical potential greater than 35,000 GWh per year of combined output from four fuel cell technologies. However, by definition, technical potential estimates do not account for cost and other market barriers. Thus, for policy, program, and market planning, the projected levels of development under the base case and currently planned initiative (CPI) scenarios have more direct bearing.

The projected electric generation under these two scenarios is illustrated in Figure 4.3.1. This figure illustrates the anticipated growth of fuel cell generation under Currently Planned Initiatives. It also illustrates that in the base case, with no new program or policy supports put in place after 2002, generation from fuel cells is expected to decline to zero, as units currently planned or on-line units retire by 2022. In the CPI scenario, by 2022 the expected level of fuel cell generation is close to 575 GWh. Phosphoric acid fuel cells are expected to account for the largest share of this generation (39%), followed by molten carbonate fuel cells (32%). Proton exchange membrane (10%) and solid oxide fuel cell (19%) technologies are expected to contribute smaller shares.

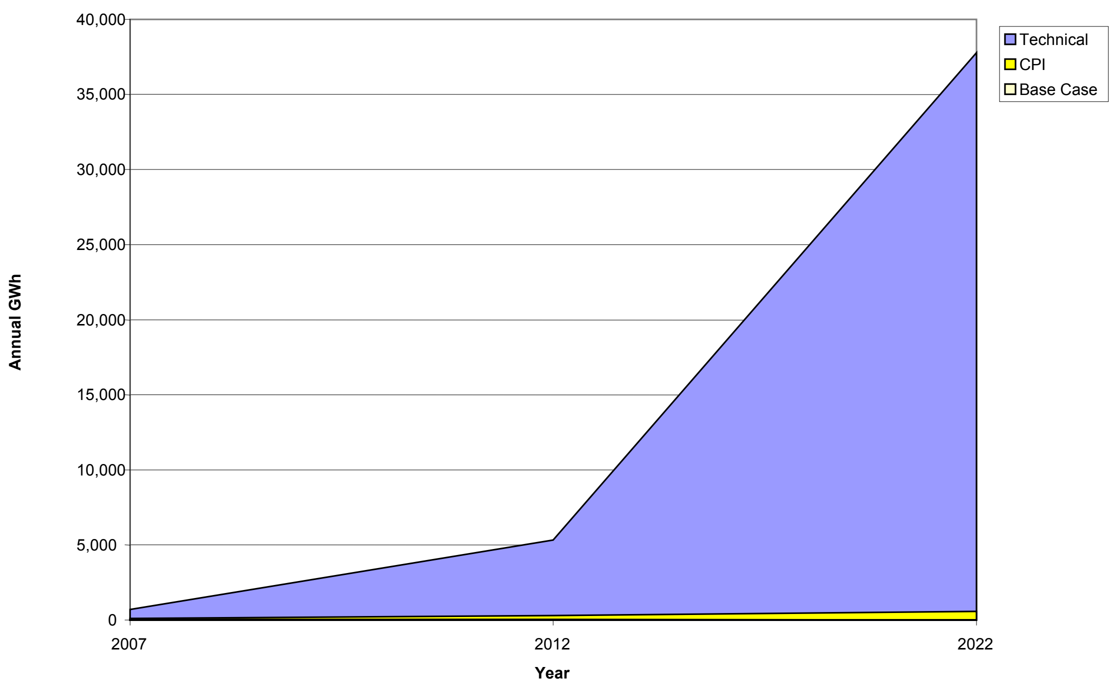
Figure 4.3.1 New York State Fuel Cells Base Case and CPI Scenario Potential Summary



The differential between the expected generation in the base case and CPI scenarios is greatest later in the study's time horizon. This finding suggests that the fuel cell industry is still vitally dependent on continued support through currently planned initiatives, and that without this support, expected generation from fuel cells by 2022 will be virtually non-existent.

The study results for fuel cells are most similar to the results for photovoltaics, which are also an emergent technology, with very large technical potential in comparison to the anticipated achievable potentials. The technical potential for fuel cells generation is very large, exceeding the level of generation expected through the base case and CPI scenarios by a factor of more than 65 times by 2022. Figure 4.3.2 illustrates the magnitude of this technical potential by charting it in comparison to the expected generation in the CPI scenario from Figure 4.3.1. The magnitude of the technical potential resource for fuel cells, more than 37,000 GWh in 2022 makes fuel cells a major component (roughly 1/4) of the total renewable technical potential, and by its very size represents an important finding from this study. Molten carbonate, or "direct" fuel cells are the largest contributor to the projected technical potential accounting for more than 50% of the total fuel cell technical potential in 2022. These fuel cells are most suitable to industrial applications with heat recovery and steam generation requirements.

Figure 4.3.2 New York State Fuel Cells Potential Summary



Fuel cell generation does not pass the societal economic screening tests applied in this study. It also does not contribute to the least-cost integrated set of efficiency and renewable resources to attain greenhouse-gas reduction targets.

TECHNOLOGY DESCRIPTION

A fuel cell is an electrochemical device in which a fuel reacts with an oxidant to directly produce electricity. A fuel cell consists of an electrolyte surrounded by two electrodes. Hydrogen is fed into the anode of the fuel cell. Oxygen or air enters the fuel cell through the cathode. Encouraged by a catalyst, the hydrogen atom splits into a proton and an electron, which take different paths to the cathode. The proton passes through the electrolyte. The electrons create a separate current that can be utilized before they return to the cathode, to be reunited with the hydrogen and oxygen in a molecule of water. Individual fuel cells can be then combined into a fuel cell stack. The number of fuel cells in the stack determines the total voltage, and the surface area of each cell determines the total current. Multiplying the voltage by the current yields the total electrical power generated.

A variety of fuels can be used for fuel cells. Pure hydrogen is the fuel of choice for nearly all designs currently under commercial development. For such fuel cell systems, another fuel can be used as a hydrogen carrier by reforming it in a device that is typically external to the fuel cell unit itself. A fuel cell system, which includes a fuel reformer, can utilize the hydrogen from any hydrocarbon fuel. Since the fuel cells employ a chemical process instead of a combustion process, air emissions from this type of a system are typically much lower than those from various combustion technologies.

Fuel cells hold promise for providing highly reliable electricity with very low air emissions in both stationary and mobile applications. Fuel cell systems currently under development have ranged in size from just a few watts (suitable for providing power for portable electronic devices) to about 3 Megawatts (MW) (suitable for providing electrical power and thermal energy to an industrial manufacturing facility or large commercial building).

This study will focuses on stationary applications that will serve the distributed-generation market. In this market, there are four types of fuel cells that appear to have operational profiles that match well with the electrical needs of the residential, commercial, and industrial sectors. Fuel cells are most likely supply end-use markets for several reasons. The small overall size and high cost of the systems make them a less suitable technology choice for supplying wholesale power. Stationary fuel cells also have a relatively long start-up time and cannot be shut down easily once they have reached proper operating temperatures. This characteristic makes the technology most suitable for providing base-load power. However, fuel cells do offer highly reliable power with a minimal environmental footprint. In addition, the systems can be utilized for the generation of both power and process heat.

Technologies Fully Analyzed in this Study

Fuel cell technologies are typically classified according to their electrolyte type. The following technologies have been selected for detailed analysis in this study based on several factors, including their attractiveness to their particular customer segment, the amount of resources that have been devoted and will continue to be devoted to research and development in their class, and their degree of commercialization.

- Polymer Electrolyte Membrane (PEM), also frequently referred to as "Proton Exchange
- Membrane" cells
- Phosphoric Acid Fuel Cell (PAFC)
- Solid Oxide Fuel Cell (SOFC)
- Molten Carbonate Fuel Cell (MCFC)

In the technology descriptions that follow, these are matched to the various market segments where they will be most attractive, based on their operating and performance characteristics. Other fuel cell technology and scale combinations that are not included in this section may very will succeed in the marketplace, but due to resource restrictions in the study, the most successful technology scale combinations in New York State (based on its residential, industrial, and commercial mix) were chosen.

Polymer Electrolyte Membrane Fuel Cell (PEM) 5-10 k. This technology will most likely arise as the dominant technology for the residential and small commercial sectors. The operating temperatures for PEM cells are low (under 200°F/93°C), and can be used with or without heat recovery. The low temperatures would allow for residential-grade water heating, but are too low for producing high-quality steam. Several manufacturers have introduced demonstration and field trial units with this technology in this size. The primary fuel for residential PEM fuel cells will be natural gas. The technical market will therefore be constrained by the location and availability of natural gas service. Early market reports indicate that the adopters of residential fuel cells will be high-end, new-construction single-family residences. Most of these types of residences are built in areas with natural gas service. GE Fuel Cell Systems (a joint venture between General Electric Distributed Power and Plug Power Inc.) has been the leader in development of residential PEM systems. Other developers have included H Power and Ballard.

Phosphoric Acid Fuel Cell (PAFC) 200 kW. 200 kW Phosphoric Acid is the technology that has been utilized in the only commercialized fuel cell product to date. The technology was first introduced into the commercial market by International Fuel Cells/ONSI (now called UTC Fuel Cells) and has over 200 installed units worldwide, including at Times Square and the Central Park police station. This technology lends itself to commercial and small industrial applications and is a good candidate for combined heat and power (CHP). The technology remains expensive relative to other distributed-generation technologies, but running the units with heat recovery makes the economics more favorable. The initial market for PAFCs has been in high-value niche industries. Early adopters have included high-reliability and high-value

applications, such as the Bank of Omaha central credit-card processing center. The technology is also attractive in situations were a minimal environmental footprint is desired, as was the case with the New York Central Park police station. The market will continue to grow in these niche areas before being adopted by a broader audience. However, PAFCs may begin to lose favor when overall fuel cell costs begin to come down due to the lower overall electrical efficiencies (30-40% compared to 40-50% for SOFC and MCFC). PAFCs also require a fuel reformer to extract hydrogen from a hydrocarbon fuel, whereas some of the higher-temperature technologies, such as SOFC and MCFC, do not require this extra fuel treatment.

Solid Oxide Fuel Cell (SOFC) 200-250 kW. Solid oxide fuel cells in this size range will compete with the currently commercialized PAFCs in the commercial and small industrial market. SOFC will be used only in facilities with high heating loads, such as Internet data centers and industrial manufacturing facilities. This technology can be operated at high enough temperatures (~600° F) to eliminate the use of a fuel reformer. This may eventually give this technology a competitive advantage over PAFCs. Developers of this technology include Siemens Power Generation and Fuel Cell Technologies, Ltd. Mass manufacturing of SOFC technology remains difficult due to the susceptibility of the fuel cell membranes to fouling by sulfur and other contaminants. The higher operating temperatures and higher electrical efficiency (40-50%) of this type of fuel cell will make it an attractive electricity- and heat-generating option once initial manufacturing difficulties are overcome.

Molten Carbonate Fuel Cell (MCFC) 250-2000 k. This technology is attractive because it does not require a fuel reformer. Direct fuel cells can be operated on many types of hydrogen-rich fuel. The direct fuel cell systems operate at higher temperatures than many technologies, which makes the technology an excellent candidate for heat recovery and steam generation in industrial applications. The industrial and large commercial building market will be where this technology will primarily take hold. This technology is currently in field trials. Fuel Cell Energy Corp. is the primary developer of MCFCs. Although this technology has been plagued with similar manufacturing difficulties as SOFC, the larger proposed unit size makes this fuel cell attractive to industrial customers in high-value markets. Initial markets for MCFCs include the biotechnology and pharmaceutical industries.

Technologies NOT Selected for Full Analysis in this Study

Alkaline 10-100 k. While this technology has been utilized successfully in aerospace applications, it does not seem to have great potential for stationary applications. Few manufacturers are exploring alkaline fuel cells.

Proton Exchange Membrane (PEM) 0.025-0.5 kW. This size range is most applicable to residential back-up applications. This market is very small, and the high costs of these systems would prohibit their penetration into all but the smallest high-end residential customer segment.

Proton Exchange Membrane (PEM) 100-250 kW. PEM fuel cells in this size range will be most attractive as power generation in commercial facilities with low or inconsistent heating loads. Commercial facilities requiring high-reliability power would be the market for this technology. Several manufacturers are demonstrating units. Units of this size will have to compete with existing commercialized PAFCs and will most likely have difficulty entering the marketplace.

Solid Oxide (SOFC) 5-10 k. This size class is most suited to residential and small commercial customers. The high operating temperatures of these cells would require heat recovery to be viable. The majority of residential and small commercial customers do not have appropriate heat requirements to allow this technology to be operated optimally.

COMMERCIALIZATION STATUS

Manufacturing and Distribution Infrastructure in New York State

The demand for fuel cells is currently greater than national manufacturing capacity. The production of the membrane cells remains both expensive and technically difficult, as the membranes foul easily. Because of this, early-year projections (2003-2007) typically reflect the rate at which manufacturers can produce the product. Overall, the manufacturing and distribution infrastructure in New York State is better developed than in most other parts of the U.S. simply because of the proximity to many Connecticut-based fuel cell manufacturers and developers. Equity research from CIBC World Markets indicates that manufacturers need to at least triple or quadruple their production capacity by year-end 2004 in order to bring the selling price of units down to the $1,500-$2,000 per kW range. This would be a steep ramp-up in production, but one that is not impossible.

Sales, Service, and Installation Infrastructure in New York State

New York State is home to many early adopters and developers of stationary fuel cell technologies, and the required expertise and working relationships among the developers, industrial energy managers, environmental permitting offices, and construction staff are already being developed. New York State is likely to rely on existing engineering and C&I electrical HVAC firms for expertise in the short term.

Many fuel cell companies have forged strategic alliances with automotive and distributed-generation technology companies. The fuel cell developers hope to capitalize on the relationships that these more established companies have with their customers in order to introduce them to fuel cell technology.

Current Investment Situation at Fuel Cell Companies

Companies that manufacture and develop stationary fuel cells are focusing on two main markets for the short term: premium power and residential. Most viable markets in the premium-power sector are still developing. Fuel cells in this market are competing with more established technologies, such as batteries and advanced uninteruptable power supply (UPS) systems. The high-security data market as well as the telecommunications sector is the area in which some progress has been made.

In the residential market, the 5-10 kW PEM fuel cell has seen the most promise. Several demonstration projects in the high-end residential market have proved technologically viable. PEM cells, however, have had difficulty reaching the level of 40,000 continuous operating hours, whichis deemed necessary for achieving success in the stationary market. Furthermore, the continued high costs of the systems will limit the technology to all but a few high-end residential segments.

The investment situation at fuel cell development will contribute the ultimate success or failure of this technology. The softening of technology stock prices in 2001 through 2002 has had a dampening influence in the advancement of fuel cell technologies. The overall investment retreat in the “tech” sector contributed to this phenomenon, as the broader realization emerged that enterprises valued at $5 billion or more (such as many fuel cell companies) should be generating higher revenues and profits than had been the case in the fuel cell companies (Primen 2001). Most fuel cell companies also have fallen behind on delivering fully commercial products to market; International Fuel Cell is the only company to succeed in this regard as of this writing. Developers are still in the development phase, and this overall trend has remained unchanged for the past two years.

According to Primen, the revised commercialization schedules of many fuel cell developers still remain too optimistic. A historical perspective on how predictions made by fuel cell companies compare with reality helps justify this conclusion. For example, in early 1999, at least five PEM fuel cell companies —

including Dais-Analytic, Energy Partners, H Power, IdaTech, and Plug Power — announced plans to ship market-ready residential fuel cells in 2000 or early 2001 (Primen 2001). As of this writing, none of these companies has yet to deliver commercial-ready product. Even mobile fuel cell developers and partners, such as Daimler-Chrysler, made tentative commitments (e.g., to put 100,000 fuel cell vehicles on the road by 2004). In a far cry from the earlier pronouncements, currently only one company has plans to release a limited edition fuel cell vehicle for the model year 2003 — and the vehicle will require difficult-to-come-by hydrogen as a fuel.

Technical Market Barriers to Increased Demand

An assortment of technical problems and costs issues related to market entry and expansion remain for fuel cell manufacturers. The problems lie in three main areas:

- *Stack Life:* Typical stack lives of seven years have been reported by several fuel cell stack developers (Kreutz and Ogden, 2000). This issue is particularly problematic for PEM cells, whose reported stack lives do not exceed 10,000 hours (and no more than five years in typical residential applications). For stationary residential applications, the stack life should be guaranteed for 50,000 hours in order to gain a significant market share (Lenssen and Reuter, 2001).
- *Fuel Reformers:* The cost of fuel reformers continues to be a barrier to creating economically attractive fuel cell systems. The efficiency of a fuel reformer is generally around 75%. This in and of itself is not particularly distressing, but when combined with the efficiency of the fuel cell stack, the overall system efficiency can sometimes falls below 40% — a level much below what many engines, and especially many engine cogenerating systems, can reach.
- *Power Electronics and Overall System Integration:* Overall integration of the reformer, fuel cell stack, and back-end power electronics has not been optimized, and estimated lifetimes for overall systems have yet to be proved. Furthermore, inverters and other power electronic components remain significant costs in the overall fuel cell system and must be reduced in order to gain market acceptance.

Other Market Barriers

Back-end emissions-control technologies for generators, such as selective catalytic reduction, employ platinum and/or palladium catalysts for reduction of various harmful oxides. EPA Tier II emissions standards will essentially make the use of this type of control mandatory for all fossil-fuel burning technologies. Gasoline vehicles already require platinum catalytic converters for control of tailpipe emissions as well. There has been a good deal of research and discussion about whether the continually increasing demand for precious metal catalysts will become a limiting factor in the commercialization of fuel cells. According to the U.S. Geological Survey, the world reserves of platinum-group metals are estimated to be 100 million kilograms (Tonn, et al 2001). The amount of platinum in fuel cells is steadily decreasing. According to the U.S. Department of Energy (DOE), current 50 kW fuel cell designs use approximately 100 grams of platinum as a catalyst, down from over 200 grams just a couple of years ago. The long-term goal of the DOE program is 10 grams of platinum per 50 kW fuel cell (DOE 2000). Under favorable conditions for platinum and palladium supplies — including low catalyst requirements, low

population growth, low market penetration rates of both stationary and mobile fuel cells, and low growth in demand of developing nations — there will be no shortage of these metals before 2030. If the demand for fuel cells is higher than anticipated, however, a shortage of metal catalysts as well as unreasonable high prices may result (Tonn, et al 2001).

Regulatory, Permitting, and Siting Issues

Potential Environmental Impacts. Fuel cells have the potential to have the lowest level of air emissions of any fossil fuel-based electricity-generating technology. Because fuel cells do not involve the combustion of a fuel, the NO_x and SO_x emissions that are typically byproducts of electric-generating technologies are avoided.

The volumetric criteria air pollutants of fuel cell systems are typically as follows[9]:

- NO_x : <1 ppm
- SO_2 : < 1 ppm
- CO2: < 2 ppm

These volumetric emissions rates do not reflect the various efficiency levels of the fuel cell technologies included in this study. The table below takes the efficiencies of the various fuel cell technologies into account to estimate a real-world emissions rate on a lb/MWh scale.

Table 4.3.1 Emissions Rates of Various Fuel Cell Technologies

	PEM	PAFC	SOFC	MCFC
NO_x (lb/MWh)	TBD	0.03	0.01	TBD
SO_2 (lb/MWh)	TBD	0.006	0.005	TBD
PM-10 (lb/MWh)	TBD	0	0	TBD
CO2 (lb/MWh)	TBD	1,078	950	TBD

Source: Personal Communication with Joel Bluestein

Regulatory Barriers to Installation of Fuel Cell Systems. Fuel cell systems are highly efficient and reliable, and they offer some flexibility in fuel selection. Most stationary fuel cell systems will be installed with heat recovery for the creation of hot water or steam. A combined heat and power (CHP) fuel cell system offers the inherent environmental benefits of fuel cells along with much higher overall efficiencies by utilizing more of the useable output of the system. Modeling analysis has demonstrated that clean CHP technologies such as fuel cells have significant benefits with regard to air emissions, transmission, and

[9] UTC Fuel Cells – http://www.utcfuelcells.com/commercial/pc25summary.shtml

price (Morris 2001). Despite these benefits, fuel cell CHP remains an underutilized technology hindered by a number of disincentives. These barriers can be summarized as:

- complicated permitting systems that are complex, time consuming, and varied;
- regulations that do not account accurately for the overall system efficiency of fuel cell CHP or give credit for displaced emissions and grid losses;
- difficult and frequently prohibitive interconnection arrangements with utilities; and
- depreciation schedules that do not reflect the true life of fuel cells and other CHP assets (Elliott and Spurr 1999).

One of the greatest barriers to the installation of fuel cell systems is the complicated and lengthy plant siting and permitting process. In nitrous oxide and ozone environmental quality non-attainment areas, major new emission sources are required to meet New Source Review (NSR) requirements to obtain operating and construction permits. NSR sets stringent emission rates for criteria pollutants and requires the installation of the best available control technology. New sources are also required to offset existing emissions in non-attainment areas. However, current emissions standards are generally based on fuel input, an approach that does not recognize the fuel efficiency of fuel cell CHP. Moreover, non-uniform interconnection standards and unfair utility tariffs inhibit the installation of fuel cells and other distributed-generation resources. The following paragraphs outline some of the strategies that can be employed on the state level to help make CHP an attractive option.

Cost and Related Information

In order for fuel cells to become widely adopted, they will have to be competitive with other distributed-generation technologies in their same size range. Fuel cells already have attractive NO_x and SO_x emissions characteristics. In order to truly compete with other distributed-generation technologies, they will have to come closer in equipment life, cost, and supply and service infrastructure. The following table lists current cost characteristics for fuel cells.

Table 4.3.2 Fuel Cell Costs

Technology	2003 Installation Cost ($/kW)	Operating and Maintenance Costs ($/kW/yr)
5–10 kW PEM	$5,500	$71
200 kW PAFC	$4,500	$81
200–250 kW SOFC	$3,500	$84
250–2000 kW MCFC	$2,800	$96

TECHNICAL POTENTIAL

The demand for fuel cells is currently greater than national manufacturing capacity. The eligible market base for technical potential far exceeds the current manufacturing capacity. The production of the membrane cells remains both expensive and technically difficult, as the membranes foul easily. Because of this, early-year projections (2003-2007) typically reflect the rate at which manufacturers can produce the product. Later-year projections follow a typical technology diffusion curve.

The analysis described below is for a bounded technical potential. Strictly speaking, the potential of the small-scale (under 1 MW) distributed-generation market that can technically be served by fuel cells is close to 100%. There is not nearly enough manufacturing capacity — nor will there be for at least 10 years — to serve this market. It was determined that the technical potential, in the early years of this study, will be limited by manufacturers' ability to bring products to market. This limitation is evident in all of the technology potential descriptions presented in the following section.

The technical potential in the 10- to 20-year timeframe most likely will not be constrained by this limitation. The study believes that the fuel cells will compete technically with primarily non-renewable technologies, such as natural-gas engines and turbines. Because fuel cells offer the added advantage of being able to provide hot water and steam as well as electricity, the study determined that this technology will be able to meet a portion of the combined heat and power market in the commercial and industrial sectors. The study has employed an aggressive diffusion curve to describe the growth in the technical market between 2003 and 2022. The study predicts that the growth in the beginning years will be fast (in many cases doubling or tripling each year), but that since the current manufacturing capacity is still low, the total technical potential remains rather small until 2012. The study assumes that the production barriers will begin to disappear within 10 years and that technical potential will be able to mirror that of the overall combined heat and power market in the various size ranges from 2012 to 2022.

Polymer Electrolyte Membrane Fuel Cell (PEM) 5-10 kW

The 2003 technical potential is based on an estimate of a 16.6% share of the 400 total reported North American installations (estimating 10kW per installation) plus a 16.6% share of the total annual production of 300 PEM fuel cells annually as reported by Plug Power and Ballard. 16.6% is the same share as the share of PAFCs currently in New York State of total North American installations. This figure was used as representative estimate of the number of fuel cells that will typically be installed in New York State based on current installation trends. New York State has been one of the early adopters of fuel cells and will continue to lead the market into the future. The 2007 technical potential was estimated by assuming a 100% annual increase in production of PEM fuel cells between 2003 and 2007. Between 2007 and 2012, the annual production was estimated to increase by 50%. The annual production was estimated to continue a 50% annual increase between 2012 and 2017, then to slow to a 5% annual production increase from 2017

to 2022. The total electricity consumption estimates for PEM fuel cells are based on the residential kWh/kW ratio for New York State. The electricity load curve is based on the load profile for New York single-family residences.

Table 4.3.3 Fuel Cells Technical Potential (kW) for 5-10 kW PEM

	Technical Potential			
For Technology Type and Scale - 5-10 kW PEM	Installed Capacity 2003 (kW)	Installed Capacity 2007 (kW)	Installed Capacity 2012 (kW)	Installed Capacity 2022 (kW)
Statewide	1,144	1,912	67,007	649,418
Zone A: West	103	172	6,033	58,474
Zone F: Capitol	70	117	4,098	39,717
Zone G: Hudson Valley	84	140	4,922	47,700
Zone J: NYC	321	537	18,822	182,418
Zone K: Long Island	179	298	10,461	101,386

Table 4.3.4 Fuel Cells Technical Potential (GWh) for 5-10 kW PEM

	Technical Potential			
For Technology Type and Scale – 5-10 kW PEM	Energy Generation 2003 (GWh)	Energy Generation 2007 (GWh)	Energy Generation 2012 (GWh)	Energy Generation 2022 (GWh)
Statewide	5.3	40.5	307.9	2,984.1
Zone A: West	.47	3.7	27.7	268.7
Zone F: Capitol	.32	2.5	18.8	182.5
Zone G: Hudson Valley	.39	2.9	22.6	219.2
Zone J: NYC	1.5	11.4	86.5	838.2
Zone K: Long Island	.82	6.3	48.1	465.9

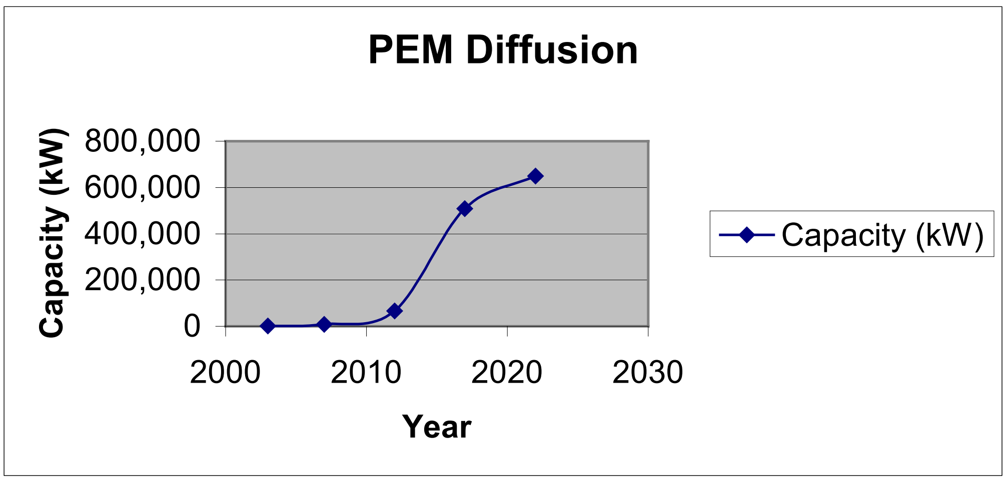
Table 4.3.5 Energy Coincidence Factors for 5-10 kW PEM

Energy Coincidence Factors						
For Technology Type and Scale 5-10 kW PEM	Summer On-Peak %	Summer Off-Peak %	Summer Shoulder %	Winter On-Peak %	Winter Off-Peak %	Winter Shoulder %
Statewide	6.01%	35.05%	8.53%	7.16%	36.41%	6.84%

Table 4.3.6 Capacity Coincidence Factors for 5-10 kW PEM

For Technology Type and Scale 5-10 kW PEM	Capacity Coincidence Factors	
	Summer Generation Capacity % of Max Output	**Winter Generation Capacity % of Max Output**
Statewide	59.6%	64.8%

Figure 4.3.3 5-10 kW PEM Technical Diffusion Rate



<u>Phosphoric Acid Fuel Cell (PAFC) 200 kW</u>

5000 kW of PAFCs are currently installed in New York State. Annual production capacity is about 200 units per year (assume that 16.6% of them will be dedicated to New York State). This results in a 2003 technical potential of 13,300 kW. A 2022 technical potential for fuel cells was based on the commercial/institutional CHP potential in 2002 increased by 12% total to 2022 (estimate of growth in buildings with operating hours >4000hrs/yr) from a current technical market of 1658.4 MW for units between 100-500 kW. A 20% market share by 2022 was estimated. The market share was selected based on the fact that PAFC electrical efficiencies average from 30-40%, and can be under 30% when losses attributed to fuel-reformer losses are taken into account. There are existing technologies with higher efficiencies and operating temperatures whose technical specifications make them more attractive to CHP applications than PAFC. Based on this, the 20% market share was estimated. Industrial electricity demand increases by 0.84% per year for a total potential in 2022 of 2061MW. Assume a 20% market share = 412,000 kW (Total = 412,000+ 371,500, or 783,500). The annual growth rate from 2003 to 2007 was estimated to be 20%, with the annual growth from 2007 to 2012 estimated at 50%. The kWh potential was estimated by assuming that units operate for 85% of the time (7,446 hours annually). This is a reasonable

assumption for this type of distributed-generation unit operating in commercial or small industrial settings. The load profile is based on the New York State commercial buildings load profile; the capacity coincidence factors are estimates. PAFCs will fulfill primarily baseload electricity needs; however, the study has assumed that the systems will sustain some unplanned outages.

Table 4.3.7 Fuel Cells Technical Potential (kW) for 200 kW PAFC

	Technical Potential			
For Technology Type and Scale - 200 kW PAFC	Installed Capacity 2003 (kW)	Installed Capacity 2007 (kW)	Installed Capacity 2012 (kW)	Installed Capacity 2022 (kW)
Statewide	13,300	27,579	209,427	783,500
Zone A: West	1,546	3,206	24,349	91,094
Zone F: Capitol	1,050	2,178	16,539	61,874
Zone G: Hudson Valley	882	1,830	13,896	51,986
Zone J: NYC	4,426	9,179	69,700	260,760
Zone K: Long Island	1,506	3,124	23,721	88,743

Table 4.3.8 Technical Potential (GWh) for 200 kW PAFC

	Technical Potential			
For Technology Type and Scale – 200 kW PAFC	Energy Generation 2003 (GWh)	Energy Generation 2007 (GWh)	Energy Generation 2012 (GWh)	Energy Generation 2022 (GWh)
Statewide	99.0	205.3	1,559.4	5,833.9
Zone A: West	11.5	23.9	181.3	678.3
Zone F: Capitol	7.8	16.2	123.1	460.7
Zone G: Hudson Valley	6.6	13.6	103.5	387.0
Zone J: NYC	32.9	68.3	518.9	1,941.6
Zone K: Long Island	11.2	23.3	176.6	660.8

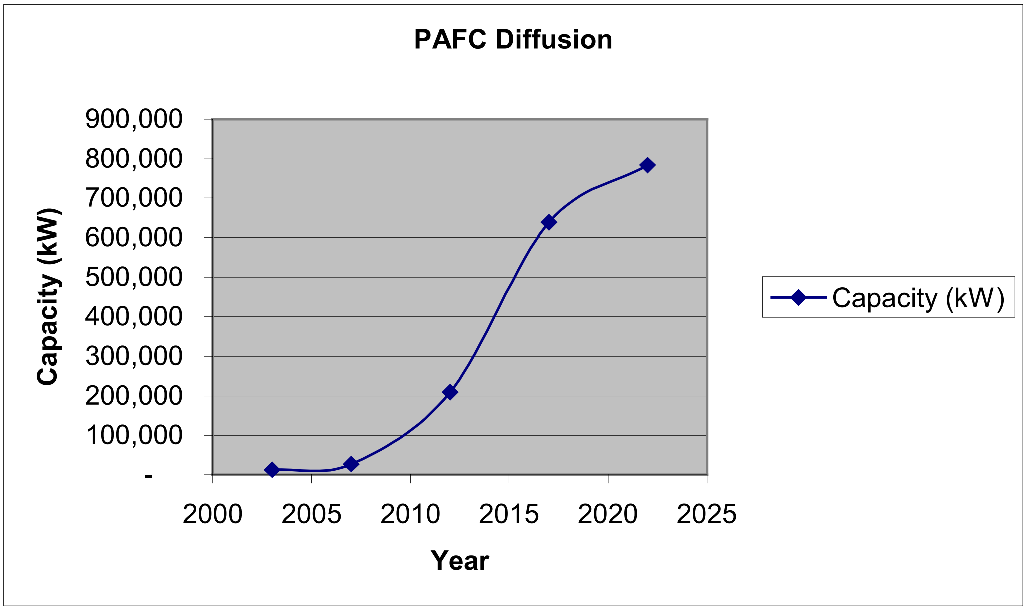
Table 4.3.9 Energy Coincidence Factors for 200 kW PAFC

For Technology Type and Scale 200 kW PAFC	Summer On-Peak %	Summer Off-Peak %	Summer Shoulder %	Winter On-Peak %	Winter Off-Peak %	Winter Shoulder %
Statewide	4.52%	38.36%	7.53%	5.84%	37.90%	5.84%

Table 4.3.10 Capacity Coincidence Factors for 200kW PAFC

For Technology Type and Scale 200 kW PAFC	Capacity Coincidence Factors	
	Summer Generation Capacity % of Max Output	**Winter Generation Capacity % of Max Output**
Statewide	90%	90%

Figure 4.3.4 200kW PAFC Diffusion Rate



<u>Solid Oxide Fuel Cell (SOFC) 200-250 kW</u>

2003 technical potential is based on Siemens estimates of a current manufacturing capacity of 20 MW per year. A New York State share is estimated to be 16.6%. The 2022 technical potential is based on the commercial/institutional and industrial CHP potential in 2002 increased by 12% total to 2022 (estimate of growth in buildings with operating hours >4000hrs/yr) from current technical market of 1658.4 MW for units between 100-500 kW. A 50% market share by 2022 was estimated. The annual growth rate for new capacity manufacture was estimated to be 50% from the current level for 2003 to 2007. The annual growth from 2007 to 2012 was estimated to be 50%. The kWh potential was estimated by assuming that units operate for 85% of the time (7,446 hours annually). This is a reasonable assumption for this type of distributed-generation unit operating in commercial or small industrial settings. The load profile is based on the New York State commercial buildings load profile. The capacity coincidence factors are estimates. As with PAFCs, SOFCs will fulfill primarily baseload electricity needs; however, the study has assumed that the systems will sustain some unplanned outages.

Table 4.3.11 Fuel Cells Technical Potential (kW) for 200-250kW SOFC

	Technical Potential			
For Technology Type and Scale 200-250 kW SOFC	Installed Capacity 2003 (kW)	Installed Capacity 2007 (kW)	Installed Capacity 2012 (kW)	Installed Capacity 2022 (kW)
Statewide	3,320	19,529	148,230	928,704
Zone A: West	386	2,271	17,234	107,976
Zone F: Capitol	262	1,542	11,706	73,341
Zone G: Hudson Valley	220	1,296	9,835	61,620
Zone J: NYC	1,105	6,500	49,333	309,086
Zone K: Long Island	376	2,212	16,789	105,189

Table 4.3.12 Fuel Cells Technical Potential (GWh) for 200-250kW SOFC

	Technical Potential			
For Technology Type and Scale 200-250 kW SOFC	Energy Generation 2003 (GWh)	Energy Generation 2007 (GWh)	Energy Generation 2012 (GWh)	Energy Generation 2022 (GWh)
Statewide	24.7	145.3	1,103.7	6,915.1
Zone A: West	2.9	16.9	128.3	803.9
Zone F: Capitol	1.9	11.5	87.1	546.0
Zone G: Hudson Valley	1.6	9.6	73.2	458.8
Zone J: NYC	8.2	48.4	367.3	2,301.5
Zone K: Long Island	2.8	16.5	125.0	783.2

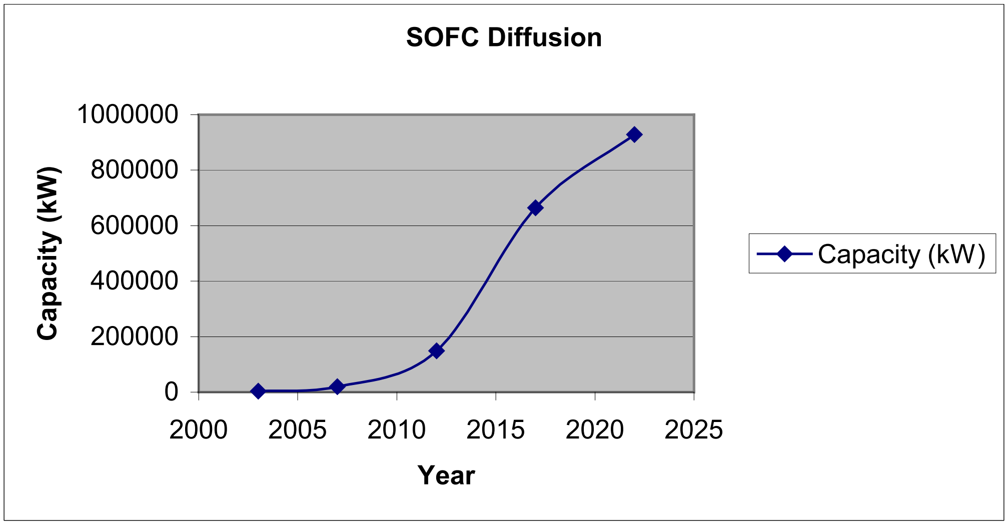
Table 4.3.13 Energy Coincidence Factors for 200-250kW SOFC

For Technology Type and Scale 200-250 kW SOFC	Summer On-Peak %	Summer Off-Peak %	Summer Shoulder %	Winter On-Peak %	Winter Off-Peak %	Winter Shoulder %
Statewide	4.52%	38.36%	7.53%	5.84%	37.90%	5.84%

Table 4.3.14 Capacity Coincidence Factors for 200-250kW SOFC

For Technology Type and Scale 200-250 kW SOFC	Capacity Coincidence Factors	
	Summer Generation Capacity % of Max Output	Winter Generation Capacity % of Max Output
Statewide	90%	90%

Figure 4.3.5 200-250kW SOF Diffusion Rate



Molten Carbonate Fuel Cell (MCFC) 250-2000 kW

2003 technical potential is based on a 16.6% share of the current annual capacity of 50 MW/year produced by Fuel Cell Energy. It is estimated that this capacity will increase by 30% per year until 2007, and that the market diffusion will increase 50% per year between 2007 and 2012. Total industrial and commercial technical potential in New York State in 2022 is 6236 MW (for units under 2MW). The study estimates that 40% of these sites will be amenable to MCFCs. The kWh potential was estimated by assuming that units operate for 85% of the time (7,446 hours annually). This is a reasonable assumption for this type of distributed-generation unit operating in industrial settings. The MCFC load profile is based on the load shape of the glass industry. This industry was chosen because it has a mix of continuous and batch processes that best describe industry as a whole. The capacity coincidence factors are estimates. Again, MCFCs will fulfill primarily baseload electricity needs, but the study has assumed that the systems will sustain some unplanned outages.

Table 4.3.15 Fuel Cells Technical Potential (kW) for 250-2000kW MCFC

	Technical Potential			
For Technology Type and Scale 250 – 2000 kW MCFC	Installed Capacity 2003 (kW)	Installed Capacity 2007 (kW)	Installed Capacity 2012 (kW)	Installed Capacity 2022 (kW)
Statewide	8,300	3,2005	243,042	2,494,750
Zone A: West	1,710	6,594	50,075	514,001
Zone F: Capitol	1,162	4,479	34,012	349,127
Zone G: Hudson Valley	799	3,082	23,401	240,199
Zone J: NYC	329	1,267	9,621	98,758
Zone K: Long Island	599	2,308	17,529	179,932

Table 4.3.16 Technical Potential (GWh) for 250 – 2000kW MCFC

	Technical Potential			
For Technology Type and Scale 250 – 2000 kW MCFC	**Energy Generation 2003 (GWh)**	**Energy Generation 2007 (GWh)**	**Energy Generation 2012 (GWh)**	**Energy Generation 2022 (GWh)**
Statewide	61.8	238.3	1,809.7	18,575.9
Zone A: West	12.7	49.1	372.9	3,827.2
Zone F: Capitol	8.6	33.3	253.3	2,599.6
Zone G: Hudson Valley	5.9	22.9	174.2	1,788.5
Zone J: NYC	2.4	9.4	71.6	735.3
Zone K: Long Island	4.4	17.2	130.5	1,339.8

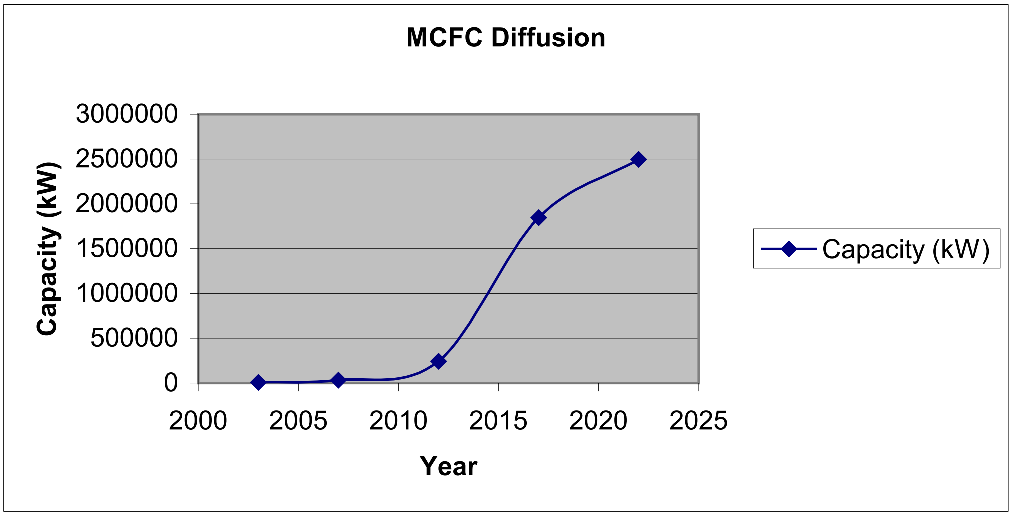
Table 4.3.17 Energy Coincidence Factors for 250 – 2000kW MCFC

For Technology Type and Scale 250 – 2000 kW MCFC	Summer On-Peak %	Summer Off-Peak %	Summer Shoulder %	Winter On-Peak %	Winter Off-Peak %	Winter Shoulder %
Statewide	7.823%	5.781%	35.985%	6.281%	7.625%	36.504%

Table 4.3.18 Capacity Coincidence Factors for 250 – 2000kW MCFC

For Technology Type and Scale 250 - 2000 kW MCFC	Capacity Coincidence Factors	
	Summer Generation Capacity % of Max Output	**Winter Generation Capacity % of Max Output**
Statewide	90%	90%

Figure 4.3.6 250-2000IW MCFC Diffusion Rate



ECONOMIC POTENTIAL

Throughout the time horizon of this analysis, fuel cell technologies do not become cost-effective in terms of comparison to the projected avoided utility costs for energy and capacity that have been used in this study. Therefore, the economic component of the technical potential in both the high and low avoided cost analyses is zero for each of the fuel cell technologies analyzed.

ACHIEVABLE POTENTIAL

Base Case

This section indicates how much of the technical potential defined above is likely to be realized assuming three different policy scenarios. The base case scenario indicates the amount of additional fuel cell power likely to be generated assuming no additional market intervention occurs after this year. Because the technology is not assumed to be cost-competitive with other distributed technologies during the study period, and because the currently installed systems are projected to have exceeded their useful lives by 2022, the projected installed capacity in 2022 will be zero. In effect, this scenario assumes the continuation of existing fuel cell power production and some capacity attrition due to age, machinery depreciation, and other losses. Thus, in forecasting this scenario, the study assumes not only that market interventions already in place will not be revoked or neutralized, but also that no significant improvement will be experienced in the regulatory arena. The study's general conclusion is that there will be no increase in fuel cell capacity or energy in New York State under the base case scenario. The costs used for this portion of the analysis are 2003 (current) costs for each of the technologies.

Table 4.3.19 Fuel Cells Installed Capacity (Statewide) — Base Case

For All Technologies Statewide	Installed Capacity 2003 (kW)	Installed Capacity 2007 (kW)	Installed Capacity 2012 (kW)	Installed Capacity 2022 (kW)
5-10 kW PEM	770	770	770	0
200 kW PAFC	5600	5600	5600	0
200-250 kW SOFC	0	0	0	0
250 – 2000 kW MCFC	0	0	0	0

Table 4.3.20 Fuel Cells Installed Capacity (Load Control Zone) — Base Case

	Installed Capacity 2003 (kW)	Installed Capacity 2007 (kW)	Installed Capacity 2012 (kW)	Installed Capacity 2022 (kW)
5-10 kW PEM	770	770	770	0
Zone A: West	69	69	69	0
Zone F: Capitol	47	47	47	0
Zone G: Hudson Valley	57	57	57	0
Zone J: NYC	216	216	216	0
Zone K: Long Island	120	120	120	0
200 kW PAFC	5600	5600	5600	0
Zone A: West	651	651	651	0
Zone F: Capitol	442	442	442	0
Zone G: Hudson Valley	372	372	372	0
Zone J: NYC	1,864	1,864	1,864	1,0
Zone K: Long Island	634	634	634	0
200-250 kW SOFC	0	0	0	0
Zone A: West	-	-	-	-
Zone F: Capitol	-	-	-	-
Zone G: Hudson Valley	-	-	-	-
Zone J: NYC	-	-	-	-
Zone K: Long Island	-	-	-	-
250 – 2000 kW MCFC	0	0	0	0
Zone A: West	-	-	-	-
Zone F: Capitol	-	-	-	-
Zone G: Hudson Valley	-	-	-	-
Zone J: NYC	-	-	-	-
Zone K: Long Island	-	-	-	-

Currently Planned Initiatives

The CPI scenario indicates the amount of capacity and energy based on "the future impacts expected from currently planned initiatives included in the State Energy Plan." The following programs and initiatives were taken into account when determining estimated future capacity under this scenario:

- Through the New York Energy $mart Distributed Generation and Combined Heat and Power Program, $67 million has been allocated to support the DG/CHP public benefits program provided through New York Energy $mart between 2001 to 2006.
- NYSERDA is administering a $6 million project, funded by the Clean Air/Clean Water Bond Act and Plug Power, LLC, to demonstrate 50 7-kW PEM fuel cells at 10 New York State-owned sites. Other anticipated NYSERDA projects include: installation and demonstration of a 250-kW fuel cell at Brookhaven National Laboratory on Long Island; implementation of test fuel cells at a remote telecommunications site with a 5-kW load; and a current project by NYPA to install eight more 200-kW fuel cells at wastewater facilities in New York City at a cost of $14 million.
- Governor Pataki's Executive Order No. 111, issued in 2001, directs State agencies and other affected entities to seek to increase their purchase of energy generated from specific renewable technologies to meet 10% of their energy requirements by 2005, and to increase that share to 20% by 2010.
- The Green Buildings Tax Credit Law, enacted in May 2000, includes a fuel cells provision that provides a 30% credit (6% per year over 5 years) for the capitalized cost of each fuel cell. The fuel cell must be serving green space and must use a qualifying alternative energy source. There is a cap of $1,000/kW multiplied by the direct-current (DC) rated capacity.

Because fuel cells currently are not economically competitive and are projected to remain that way compared to other distributed-generation technologies through 2022, it was determined that the future installed capacity will be determined by programmatic interventions. The capacity in 2007 was determined by assuming that 10% share of Executive Order 111 gains would be served by fuel cells, and that an additional 5% annual growth would occur from 2003 to 2007. For 2012, the study assumed a 20% share of Executive Order 111 gains plus 10% annual growth from 2007 to 2012. For 2022, a 5% annual growth from 2012 to 2022 was assumed. The study made the assumption that there would be growth in the rate of capacity installation in addition to that driven by the programmatic intervention because of the positive effect of these interventions on the market.

Table 4.3.21 Fuel Cells Installed Capacity (Statewide and Zone) — Currently Planned Initiatives

For All Technologies	Installed Capacity 2003 (kW)	Installed Capacity 2007 (kW)	Installed Capacity 2012 (kW)	Installed Capacity 2022 (kW)
5-10 kW PEM	770	1,544	5,707	9,771
Zone A: West	69	139	514	880
Zone F: Capitol	47	94	349	598
Zone G: Hudson Valley	57	113	419	718
Zone J: NYC	216	434	1,603	2,745
Zone K: Long Island	120	241	891	1,525
200 kW PAFC	5600	8,630	17,120	29,309
Zone A: West	651	1,003	1,990	3,408
Zone F: Capitol	442	682	1,352	2,315
Zone G: Hudson Valley	372	573	1,136	1,945
Zone J: NYC	1,864	2,872	5,698	9,754
Zone K: Long Island	634	977	1,939	3,320
200-250 kW SOFC	0	1,216	5,179	8,866
Zone A: West	-	141	602	1,031
Zone F: Capitol	-	96	409	700
Zone G: Hudson Valley	-	81	344	588
Zone J: NYC	-	405	1,724	2,951
Zone K: Long Island	-	138	587	1,004
250 - 2000 kW MCFC	0	2,431	10,357	17,731
Zone A: West	-	501	2,134	3,653
Zone F: Capitol	-	340	1,449	2,481
Zone G: Hudson Valley	-	234	997	1,707
Zone J: NYC	-	96	410	702
Zone K: Long Island	-	175	747	1,279

Potential Contributions to Greenhouse-Gas Reduction Targets

The final scenario, the greenhouse-gas reductions target scenario, is defined as "the least-cost combination of efficiency and renewable resources above those expected from currently planned initiatives that can be used to meet GHG-reduction targets defined by NYSERDA for 2012 and 2022." Essentially, the policy initiatives under this scenario are the same as those under the CPI scenario, with the added requirement that green power marketing be mandatory by 2005. The same provisions that applied to the CPI scenario also apply to the GHG-reductions scenario.

It was estimated however that an aggressive GHG-reduction plan would have significant market spillover that would make fuel cells more attractive. To estimate 2007 capacity, the study assumed a 10% share of Executive Order 111 gains plus 10 % annual growth from 2003 to 2007. For 2012, the study assumed a

20% share of Executive Order 111 gains plus 20% annual growth from 2007 to 2012. For 2022, the study assumed a 30% share of Executive Order 111 gains plus 10% annual growth from 2012 to 2022. The GHG-reduction scenario capacities for fuel cells are listed in the Table 4.3.22.

Table 4.3.22 Fuel Cells Installed Capacity (Statewide and Zone) — Greenhouse-Gas Reduction Targets Scenario

For All Technologies	Installed Capacity 2003 (kW)	Installed Capacity 2007 (kW)	Installed Capacity 2012 (kW)	Installed Capacity 2022 (kW)
5-10 kW PEM	770	1,859	9,603	43,590
Zone A: West	69	167	865	3,925
Zone F: Capitol	47	114	587	2,666
Zone G: Hudson Valley	57	137	705	3,202
Zone J: NYC	216	522	2,697	12,244
Zone K: Long Island	120	290	1,499	6,805
200 kW PAFC	5600	10,395	30,843	139,998
Zone A: West	51	1,209	3,586	16,277
Zone F: Capitol	442	821	2,436	11,056
Zone G: Hudson Valley	372	690	2,046	9,289
Zone J: NYC	1,864	3,460	10,265	46,593
Zone K: Long Island	634	1,177	3,493	15,857
200-250 kW SOFC	0	1,464	8,620	39,126
Zone A: West	-	170	1,002	4,549
Zone F: Capitol	-	116	681	3,090
Zone G: Hudson Valley	-	97	572	2,596
Zone J: NYC	-	487	2,869	13,022
Zone K: Long Island	-	166	976	4,432
250 - 2000 kW MCFC	0	2,928	17,240	78,251
Zone A: West	-	603	3,552	16,122
Zone F: Capitol	-	410	2,413	10,951
Zone G: Hudson Valley	-	282	1,660	7,534
Zone J: NYC	-	116	682	3,098
Zone K: Long Island	-	211	1,243	5,644

STRATEGIES FOR ACCELERATING MARKET DEVELOPMENT

Several actions can be taken to accelerate the development of fuel cell markets. Many strategies that would benefit fuel cells are not unique to this market. For example, fair utility interconnection practices would benefit all distributed-generation technologies, not just fuel cells. There are, however, a few strategies that could benefit fuel cells more than other renewable energy technologies.

Output–Based Regulations

Current air regulations do not take into account the increased efficiency benefits that occur when heat is recovered in a generation system. Creating output-based standards for pollutants (in pounds per megawatt-hour [lbs/MWh] output or equivalent unit) for emissions would allow fuel cell CHP to take credit for this increased fuel utilization. The creation of output-based standards is absolutely key in encouraging the adoption of the cleanest and most efficient electricity-generation technologies. Several states have prepared rules for the adoption of output-based standards. For example, the Massachusetts restructuring legislation directs its Department of Environmental Protection (DEP) to develop an output-based standard for any pollutant determined to be of concern to public health and also to have implemented at least one standard by May 2003 (Massachusetts Department of Environmental Protection, 1999). In a related effort, the Northeast States for Coordinated Air Use Management (NESCAUM) has devised a model Emission Performance Standard rule, on an output basis, for its member states (Northeast States for Coordinated Air Use Management, 1999).

When devising output-based standards, it is important to understand the importance and value of thermal energy. There have been many debates over the value of recovered heat in a fuel cell CHP system. It is difficult to consider that process-steam or heated-water output has the same value as electricity. However, one must consider how process heat is obtained in a separate heat and power arrangement. In typical industrial settings, boilers fueled by natural gas, fuel oil, or coal are required to provide steam and hot-water needs. The combustion of a fuel to produce this heat has its own set of thermal losses and emissions. These losses are in addition to the losses and emissions inherent in grid-supplied electricity that must be purchased from the local utility. The value of heat must be considered in comparison to how it is obtained in a standard situation.

While many regulators and energy experts consider fuel cell CHP to be primarily an electricity-generating technology, it is important to understand that industrial and commercial operators frequently think of CHP as a heat-generating technology with the added benefit of on-site power production. Therefore, while thermal energy may be considered lower quality (based on its difficulty in being converted to other forms of energy) than electricity, it is nonetheless highly valued in both industrial and commercial settings. In fuel cell systems, the increased fuel utilization is of even higher importance than most CHP technologies. Fuel utilization helps to lower the overall costs of the fuel cell system.

Federal Initiatives That May Increase Fuel Cell Markets and Strategies for Market Development

The U.S. government has played a major role in the development of viable commercial fuel cells. The NASA space program was the initial commercial use of fuel cells. A number of other federal agencies have funded initiatives consistent with their mission, including the U.S. departments of Defense (DOD), Transportation, Commerce, and Energy, and the Environmental Protection Agency. DOD has been the single largest purchaser of fuel cell cogeneration units and has supported private purchases most years since 1994. The tax code includes incentives for the purchase of fuel cell vehicles and infrastructure, and significant new tax incentives are pending in Congress (Path Forward 2002).

In September 2002, a coalition of fuel cell and fuel cell-infrastructure developers created a proposal for federal government intervention to broaden fuel cell markets (Path Forward 2002). The proposal called for comprehensive assistance to remove technical, regulatory, and market barriers, recommending government intervention in the following six areas: research and development, demonstrations and pilots, government purchasing, financial and non-financial market incentives, fair interconnection and siting standards and requirements, and education and outreach.

Section 4:
HYDROPOWER

SUMMARY RESULTS

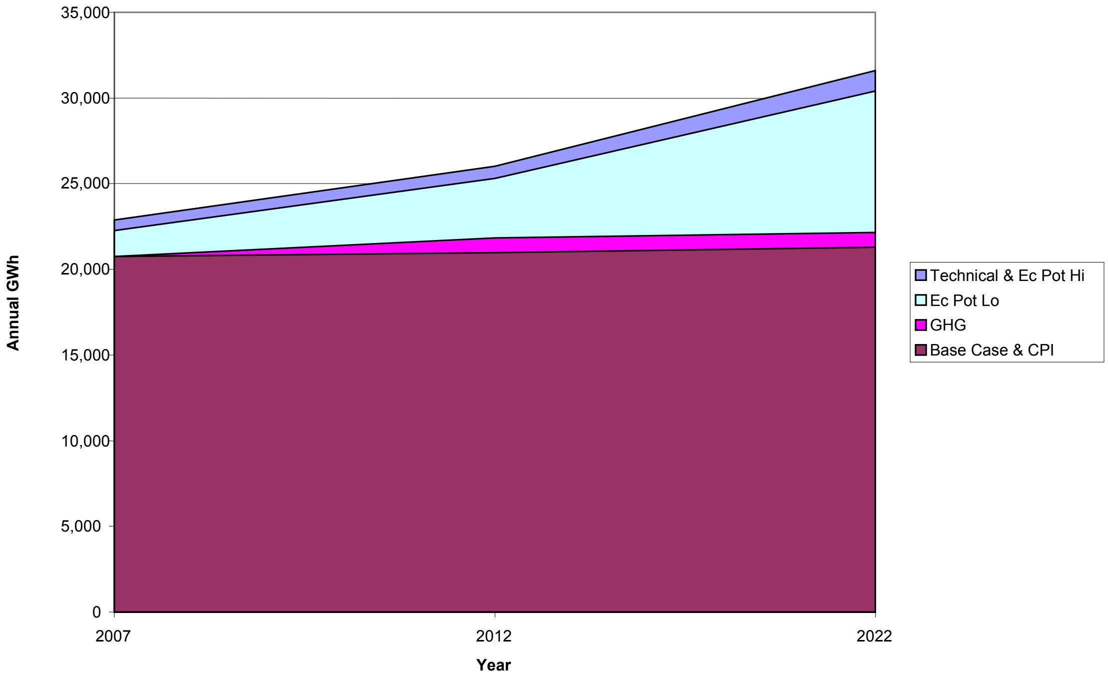
Hydropower is a technically mature and well-developed renewable resource both nationally and in New York State. Hydropower has provided a significant share of New York State's electric power requirements for more than a century and will continue to be a major source of renewable energy in the future.

This study analyzed new hydropower capacity and generation available throughout New York State during the next 20 years. Included in the analysis are approximately 3,800 MW of conventional hydropower scheduled for federal relicensing during the study time horizon. Also included are repowering and modernization, expanded capacity at existing dams, new capacity at existing dams (with no current hydropower production), and development of new dam sites. Existing capacity not scheduled for relicensing (approximately 783 MW) and pumped storage facilities that provide additional hydropower generation are not reflected in results.

New hydroelectric capacity and generation are estimated through 2022 under six cases: technical potential, economic potential (assuming high statewide avoided cost), economic potential (assuming low statewide avoided costs), currently planned initiatives (CPI), greenhouse gas (GHG) reduction targets, and the base case. Technical potential is defined as the upper limit for hydroelectric capacity and generation theoretically possible in New York State without regard to cost, market barriers, or market acceptability. Economic potential is the subset of technical potential that is cost-effective from a societal perspective compared to the cost of electricity hydro would replace. Economic potential is assessed separately for both high and low statewide avoided costs (provided by NYSERDA). The CPI case is defined as future impacts expected from currently planned initiatives included in the 2002 New York State Energy Plan. The GHG-reduction targets case identifies hydroelectric potential under an expanded set of policy and program supports above and beyond those analyzed in the CPI case. The policy and program supports are intended to assist in achieving GHG-reduction targets established by the State using a least-cost portfolio of efficiency and renewable energy options. The base case is defined as electric capacity and generation already on-line, already permitted, or well along in planning as of late 2002.

The projected potential for electric generation from hydropower under the study scenarios ranges between 21,000 and 31,000 GWh per year (Figure 4.4.1).

Figure 4.4.1 New York State Hydropower Potential Summary



The majority of this potential is forecast to be deployed in both the base case and CPI scenarios. Annual generation in both of these scenarios grows slightly (from 20,700 to 21,300 GWh/year) during the 2007 to 2022 time horizon. This growth is the net result of a slight loss of generating capacity through the relicensing process, which is offset by increased generation from repowering and modernization that is already planned or under way. Under the integrated (least-cost efficiency and renewable resources) GHG scenario, it was assumed there is no loss of capacity due to attrition through the relicensing process, resulting in additional generation of approximately 860 GWh per year.

Aside from planned repowering and modernization upgrades, the scenarios discussed above do not project the development of new hydropower resources in New York State. In contrast, the technical and economic potential analyses indicate that by 2022 further development of existing and new dam sites could result in 10,300 GWh of additional annual generation. All of this additional potential passes societal economic screening in comparison to the high statewide avoided costs, and approximately 90% passes economic screening using low statewide avoided costs.

The study suggests that hydropower will continue to be a dominant source of renewable energy in New York State over the next two decades. While there is technical and economic potential to expand the hydropower resource by a factor of approximately 50%, a combination of environmental, siting, financial and regulatory barriers suggest relatively little new development (beyond relicensing and

repowering/modernization) of the resource will occur. As other renewable resources (such as wind and biopower) are expected to expand at a faster rate, hydropower will remain a significant renewable resource asset for the State, but overtime it will contribute a smaller share of overall renewable generation.

TECHNOLOGY DESCRIPTION

Hydropower is created by the natural fall of water from higher to lower elevations. As such it is part of the natural solar-based cycle of renewable energy. Through the use of water wheels, the conversion of the kinetic energy of falling water into rotary motion and mechanical power began over 2,000 years ago, primarily for purposes of grinding wheat into flour. At the end of the 19th century, technology for the conversion of mechanical to electrical power became available. During the 20th century, technology for the transmission of electricity so improved that it became possible to develop remote hydroelectric stations and transport electricity some distances to electrical load centers. As a consequence, it was no longer necessary to distribute hydropower in the form of mill privileges, liberating the technology from costly canal systems like those that powered the early industrial revolution. This permitted extensive development of the resource in the first half of the 20th century.

The potential energy of water impounded behind a dam becomes kinetic energy when released from the dam. This kinetic energy is then turned into mechanical energy by the rotary motion of a hydropower turbine or water wheel. By connecting the turbine to a generator, this mechanical energy is converted to electrical energy. Thus a typical hydroelectric plant consists of a dam (to create elevation and store water), turbine(s) to create mechanical energy, generator(s) to convert mechanical to electrical energy, and facilities for transmitting or distributing electricity to end users. Other ancillary features include water passages (water intake structures, gates and valves, pipes, and penstocks or canals), a powerhouse (which typically houses the turbine, generator, switchgear, and controls), an electrical substation, and transmission or distribution lines.

Conventional hydropower is provided in one of two variants:

- Run-of-river hydropower is electricity generated at dams where the amount of water discharged from the station is equal to inflow. At such stations, the amount of electricity able to be produced at any one time is primarily determined by the amount of water naturally available. As such, output from these stations cannot be predicted with precision, though predictability can be increased on rivers that are subject to control by headwater reservoirs.
- Store-and-release hydropower plants are able to generate electricity, within seasonal limits of precipitation, largely on demand. As such, output from these stations can be predicted with greater precision. They also have the advantage of being able to be brought into service very quickly and are typically used to serve peak demand.

A third type of hydropower is represented by pumped-storage hydroelectric plants, which are used primarily to store electricity and to shape system-wide electrical load. At a pumped-storage plant, water is pumped up to an upper reservoir during times of baseload demand and released through the turbines

(reverse pumps) during times of peak demand. By keeping demand high during base-load periods, pumped storage plants help to avoid the high cost of backing down large base-load plants. In addition, because they are available on demand during peak hours, they offer considerable value as reserve capacity. Notwithstanding these important system-wide benefits, pumped storage plants are net users of electricity.

The hydropower potential of any particular site is a function of the volume of water flow and the distance the water falls. This is reflected in the standard formula:

$$KW = Q*H*e/11.8$$

Where Q = volume of flow

H = head (difference in elevation between headwaters and tailwaters)

e = efficiency of the turbine-generator

It should be noted that the kW output at any site is a dynamic condition, varying with changes in flow and head over time. If water flow is insufficient, the plant may not be able to operate (during drought conditions, for example). With more water flow, the plant may be able to operate, though only at a fraction of its capacity. If water flow is very high, the plant may operate at full capacity for a sustained period of time (e.g., during spring runoffs), but lower its output as inflows again fall off. Given this variability, the plant factor[10] at a typical run-of-river hydroelectric station during a typical year may be expected to be in the 40% to 50% range.

Hydroelectric power has the advantage that, once constructed, station operations are not burdened by the cost of fuel. Thus, the operating costs of hydro are among the lowest of all electrical generating resources. For this reason, it is not unusual to find hydroelectric stations serving a significant portion of the on-site electrical load at energy-intensive industrial locations such as paper mills.

Stations with large storage reservoirs also have the advantage of being started easily and quickly. As such, they facilitate integrated electric-system management and are able to offer considerable value as backup capacity. On the other hand, hydroelectric power (especially at run-of-the-river stations without any storage capability) has the disadvantage that it is highly weather dependent. Seasonal changes in precipitation patterns can cause hydropower to be least available when the demand for capacity is highest, especially in a summer peaking system.

10 Plant factor is defined as the percent of the full capability of a plant that is achieved over a period of time, typically a year.

Commercialization Status

Hydroelectricity is a mature and fully commercialized technology, constituting approximately 10% of total U.S. electrical supply and 81% of the U.S. supply of renewable electrical energy[11]. In New York State, hydroelectric power contributed 16.2% to total statewide electrical generating capability in 1999[12]. Used for centuries throughout the world for mechanical power, conversion of waterpower to electricity began in the U.S. in the 1890s. By 1940, approximately one-third of the America's electrical energy came from some 1,500 hydroelectric facilities.[13] Some of the early history of hydroelectricity was made in New York State. The first large-scale hydroelectric operation occurred at Niagara Falls in 1895 with the installation of 5,000-horsepower, 3-phase, 60-cycle generators, and the first high-head (approximately 250') reaction turbine was installed at Trenton Falls in 1901. Both plants, though expanded since their original installation, continue to operate today. Total licensed hydroelectric capacity (conventional and pumped storage[14]) existing in New York State today is approximately 5,900 MW, based on nameplate data recorded Federal Energy Regulatory Commission (FERC). Of this, total conventional hydroelectric capacity represents approximately 4,660 MW. For the period 1986 to 2000, conventional hydroelectric energy production averaged 26,683 GWh, varying depending largely upon weather conditions, from a low of 23,643 GWh in 1999 to a high of 29,767 GWh in 1997.

Technology Scale

Conventional hydroelectric plants in the U.S. range in size from micro hydro stations less than 10 kW in size to very large plants such as the Glen Canyon Dam (1,042 MW), Hoover Dam (2,074 MW), and Grand Coulee Dam (6,480 MW). In New York State, the two largest hydroelectric stations are the Robert Moses station at Niagara Falls (2,160 MW) and the Blenheim-Gilboa pumped-storage facility (1,040 MW).

Given their system-wide benefits, most pumped-storage plants tend to be quite large, on the order of 600 to 1,000 MW. The Blenheim-Gilboa plant, owned by the New York Power Authority, with an installed capacity of 1,040 MW, is at the upper end of this range.

---

11 National Hydropower Association, "Hydro Facts," http://www.hydro.org/facts.htm (2000).

12 U.S. Department of Energy, Energy Information Administration, "State Electricity Profiles — New York" (November 28, 2001)

13 U. S. Department of the Interior, Bureau of Reclamation, "History of Hydropower Development in the United States," http://www.usbr.gov/power/edu/histroy.htm (August 16, 2001)

14 Pumped-storage capacity is at two projects: Blenheim-Gilboa @ 1,040 MW and Lewiston Pump Generating Facility (Niagara) at 240 MW.

Irrespective of scale, all conventional hydropower is essentially the same. There are no qualitative technological differences in scale that indicate the proper threshold to distinguish among different scales of conventional hydro. While it is true that the environmental and social impact of large dams is thought to be qualitatively more severe than that of smaller dams,[15] the distinction is not applicable in New York State, where the vast majority of existing dams do not qualify as large.

The U.S. Department of Energy defines large hydropower as facilities having capacity greater than 30 MW, with micro hydro plants being smaller than 100 kW. In fact, various definitions of micro, mini, and small hydropower can be found in the literature. For purpose of this study, based in part on the availability of data, the study distinguishes among five different scales of conventional hydropower:

- *Micro hydro:* stations less than 10 kW in capacity. These typically will be used as independent stand-alone operations, for residential purposes, and involve very minor civil works.
- *Mini hydro:* stations ranging in size from 10 kW to 100 kW in capacity. These may or may not be stand-alone operations but approach the maximum size for reliable stand-alone operations.
- *Small Hydro:* stations ranging in size from 100 kW to 5 MW in capacity. These typically will not be stand-alone operations. At industrial sites, the electricity generated may be used on site, but all of it is suitable for distribution in the wholesale electricity market.
- *Medium Hydro:* stations ranging in size from 5 MW to 50 MW. These constitute the bulk of the hydroelectric resources in New York State and are used almost exclusively for sale of power into the wholesale market.
- *Large hydro:* stations greater than 50 MW in capacity. The numbers of these are small due to the limited number of sites with the required natural characteristics.

Of the five different conventional hydro scales listed, the study has chosen not to explore in detail the possibilities for micro-hydro applications. A database of information about viable, potential micro-hydro sites in New York State does not appear to exist. In addition, because there are economies of scale that are available for larger stations and not available for micro hydro, the study believes that the number of viable micro-hydro sites is limited. Perhaps most important, at less than 10 kW, micro-hydro stations are so small that their potential contribution to overall New York State energy supply is negligible. In addition, because pumped-storage hydro is a net user of electricity, the study has chosen to exclude pumped-storage hydro from this report on renewable resource technologies.[16]

---

15 See World Commission on Dams, *Dams and Development: A New Framework for Decision Making* (Earthscan Publications, 2000).

16 There are only two pumped-storage plants in New York State (Blenheim-Gilboa and the Lewiston Pumped Generating Station at Niagara). A proposed new pumped-storage facility on the Schoharie Reservoir (Plattsville), was rejected by NYPA, and no new pumped-storage hydro stations are under active consideration in New York State. NYPA will also investigate the feasibility of modernization and upgrade (repowering) at its two pumped-storage plants. This is noteworthy, as some have predicted possible upgrade potential on the order of more than 230 MW.

This study will consider these scales in the context of four different hydroelectric technology types. In part based on the availability of information, the choice of these four technology types is primarily motivated by the qualitative differences in environmental impact represented by each. In increasing order of environmental impact, the four types are:

- *Repowering at existing hydroelectric site:* In general, this technology type would be expected to have the least environmental impact, since all that is involved is upgrading existing equipment already installed and operating. The U.S. Bureau of Reclamation has undertaken a program of modernization and upgrading that is expected to improve individual site performance by as much as 20%. Likewise, prior to selling its hydroelectric stations to Orion Power New York, Niagara Mohawk undertook an extensive upgrade program at several of its sites, with similar results.
- *Installation of additional capacity at existing hydropower stations:* Many hydroelectric stations may have been built to serve particular loads and were thus not built to maximize potential output. In an integrated electric system with less limited markets, there is incentive to supplement existing capacity with additional machinery.
- *Installation of hydroelectric capacity at existing dams used for other purposes:* There are far more dams in the U.S. and in New York State than there are hydroelectric stations. Many dams may previously have been used for power were retired for that purpose. In addition, many dams exist for other purposes, including flood control, water supply, recreation, and irrigation. Adding hydroelectric capacity to existing dams obviously saves the expense of dam construction and avoids the substantial environmental and social impact that may result from new dam construction and impoundments.
- *Construction of new dams for hydroelectric purposes:* This is self-explanatory and obviously represents the type of hydroelectric project with the largest potential environmental impact. While the electricity benefits of these projects may be substantial, the likelihood of their being permitted is very small.

Regardless of the high level of technological maturity enjoyed by hydropower, the possibility for expansion in hydropower capacity is significant. The National Hydropower Association reports that hydropower is installed at fewer than 3% of the 75,187 existing dams in the United States and, taking into consideration sites where dams have never been constructed, it would be possible to install an additional 70,000 MW of hydropower in the U.S. Yet, in the past decade, there has been essentially no growth in the hydroelectric industry, and hydroelectric capacity has been essentially stagnant. As will be discussed in greater detail elsewhere, this is largely attributable to the extensive legal and regulatory obstacles that characterize the hydroelectric industry. The potential for future growth in the industry depends largely on the ability to implement public policies that eliminate or overcome these institutional obstacles.

Manufacturing and Service Infrastructure

The combined impact of economic globalization and stagnation of hydroelectric development in the U.S. has caused the bulk of hydroelectric turbine manufacturing to move off shore. Germany-based Voith Hydro GmbH & Co., Austria-based Voest-Alpine MCE GmbH, France-based Alstom Power, and Norway-based Kvaerner Inc. represent four of the largest consolidated manufacturers of hydroelectric machinery and equipment, including turbines, gates, pipes, and valves. Voith Hydro GmbH has nine subsidiaries with

manufacturing facilities in eight countries, including the U.S. The U.S. subsidiary, Voith Hydro Inc., was acquired from Allis-Chalmers Inc., with manufacturing facilities in York, PA.

With Voith's takeover of Allis Chalmers, the only remaining, U.S.-based large turbine manufacturer is American Hydropower Corporation (AH), also with manufacturing facilities in York, PA. As an offshoot from the Allis-Chalmers/Voith transaction, AH was founded in the 1980s to manufacture large turbine runners primarily to serve the market for repowering and upgrading existing hydroelectric sites with improved efficiency runners. In addition, remaining U.S. companies that manufacture turbines (primarily in the small-hydro range) include the James Leffel Company (Ohio) and Hydro West Group (Oregon). Not far from New York state, there is Canadian Hydro Components Ltd. in Almonte, Ontario. Canadian Hydro manufactures new turbines and upgraded replacement runners in the mini- to small-hydropower range.

In summary, while New York State does not itself host manufacturers that specialize in the construction of hydroelectric machinery and equipment, such a manufacturing infrastructure does exist in reasonable proximity to the State. Moreover, for larger equipment, the global market for hydroelectric components offers an abundant supply of alternatives, and many of these corporations have sales representatives in the Northeast — and in New York State in particular.

Also of some note, the growth of the electric-utility industry in New York State was in large part based on the early development of hydroelectric power. In addition to the obvious importance of Niagara Falls as a hydroelectric resource, Niagara Mohawk Power Corporation in particular controlled some 68 hydroelectric stations in the small-hydro range. Likewise, Central Hudson Gas and Electric, Orange and Rockland Utilities, and New York State Electric and Gas all had some hydropower in their portfolios. With deregulation and restructuring of the electric utility industry, the operational personnel of these companies are available for outsourcing. In particular, Orion Power New York, which now owns all of the former Niagara Mohawk hydroelectric assets, and CH Resources both offer operational services based on many years of hydroelectric-operations experience.

It does not appear that the absence of infrastructure will be a significant obstacle to increasing hydroelectric capacity in New York State. However, one potential obstacle is worthy of note. In the deregulated-electricity market, energy and capacity will be sold at market clearing prices administered through the New York Independent System Operator (NYISO). Transactional costs associated with marketing through NYISO can be significant and very likely can have a negative effect on small, single hydroelectric stations. For large portfolios of plants, these transactional costs can be spread over large numbers of stations and thus minimized as a per kWh expense. For single plants or small portfolios, however, this is not the case. To the extent that small, independent power producers can contribute to the electrical-generating capacity

in New York State, minimization of these transactional costs and removal of barriers to access by small plants should be encouraged by public policy.

Additional market obstacles may be found in the public policy tendency to distinguish hydroelectric power from other renewable energy resources. While the average “man on the street” does not appear to make this distinction, resource-protection advocates commonly distinguish between “good hydropower” and “bad hydropower,” the latter being understood as hydropower that fails to meet a minimum threshold of environmental compatibility. Thus, the Low Impact Hydropower Institute (LIHI), an organization based in Portland, OR, that was founded by the river-protection group American Rivers, is having some success in persuading green-power labeling organizations to adopt LIHI certification criteria as a prerequisite to qualifying for price premiums that may be available for green-power sales. Because the line between “good” and “bad” hydropower is not clear, all hydropower tends to be viewed with suspicion, and the burden of proof appears to lie with project proponents to assure that their hydroelectric proposals are not the “bad” variety.

Regrettably, discrimination between good and bad hydropower fails to acknowledge the one significant environmental benefit of all hydropower, which is its absence of impact on air quality. Unfortunately, the current system of cap and trade emissions allowances only adds to the potential cost of polluting thermal-generating sources, combustion turbines, and industrial boilers without rewarding existing hydropower for its continuation. Thus, there appears to be no existing policy mechanism to assure recognition of the positive air-quality benefits of all hydroelectric capacity.

Regulatory, Permitting and Siting Issues

The environmental impacts of hydroelectric power are not insignificant. These impacts may include:

- fish mortality, primarily associated with passage through a turbine
- obstacles to the passage of migratory fish, generally limited to sites located on rivers slated for restoration of anadromous or catadromous fish species
- reduced water quality, typically associated with reduced dissolved-oxygen concentrations
- riparian habitat impacts, primarily resulting from fluctuations in water levels upstream of storage sites and variable rates of discharge downstream of such sites
- aquatic habitat impacts, related both to fluctuating river flows and to the creation of bypassed river reaches
- possible impacts on specific rare or endangered plant and/or animal species
- visual and scenic impacts, especially on designated wild and scenic or otherwise protected rivers
- recreational impacts, both positive and negative, particularly for white-water boaters
- historical/archaeological impacts, typically associated with heavy excavation
- geologic impact, typically associated with submergence of unique rock formations.

If a proposed hydroelectric development involves construction of a new dam, these impacts would not only be more severe but would include the additional impacts — environmental, social, and economic — of a sizeable water reservoir where free-flowing waters previously existed. However, the vast majority of proposed hydroelectric projects and a significant portion of the potential hydroelectric capacity increases, both in New York and nationwide, involve installation of new hydroelectric capacity at existing dams. Of the approximately 70,000 MW of theoretically possible undeveloped hydroelectric capacity identified by the FERC in 1990, approximately 54% of this capacity is located at 2,916 sites where dams already exist. Studies completed by the U.S. Department of Energy in 1998 pared this number down by screening for environmental factors and indicated that, nationwide, some 30,000 MW of undeveloped hydropower capacity is developable. Approximately 72% of this (over 21,000 MW) is found at existing dams, many of which already have some hydroelectric capacity in place.[17] In these instances, the environmental impacts are largely limited to the impact of subsequent station operations on instream flows.

By far the most significant obstacle to the future expansion of hydroelectric capacity is the extensive regulatory process developed to address these many environmental concerns. Because most rivers and hydroelectric projects can be seen as involving interstate commerce, the primary regulatory process is at the federal level. Specifically, the Federal Energy Regulatory Commission (FERC) is responsible for granting waterpower licenses to virtually all hydroelectric projects in the United States, and in so doing FERC is specifically charged with the duty of "balancing" power and non-power interests. Specific statutory provisions can require the involvement of a variety of federal agencies, including the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, the Army Corps of Engineers, and the Environmental Protection Agency. Virtually all potentially interested parties are invited to participate in the licensing process, including other federal agencies, state resourced agencies, and non-governmental organizations. In addition, FERC is charged with the requirement of considering any comprehensive plans that may exist for rivers or river corridors, which in turn requires the participation of river-planning agencies and watershed associations.

Because many state resource-protection programs are undertaken in cooperation with the federal government, most of the listed federal agencies have counterparts at the state level. These agencies, too, have an interest in proposed hydroelectric projects and the opportunity to comment on them. In New York State, the comments of these many agencies are coordinated through the New York State Department of Environmental Conservation, Division of Environmental Permits, which is an effort to simplify the process at the state level with something akin to a one-stop permitting process. Nevertheless, the National Hydropower Association estimates that, nationwide, the average time required to obtain a new license is eight to 10 years. In general, the process for siting and permitting new hydroelectric capacity is

---

17 Alison M. Conner, James E. Francfort, Ben N. Rinehart, *U.S. Hydropower Resource Assessment Final Report*, DOE/ID-10430.2, December 1998.

complicated, time consuming, filled with uncertainty, and potentially costly.[18] As a consequence, investors are less willing to accept the financial risk of hydroelectric development, particularly given its very high upfront costs.

Federal waterpower licenses have limited terms of 30 to 40 years. Therefore, many existing hydroelectric projects, previously licensed in a different regulatory environment, are coming up or have recently come up for relicensing. Over the next 15 years, some 240 projects, totaling approximately 29,000 MW of power located in 38 states, will go through the federal license process. In anticipation of this a number of non-governmental organizations (NGOs) have organized themselves to participate extensively in the relicensing process, including the Appalachian Mountain Club, the Conservation Law Foundation, and American Rivers.

Given the changed environment for hydroelectric relicensing, it is likely that, instead of expanding, hydroelectric capacity in the U.S. will actually decline going forward. The National Hydropower Association reports that from 1986 to 2001, some 246 projects were relicensed, resulting in an average annual energy-production loss of 4.23%. As can be seen in Table 4.4.1, the challenge of relicensing will be felt in New York State as well, as 83% of the State's hydroelectric capacity (based on FERC-recorded nameplate data) will begin relicensing within the next 18 years. In addition to those listed, three sites entered relicensing in 2000 and 2001, and 10 sites, which began relicensing in 1993, remain unsettled.

---

[18] See: Richard T. Hunt, P.E., "The High Cost of Hydro Licensing," *Independent Energy* (October 1990). Depending on project size, hydroelectric licensing costs were reported then to range from $35/kW (for very large hydro) to $120/kW for small developments (1 MW). The average 10 MW project reported licensing costs of $100/kw. Costs are higher still today.

Table 4.4.1 Hydroelectric Relicensing Schedule in New York State

Lic. Exp. Date	Project Name	Owner	County	River	KW
1/31/02	Raquette	Orion	St. Lawrence	Raquette	101,250
10/31/02	Fowler #7	HDG	St. Lawrence	Oswegatchie	900
12/31/02	Hailesboro #4	HDG	St. Lawrence	Oswegatchie	1,490
11/1/02	Rainbow Falls	NYSEG	Clinton	Ausable	2,640
2/28/03	Keuka	NYSEG	Steuben	Mud Creek	2,000
10/31/03	St Lawrence-FDR	PASNY	St. Lawrence	St. Lawrence	912,000
1/31/04	Newton Falls	Newton Falls Inc.	St. Lawrence	Oswegatchie	2,220
8/31/05	Stuyvesant Falls	Orion	Columbia	Kinderhook	2,800
10/31/05	Piercefield	Orion	St. Lawrence	Raquette	2,700
4/12/06	Saranac	NYSEG	Clinton	Saranac	38,950
11/30/06	North Fork	Orion	Franklin	Salmon	1,000
8/31/07	Robert Moses	PASNY	Niagara	Niagara Rvr	2,755,000
3/2/11	Green Hydro	Orion	Albany	Hudson	6,000
3/31/12	Natural Dam	Fonda Group	St. Lawrence	Oswegatchie	1,020
5/31/12	Emeryville	Hampshire Paper	St. Lawrence	Oswegatchie	3,540
12/31/12	Oswegatchie	Orion	St. Lawrence	Oswegatchie	28,471
6/30/15	Chasm	Orion	Franklin	Salmon	3,350
2/28/19	Colliersville	HDG	Otsego	N. Br. Susquehanna	1,450
4/30/19	Blenheim Gilboa	PASNY	Schoharie	Schoharie Cr	1,000,000
9/30/19	Lower Beaver Falls	Beaver Falls Assoc	Lewis	Beaver River	1,000
3/31/20	Granby	Orion	Oswego	Oswego Rvr	10,000
				TOTAL:	4,877,781

N.B. The Blenheim-Gilboa project and 240 MW of the Robert Moses project (Lewiston) are pumped storage projects.

Cost and Related Information

As noted, hydroelectric generation offers one of the lowest operating costs in the electric-power industry. Operating expenses are kept down by a combination of factors, including the absence of fuel costs and long service lives (and hence lower real depreciation), and improvements in site automation, which have reduced labor costs significantly in recent years. Industry-wide, utility-owned hydroelectric stations reported average operations and maintenance expenses totaling less than $0.01/kWh in 1994. More recently, financial information reported for Niagara Mohawk's hydroelectric portfolio in 1997[19] indicate a range of operating costs from a low of 0.00102/kWh to a high of 0.0399/kWh, with average operating costs of $0.004/kWh. Nationwide, RDI estimated average total production costs for hydro ranging from

[19] See FERC Form 1 for 1997, the last year for which NMPC was required to file this information. Transfer of NMPC's hydroelectric portfolio to Orion Power in December 1998 removed these facilities from cost of service regulation.

$0.00668/kWh in 1996 and $0.00951 in 2000. Average total hydroelectric production cost over the six-year period from 1995 to 2000 was $0.00767/kWh.

On the other hand, hydroelectric capacity represents some of the most expensive construction in the electric-power industry. Initial land acquisition (and relatively large land requirements), extensive site work, the construction of dams and other civil works, and very high permitting costs all contribute to this phenomenon. While unit construction costs can be quite variable depending upon the size of the project (larger projects benefit from economies of scale), the head (higher head sites tend to be less costly because they require smaller machinery), and flow (high-flow sites involve large turbines and typically require a larger dam), the U. S. Department of Energy has estimated that the average cost of hydroelectric construction was $1,000/kW[20] during the years 1990 to 1994, which was limited primarily to new construction at existing dams. Trending these costs to 2003, the study estimates that the average hard cost of hydroelectric construction is approximately $1,300/kW.

Recognizing that both construction costs and operating costs are quite site-specific and thus quite variable, the study has adopted the costs indicated in Table 4.4.2 and Table 4.4.3 as reasonable estimates of costs associated with each of the relevant technology scales.

Table 4.4.2 Hydroelectric Costs with Pre-Existing Dam (2003 $)

Technology Scale	Capital Costs	Operation/Maintenance Costs
Mini (10 kW- 100 kW)	$2100/kW	$0.050/kwh
Small (100 kW – 5 MW)	$1800/kW	0.030/kwh
Medium (5 MW – 50 MW)	$1500/kW	0.010/kWh
Large (>50 MW)	$1150/kW	0.002/kWh
All Hydro Average	$1300/kW	$0.0077/kWh

In 1979, the U.S. Army Corps of Engineers[21] and subsequently the Electric Power Research Institute[22] both reported that civil components of hydroelectric projects constitute from 15% - 45% of total hydroelectric project costs. Assuming that civil components constitute 30% of total costs, Table 4.4.3 indicates capital and operating costs of hydroelectric production involving new dams.

---

20 This is also the number that we have selected to represent the cost of installing expanded capacity at existing hydro stations.

21 Source:U.S. Army Corps of Engineers, Hydrologic Engineering Center and Institute for Water Rsources, *Feasibility Studies for SmallScale Hydropower Additions: A Guide Manual,* July 1979.

22 Electric Power Research Institute, Simplified Methodlogy for Economic Screening of Potential Low-Head Small-Capacity Hydroelectric Sites, EPRI EM-1679, Project 1199-5m January 1981

Table 4.4.3 Hydroelectric Costs with New Dam (2003 $)

Technology Scale	Capital Costs	Operation/Maintenance Costs
Mini (10 kW- 100 kW)	$2900/kW	$0.050/kwh
Small (100 kW – 5 MW)	$2600/kW	0.030/kwh
Medium (5 MW – 50 MW)	$2150/kW	0.010/kWh
Large (>50 MW)	$1650/kW	0.002/kWh
All Hydro Average	$1900/kW	$0.0077/kWh

The repowering option, which is not included in Table 4.4.2 or Table 4.4.3, is by far the least costly hydroelectric option, since it involves making use of pre-existing sites and pre-existing machinery and equipment. From 1978 to 1995, the U.S. Bureau of Reclamation (BUREC) completed 58 generator unit upratings at an average cost of $69/kW. Trending this cost to 2003, the study estimates that the average base cost of repowering is $100/kW. The study notes, however, that there are different levels of repowering that can be implemented. While the BUREC focused its repowering program on generator upgrades or runner upgrades alone, more significant turbine improvements would be more costly. Turbine work can run the gamut from simple runner replacement to removal and replacement of all embedded parts; moreover, these actions can be supplemented with generator upgrade. Obviously, the cost of the last option can be quite significant. Thus, the ongoing modernization program at Niagara Falls is expected to cost $500 million and produce 300 MW of additional capacity, indicating a cost of $1,667/kW. An additional $254 million has been earmarked for the modernization program at the St. Lawrence-FDR project over a 15-year period extending from 1998 to 2013. While this project is not expected to result in any material increase in capacity, an overall 2% improvement in efficiency is expected to produce additional energy on the order of 140 to 210 GWh/year.

For purposes of estimating associated capital and operating costs, the study uses $1,600/kW for repowering in Zone A – West and $1,000/kW for Statewide. These numbers reflect the strong influence of the Niagara and St. Lawrence projects respectively. In Zones F and G (Capitol and Lower Hudson Valley), the study uses $100/kW. At $0.0077/kWh, associated operating costs are the average total industry-wide operating costs of hydroelectric power for the 1995 to 2000 period.

Table 4.4.5 indicates the relative contribution of each technology scale and technology type. Based on these relative contributions, Table 4.4.5 also indicates the weighted average capital cost and operating cost of each technology type and scale.

TECHNICAL POTENTIAL

As noted, currently installed conventional hydroelectric power totals approximately 4,660 MW. Of this, less than 1% is mini hydro (approximately 400 kW), 4.2% is small hydro (approximately 195 MW at 110 sites), 17.3% is medium hydro (approximately 805 MW at 45 sites), and 78.5% is large hydro (in five

different projects,[23] mostly at St. Lawrence and Niagara Falls). Estimated distribution of this capacity throughout the State is shown in Table 4.4.4.

Table 4.4.4 Existing Hydroelectric Capacity in New York State (2002 MW)

Scale	Statewide	Zone A – West	Zone F – Capitol	Zone G – Lower HV	Zone J – New York City	Zone K – Long Island
Mini	0.4	0	.08	.15	0	0
Small	195.1	4.3	49.2	16.6	0	0
Medium	804.6	51.4	208.04	29.2	0	0
Large	3659.8	2515.5	131.1	0	0	0
Total:	4659.9	2571.2	388.4	46	0	0

It is worth noting that this base existing capacity is not static and is likely to suffer some decay going forward as the stations listed in Table 4.4.1 complete the relicensing process.

[23] St. Lawrence is estimated at 912 MW and Robert Moses at 2515 MW conventional capacity, with the remainder at Raquette (101.2 MW), Hudson (72.8 MW), and Palmer Falls (58.3 MW).

Table 4.4.5 Hydroelectric Costs by Technology Type and Scale (2003 $)

Technology Type and Scale	Relative Contribution	Capacity Cost $/kW	Operating Cost $/kWh
Repowering & Modernization			
Statewide	Mostly St. Lawrence	$1000	$0.0077
Zone A — West	100% Niagara	$1600	$0.0077
Zone F & G	100% Small/Medium	$ 100	$0.0077
Expanded Capacity at Existing Dams		$1434	$0.01392
Mini	<1%		
Small	13.5%		
Medium	55.9%		
Large	30.6%		
New Capacity at Existing Dams		$1526	$0.01532
Mini	<1%		
Small	23.8%		
Medium	62.4%		
Large	13.5%		
New Capacity at New Dams		$1975	$0.0061
Mini	<1%		
Small	9.7%		
Medium	46.5%		
Large	43.7%		

Currently, approximately 78,200 MWs of potential increased conventional hydroelectric capacity have been identified at some 2,337 sites in the U.S. Studies of nationwide undeveloped hydroelectric capacity suggest widely varied conclusions. The U.S. Army Corps of Engineers has offered a theoretical estimate of 580,000 MW, which assumes the construction of many large new dams. A more realistic upper limit is offered by the FERC,[24] which estimates there are approximately 70,000 MW of undeveloped conventional hydroelectric capacity available in the U.S. Of this total, approximately 2,119 MW is located in New York State. To this the study adds approximately 400 MW in potential increased output of existing plants through modernization, upgrades, and efficiency improvements, mostly at Niagara and St. Lawrence. This total potential of 2,529 MW of increased hydroelectric capacity in New York State marks an increase of approximately 54.3% statewide. The study believes this accurately represents the plausible upper limit of

[24] Hydroelectric Power Resources of the United States: Developed and Undeveloped, FERC, Washington, DC, January 1, 1990.

the theoretically possible hydroelectric resource base in New York State, without regard to cost, market barriers, or market acceptability.[25]

In order to estimate the possible schedule for development of this potential capacity, the study has considered two factors. First, if licensing and permitting work were to begin on these projects today, it would be a minimum of five years (2008) before significant construction work could begin[26]. Assuming one-year average construction time, this means that no new capacity would be seen until 2009. If properly planned, all new capacity could be phased in on a fairly equal annual basis thereafter. Second, capital markets and developer availability would be a significant constraint on overnight development of these stations. With over 350 sites involved and possible total costs in excess of $5 billion, it is obvious that these hydroelectric projects would have to be phased in over time. To account for this, the study assumes that new capacity would be constructed on a more or less equal annual basis starting in 2007, for 15 years until 2022.

In addition to capacity added by expansion at new or existing sites, there is also potential for increasing hydroelectric output by repowering and modernizing existing hydroelectric facilities. This takes the form of generator rewinding, turbine runner upgrades, and other modernization efforts aimed at increasing the efficiency of the machinery already installed at existing hydroelectric stations. As an example, the U.S. Bureau of Reclamation uprated 58 generators and replaced 18 runners at 15 different sites, for a total capacity increase of 1,782.8 MW, or 48.1%. Turbine-upgrade increases ranged from 24% to 41%, and generator-rewind increases ranged from 19% to 66.7%. Short of a site-by-site analysis of existing hydroelectric capacity in New York State, it is impossible to measure with precision how much additional hydropower can be achieved in New York State through this repowering option. Modernization and upgrade programs are already in place on the largest two conventional hydroelectric plants in the state — the FDR plant on the St. Lawrence River and the Robert Moses plant at Niagara.[27] Prior to selling its hydroelectric portfolio, Niagara Mohawk installed new runners at several of its plants. New runners

---

25 This estimate of the theoretically possible is in fact already limited by plausibility. That is, while it would be possible to dam every river in the state in order to capture every foot of changing river elevations, FERC's basic HPRA already excludes these. Therefore, in the words of the DOE study on which this is based: "The resource assessment is limited to sites with conventional undeveloped hydropower potential. In addition, while every reasonable effort was made to include all sites with undeveloped potential, the authors acknowledge that not every site in the United States with undeveloped hydropower potential was included. Only sites that have been either previously identified by third parties and included in the FERC HPRA database, or sites that local state agencies are aware of, are included in the database." See Conner, Francfort, Rinehart, *U.S. Hydropower Resource Assessment Final Report*, DOE/ID-10430.2, December 1998, page 1.

26 For mini hydro (10kW – 100 kW) we estimate a licensing time of three years. For projects involving new dam construction, we estimate a licensing time of eight years.

27 The FDR/St.Lawrence relicense application indicates that a 15-year construction program began in 1999. Each of the 16 units will be upgraded with a new turbine runner and other components to produce minimum efficiency increase of 2% per unit, or approximately 20 MW. Total annual energy output is expected to increase by as much as 210 GWh. In addition, units at the Robert Moses plant are being upgraded. Work on eight of 13 units has been completed, with full project completion scheduled for 2006.

installed at Schagticoke, School Street, Eagle, and Bennetts Bridge resulted in unit power increases ranging from 20% to 33%.[28]

It is obvious that upgrading offers the potential for substantial increases in hydropower capacity and energy. In an effort to measure the potential for future upgrades in New York State, the study adopts as a guideline the uprate criteria established for the Bureau of Reclamation's upgrade program: "For pre-1960 turbines, it is frequently possible to obtain output increases as high as 30% and efficiency increases of 1% by replacing existing runners with runners of improved design." Thus, for predictive purposes, the study estimates future power potential through repowering will be only half this, or 15% of the capacity of all pre-1960 turbines, not otherwise accounted for, in New York State.[29] When added to the scheduled improvements at St. Lawrence and Robert Moses, this amounts to total increased hydroelectric capacity of approximately 408 MW. Note that these totals consider the potential for upgrade only at existing conventional hydropower plants. Pumped storage, which could offer very substantial increases in uprated capacity, is not considered in this report for the reasons explained earlier.

Tables 4.4.6 to 4.4.9 identify future technical potential capacity, and Tables 4.4.10 to 4.4.13 identify the future technical potential annual energy output for each of the four technology types investigated. *Note that all of these figures are cumulative incremental additions to existing capacity and energy, assuming no degradation due to relicensing.*

Table 4.4.6 Hydroelectric Technical Potential — New Capacity from Repowering, Modernization, and Upgrading

	Technical Potential			
For Technology Type #1 Repowering	**Installed Capacity 2003 (kW)**	**Installed Capacity 2007 (kW)**	**Installed Capacity 2012 (kW)**	**Installed Capacity 2022 (kW)**
Statewide		300,000	310,835	408,353
Zone A: West		300,000	300,000	300,000
Zone F: Capitol			6,500	20,000
Zone G: Hudson Valley			3,500	10,000
Zone J: NYC				
Zone K: Long Island				

28 These increases are not reflected in the estimates of existing capacity in Table 4.4.4.

29 In the new restructured age of competition and market pricing, acquiring complete and accurate information on the amount of modernization that has already been completed is difficult, as companies are no longer required to provide such information, and they guard such information quite carefully. Based on independently collected information, we estimate that approximately 15% of existing pre-1960 hydroelectric capacity has already been modernized.

Table 4.4.7 Hydroelectric Technical Potential — Expanded Capacity at Existing Hydro Stations

	Technical Potential			
For Technology Type #2 **Expanded Capacity at Existing Hydro**	**Installed Capacity 2003 (kW)**	**Installed Capacity 2007 (kW)**	**Installed Capacity 2012 (kW)**	**Installed Capacity 2022 (kW)**
Statewide		19,063	114,376	285,939
Zone A: West		395	2,370	5,925
Zone F: Capitol		4,888	29,326	73,315
Zone G: Hudson Valley				
Zone J: NYC				
Zone K: Long Island				

Table 4.4.8 Hydroelectric Technical Potential — New Capacity at Existing Dam Sites

	Technical Potential			
For Technology Type #3 **New Capacity at Existing Dam Site**	**Installed Capacity 2003 (kW)**	**Installed Capacity 2007 (kW)**	**Installed Capacity 2012 (kW)**	**Installed Capacity 2022 (kW)**
Statewide		50,260	301,563	753,908
Zone A: West		83	83	83
Zone F: Capitol		13,356	80,138	200,346
Zone G: Hudson Valley		1,801	10,808	27,020
Zone J: NYC				
Zone K: Long Island				

Table 4.4.9 Hydroelectric Technical Potential — New Capacity at New Dam Sites

	Technical Potential			
For Technology Type #4 New Capacity at New Dam Sites	**Installed Capacity 2003** (kW)	**Installed Capacity 2007** (kW)	**Installed Capacity 2012** (kW)	**Installed Capacity 2022** (kW)
Statewide				1,078,970
Zone A: West				471,480
Zone F: Capitol				130,880
Zone G: Hudson Valley				96,715
Zone J: NYC				2,100
Zone K: Long Island				

Table 4.4.10 Hydroelectric Technical Potential — New Generation from Repowering, Modernization and Upgrades

	Technical Potential			
For Technology Type #1 Repowering	**Energy Generation 2003 (GWh)**	**Energy Generation 2007 (GWh)**	**Energy Generation 2012 (GWh)**	**Energy Generation 2022 (GWh)**
Statewide		202.1	359.5	537.8
Zone A: West		202.1	202.2	202.1
Zone F: Capitol			28.3	86.9
Zone G: Hudson Valley			15.3	43.8
Zone J: NYC				
Zone K: Long Island				

Table 4.4.11 Hydroelectric Technical Potential — Expanded Generation at Existing Hydro Stations

	Technical Potential			
For Technology Type #2 Expanded Capacity at Existing Hydro	**Energy Generation 2003 (GWh)**	**Energy Generation 2007 (GWh)**	**Energy Generation 2012 (GWh)**	**Energy Generation 2022 (GWh)**
Statewide		43.4	260.3	650.8
Zone A: West		.480	2.9	7.2
Zone F: Capitol		13.7	82.4	205.9
Zone G: Hudson Valley				
Zone J: NYC				
Zone K: Long Island				

Table 4.4.12 Hydroelectric Technical Potential - New Generation at Existing Dam Sites

	Technical Potential			
For Technology Type #3 New Capacity at Existing Dam Sites	**Energy Generation 2003 (GWh)**	**Energy Generation 2007 (GWh)**	**Energy Generation 2012 (GWh)**	**Energy Generation 2022 (GWh)**
Statewide		165.1	990.7	2,476.9
Zone A: West		.650	.650	.650
Zone F: Capitol		50.3	301.7	754.2
Zone G: Hudson Valley		5.9	35.4	88.4
Zone J: NYC				
Zone K: Long Island				

Table 4.4.13 Hydroelectric Technical Potential - New Generation at New Dam Sites

	Technical Potential			
For Technology Type #4 New Capacity at New Dam Sites	Energy Generation 2003 (GWh)	Energy Generation 2007 (GWh)	Energy Generation 2012 (GWh)	Energy Generation 2022 (GWh)
Statewide				5,501.2
Zone A: West				3,775.8
Zone F: Capitol				406.5
Zone G: Hudson Valley				266.9
Zone J: NYC				11.7
Zone K: Long Island				

Tables 4.4.14 and 4.4.15 each provide statewide capacity- and energy-coincidence factors for the entire future hydroelectric resource.

Table 4.4.14 Hydroelectric Capacity Coincidence Factors [30]

	Capacity Coincidence Factors	
For All Hydropower Resources	Summer Generation Capacity % of Max Output	Winter Generation Capacity % of Max Output
Statewide	36%	47%

30 In order to measure the coincidence of hydroelectric generating capacity with summer and winter peak periods we first determined that 20% of projected future capacity is in the form of store-and-release projects that are 100% dispatchable. The remaining 80% of projected capacity operates as run-of-river projects, with an average capacity factor of 51%. To determine the summer and winter peak capacity coincidence factors we examined monthly outputs for five sample plants in the region, determined output during the months of June through August and during the months of December through February. We then determined the percentage of total possible output achieved during these periods and concluded that, for run-of-river projects, this represented a reliable proxy for capacity coincidence percent during the respective June through August and December through February periods. These numbers were multiplied by 80% to recognize that run-of-river plants constitute only 80% of total capacity. Total capacity coincidence was a summation of the results for the run-of-river stations plus the weighted capacity coincidence factors (assumed to be 100%) of storage projects (20% of total capacity).

Table 4.4.15 Hydroelectric Energy Coincidence Factors[31]

	Energy Coincidence Factors					
For All Hydropower Resources	Summer On-Peak %	Summer Off-Peak %	Summer Shoulder %	Winter On-Peak %	Winter ff-Peak %	Winter Shoulder %
Statewide	3.47%	30.08%	5.79%	7.15%	46.36%	7.15%

ECONOMIC POTENTIAL

The analysis of economic potential indicates that under the high statewide avoided costs, all of the technical potential identified above — including the further development of existing and new dam sites — passes societal economic screening. If fully developed, these could result in 10,300 GWh of additional annual generation. Approximately 90% of this potential passes economic screening using low statewide avoided costs.

ACHIEVABLE POTENTIAL

Base Case and Currently Planned Initiatives

This section indicates how much of the technical potential defined above is likely to be realized assuming three different policy scenarios. The base case scenario indicates the amount of additional hydroelectric power likely to be generated assuming no additional market intervention occurs after this year. In effect this scenario assumes the continuation of existing hydroelectric production, and some capacity attrition due to age, machinery depreciation, and losses attributable to regulatory barriers related to relicensing. Thus, in forecasting this scenario, the study assumes not only that market interventions already in place will not be revoked or neutralized but also that no significant changes will be experienced in the regulatory arena. The study's general conclusion is that, except for repowering, there will be essentially no increase in hydroelectric capacity or energy in New York State under either the base case scenario or the CPI scenario.

The primary market incentive already in place is the financial commitment by NYPA to seek relicensing and modernization or repowering of the Niagara and St. Lawrence projects. As noted, this project is already substantially under way, with some work already completed on individual units at both locations. The study also finds that existing or planned repowering efforts at other sites in the state are sufficiently

31 In order to measure the coincidence of hydroelectricity energy output with the various electrical periods of the year, we first examined actual output from several typical stations to determine what percentage of annual energy output occurs during the winter months and what percentage occurs during the summer months. Assumed that the bulk of all hydro stations in New York State are run-of-river stations, we then assumed that energy during the winter and

attractive financially that they will go forward without any policy intervention. Therefore, the study assumes that the repowering option is not subject to change or improvement by any new market interventions. Also, the environmental impacts of repowering are generally insignificant, and the study therefore assumes no adjustments related to regulatory compliance. The study expects capacity and energy additions to be the same as forecast in Tables 4.4.6 and 4.4.10**.** This is likely to be the case in the other scenarios of achievable potential (currently planned initiatives and greenhouse-gas reduction targets scenarios).

The study finds that the most serious obstacle to the continued expansion and development of hydroelectric capacity in New York State (and nationwide) is found in the burdensome regulatory, siting, and licensing process for hydropower. Irrespective of size and scale, all sites are potentially subject to the same extensive regulatory-compliance requirements. In recognition of this reality, the base case scenario predicts that the only new conventional hydroelectric capacity and energy will come from repowering, and that no additional capacity will be forthcoming from the other technologies, as many potentially feasible hydroelectric projects will be effectively prohibited from development.

In addition, the study predicts that most of the existing hydroelectric projects scheduled to go through relicensing during the next several years will suffer some capacity and energy attrition. As is indicated in Table 4.4.1 above, approximately 3,800 MW of conventional hydroelectric capacity[32] is scheduled for relicensing in New York State during the next 20 years. Based on past history, the study predicts a resulting decline in capacity of approximately 200 MW. The base case forecasts for capacity and generation contained in Tables 4.4.16 and 4.4.17 reflect these losses as well.[33]

Table 4.4.16 Hydroelectric Capacity - Base Case and Currently Planned Initiatives

For All Hydroelectric Technologies	Installed Capacity 2003 (GWh)	Installed Capacity 2007 (GWh)	Installed Capacity 2012 (GWh)	Installed Capacity 2022 (GWh)
Statewide	4,659,900	4,959,900	4,775,434	4,872,952
Zone A: West	2,571,200	2,871,200	2,744,470	2,744,470
Zone F: Capitol	388,420	376,600	382,971	396,195
Zone G: Hudson Valley	45,950	45,950	49,450	55,950
Zone J: NYC	0	0	0	0
Zone K: Long Island	0	0	0	0

summer periods would be distributed across peak, off-peak, and shoulder hours in proportion to the percentage of total hours constituted by those hours.

32 This number is net of the capacity at Blenheim-Gilboa, which is pumped storage.

33 Tables 4-16 and 4-17 include generation and capacity from existing plants that are not scheduled for relicense during the next 20 years. This is approximately 783 MW of capacity, with annual production of ~4.5 million MWh/yr.

Table 4.4.17 Hydroelectric Generation - Base Case and Currently Planned Initiatives

For All Hydroelectric Technologies	Installed Capacity 2003 (GWh)	Installed Capacity 2007 (GWh)	Installed Capacity 2012 (GWh)	Installed Capacity 2022 (GWh)
Statewide	26,696.8	28,276.0	27,358.7	27,917.3
Zone A: West	14,730.5	16,449.2	15,732.2	15,723.2
Zone F: Capitol	2,225.3	2,157.6	2,194.0	2,269.8
Zone G: Hudson Valley	263.2	263.2	283.3	320.5
Zone J: NYC	0	0	0	0
Zone K: Long Island	0	0	0	0

The currently planned initiatives scenario indicates the amount of capacity and generation based on "the future impacts expected from currently planned initiatives included in the State Energy Plan." As noted, the primary obstacle to expanded future development is found in a burdensome licensing and regulatory process. Since hydroelectric licensing is federally pre-empted, there is very little that New York State can do to assist in overcoming this obstacle. When the development of small-scale independent hydroelectric power was popular during the 1980s, New York State consolidated its participation into a single permitting and approval process, which facilitated the licensing process and continues to be available today. However, to the extent that the most severe compliance requirements are set by federal agencies, the opportunity for New York State to facilitate licensing is fundamentally limited.

In addition, there is continuing public debate as to whether hydroelectric power should qualify as a renewable resource, largely because it is perceived as having qualitatively greater environmental impacts than other renewable technologies, such as solar. For example, hydroelectric power is not eligible for the benefits of the state agency renewable-energy purchase program established by Executive Order 111. Likewise, NYSERDA PON 701-02 ("Combined Heat & Power and Renewable Generation Technical Assistance Program") currently has no money available for implementation of hydropower projects. In addition, projects over 10 MW in scale are precluded from participating in this program. Consequently, currently planned initiatives that may benefit hydropower are limited to the following:

- Environmental Attribute Accounting and Trading System
- Environmental Disclosure rules
- Tax-exempt bond financing
- Standard interconnection requirements for distributed generation projects[34]
- Continuation of Niagara and St. Lawrence modernization programs

---

34 Limited to projects 300 kW or less in size

With the exception of the modernization program at Niagara and St. Lawrence,[35] it seems unlikely that any of these five policy initiatives will result in increased capacity or energy from hydroelectric power in New York State. To the extent that environmental disclosure and accounting results in higher prices for hydro electricity, it is possible that the predicted decline in hydroelectric production due to relicensing could be less. Likewise, tax-exempt bond financing can only help the finances of hydroelectric construction projects; however, no hydroelectric projects have been so financed in recent years, and the program appears to be more oriented toward supporting less mature renewable technologies. Since standard interconnection requirements are designed to support projects less than 300 kW in capacity, their contribution to increasing hydroelectric generation is expected to be minimal.

In summary, the study believes that currently planned initiatives will not contribute materially to hydroelectric production in New York State in comparison to the base case scenario. Therefore, Tables 4.4.16 and 4.4.17, which include increases due to repowering and decreases due to relicensing, apply to both the base case and the currently planned initiatives scenarios.

Potential Contributions to Greenhouse-Gas Reduction Targets

The GHG-reductions target scenario is defined as "the least-cost combination of efficiency and renewable resources above those expected from currently planned initiatives that can be used to meet greenhouse-gas reduction targets defined by NYSERDA for 2012 and 2022." Essentially the policy initiatives under this scenario are the same as those under the currently planned initiatives scenario, with the added requirement that green-power marketing be mandatory by 2005. The study believes that this requirement to offer customers green-power purchase options consisting of 25%, 50%, and 100% green options could have the effect of increasing the price paid for such hydroelectric power and thus diminish the forecast decline in hydroelectric capacity and energy without increasing hydroelectric capacity and energy in the state.

The requirement that green-power products consist of 50% new and in-state renewable resources could contribute to an increase in hydroelectric capacity after that date, though much depends on the contributions made by other renewables. Given that hydroelectric projects generally tend to be larger scale than other renewable technologies, they offer the potential for meeting such demanding targets with greater ease as long as hydro continues to be viewed as a legitimate renewable resource. The study therefore estimates that under the GHG-reductions target scenario, it would be possible to achieve as much as 20% of additional technical potential after 2007 from expanded capacity or new capacity at existing dams. The study is pessimistic that any gain could be realized from new dam construction under current regulatory policies and therefore posits no increase from that source. The resulting numbers are reflected in Table 4.4.18 (Capacity) and Table 4.4.19 (Generation). Note that these tables present the total hydropower

[35] Because this program has already begun, we have accounted for it in the base case scenario.

resource projected to be available under the policy and program supports associated with the GHG-reduction scenario. The amount of hydropower included in the integrated least-cost solution for achieving the GHG-reduction targets, which is presented in Figure 4.1.1 and Tables 16 to 25 in Volume 2, is less the potential identified in Tables 4.4.18 and 4.4.19.

Table 4.4.18 Hydroelectric Capacity — Greenhouse-Gas Reduction Scenario

For All Hydroelectric Technologies	Installed Capacity 2003 (GWh)	Installed Capacity 2007 (GWh)	Installed Capacity 2012 (GWh)	Installed Capacity 2022 (GWh)
Statewide	4,659,900	4,959,900	4,825,711	4,998,645
Zone A: West	2,571,200	2,871,200	2,744,827	2,745,360
Zone F: Capitol	388,420	388,420	397,589	432,740
Zone G: Hudson Valley	45,950	45.950	50,996	59,814
Zone J: NYC	0	0	0	0
Zone K: Long Island	0	0	0	0

Table 4.4.19 Hydroelectric Generation — Greenhouse-Gas Reduction Scenario

For All Hydroelectric Technologies	Installed Capacity 2003 (GWh)	Installed Capacity 2007 (GWh)	Installed Capacity 2012 (GWh)	Installed Capacity 2022 (GWh)
Statewide	26,696.8	28,276.1	27,798.4	29,016.7
Zone A: West	14,730.5	16,449.2	15,725.7	15,729.3
Zone F: Capitol	2,225.3	2,157.6	2,321.7	2,258.8
Zone G: Hudson Valley	263.2	263.2	292.6	343.9
Zone J: NYC	0	0	0	0
Zone K: Long Island	0	0	0	0

STRATEGIES FOR ACCELERATING MARKET DEVELOPMENT

The three major issues and barriers affecting the future of hydropower are:

- A slow, complex, and burdensome regulatory environment that does not acknowledge the environmental benefits of hydropower relative to most conventional thermal electric resources
- The high initial capital cost of hydropower relative to most other means of generating electricity.
- The treatment of hydropower not as a renewable energy resource.

Although all of these problems can be corrected or overcome by implementing particular government policies, the first barrier must be addressed primarily at the federal level. The hydroelectric licensing processes of FERC need to be further rationalized and expedited to avoid the imbalance that appears to

exist in favor of environmental protection concerns. Without denying any opportunities for concerned citizens or interest groups to participate in the process, fixed schedules with time-certain deadlines need to be established to avoid unnecessary delays in the licensing process. Requirements for environmental studies need to be connected to known problems or issues and should not be intended simply to identify problems that may or may not exist. Most important, mechanisms need to be developed to enable the comparison of hydropower's environmental benefits — not just its environmental costs. Toward this end, tradable emissions credits should be made available to existing hydropower plants so that the additional environmental costs of not operating these plants becomes clear.

Although the initial capital costs of hydropower can be very high, especially at low-head sites or at sites involving dam construction, the service life of hydropower is usually far longer than those of competing electric-power technologies. Also, because there are no fuel costs, hydroelectric operating costs are much lower. Thus, the chief economic obstacle to hydropower is during the construction phase only, suggesting that government incentives at the front end of hydroelectric development could be particularly effective. Reducing the regulatory burden would help to lower front-end costs and thus could facilitate hydroelectric expansion. Likewise, tax credits, accelerated depreciation, or increasing access to lower cost and longer term financing could all contribute to overcoming the second barrier listed above. As well, if tradable emissions credits were extended to new hydropower, this too could improve project economics — perhaps sufficiently to overcome the high initial capital cost of this technology.

Finally, treating hydropower on an equal footing with all other renewable resources is required to assure that the contribution of hydropower does not continue to shrink. Hydropower should be acknowledged as the renewable energy resource that it is, not singled out and removed from programs that encourage the use of renewable resources. Every existing and future policy or program designed to encourage renewable resource development should explicitly include hydroelectric power as a qualifying resource.

As a mature technology, hydropower faces unique challenges as it struggles to compete with other technologies. Because it already exists, it may be assumed — incorrectly — that hydropower does not require continued government policy support. Without policy support, hydropower's contribution to energy supply will continue to shrink, and opportunities for expansion will be ignored. By far the most important step that can be taken to overcome this dilemma is public acknowledgement that hydropower is a renewable resource and needs to be treated as such.

SECTION 5:
LANDFILL GAS TO ELECTRICITY

SUMMARY RESULTS

Landfill gas (LFG) is a product of natural decomposition of organic waste materials under anaerobic (absence of air) conditions. Landfill gas is present in a municipal solid waste (MSW) landfill approximately two years after waste placement. LFG is composed of approximately 50% methane and 50% carbon dioxide (with trace amounts of other compounds). LFG has approximately 50% of the heating value of natural gas. In general, the production of LFG has a direct relationship to the amount of municipal solid waste that is landfilled. While some MSW landfills may occasionally use landfill gas directly as a heating fuel or for methanol production, such uses are not common. In New York State, it is reasonable to expect that substantially all LFG that is collected and used will be dedicated to electric-power production, with the exception of the Fresh Kills Landfill on Staten Island, which produces pipeline-quality gas.

Landfill gas to electricity (LFGTE) projects have been in operation at large landfills in New York for approximately the past 20 years. The initial impetus for development was the federal Public Utilities Regulatory and Policy Act (PURPA) enacted in 1976, which mandated that public utilities purchase power at minimum rates from “Qualifying Facilities.” During the early years of PURPA, large publicly owned landfills on Long Island led this development, since it was not usually economic to develop energy projects at landfills with in-place MSW tonnage of less than 1 million tons. Since the late 1970s, many small landfills have closed throughout New York State State. Essentially all new landfills are of sufficient size and are required to have LFG-collection systems in order to reduce odor and to comply with federal New Source Protection Standards (NSPS) for air emissions. The size of the landfills and the need to collect the gas make many landfills now amenable to electric-power production.

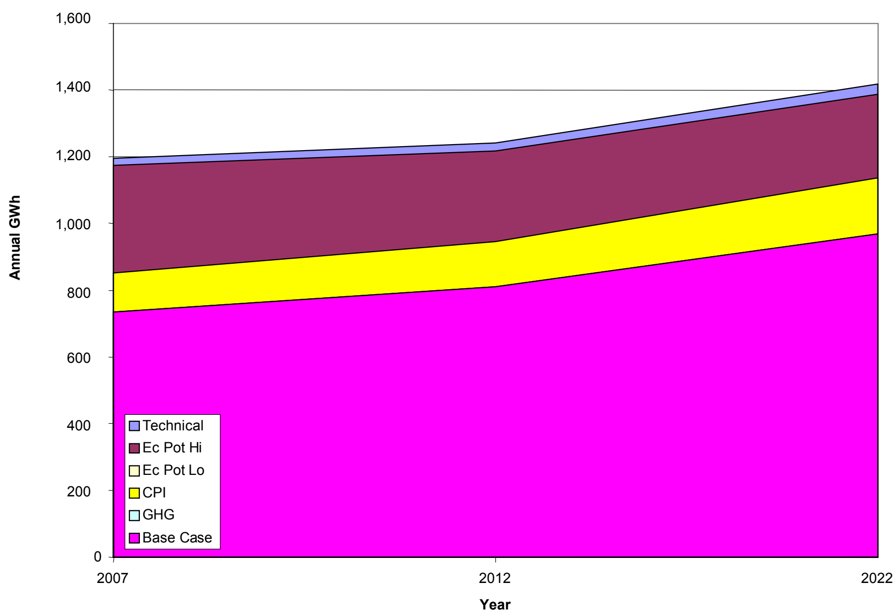
This study estimated the future amount of MSW projected to be landfilled and mathematically modeled the amount of LFG that can potentially be recovered from the landfills over the next 20 years. Technologies for converting LFG to electricity are well-established, and only a modest increase in system efficiency was projected. Electricity production has been estimated using industry-established conversion factors. LFG power plants are typically reliable and steady power producers year-round. Nevertheless, actual power production depends on individual site economics, collection efficiency, power-plant sizing, and other site-specific development factors.

LFGTE potential in New York State was projected through 2022 under six cases: technical potential, economic potential assuming high statewide avoided costs, economic potential assuming low statewide avoided costs, currently planned initiatives (CPI), greenhouse gas (GHG) reduction targets, and the base case. Technical potential is defined as the upper limit for LFGTE capacity and generation theoretically possible from the resource based in New York State without regard to cost, market barriers, or market

acceptability. The CPI case is defined as future impacts expected from currently planned initiatives included in the 2002 New York State Energy Plan. The GHG-reduction case is defined as the least-cost combination of efficiency and renewable resources (above those expected from currently planned initiatives) that can be used to meet GHG-reduction targets established by the State for 2012 and 2022. The base case is defined as LFGTE capacity and generation already on-line, already permitted, or well along in planning as of late 2002.

In each of the cases, LFGTE capacity and generation were determined based on the amount of LFG potentially available for electricity production and the ability of three specific conversion technologies, in order to avoid double-counting feedstocks. The study projected potential for electric generation from large combustion turbines (rated 3 to 15 MW), internal-combustion engines (rated 400 kW to 5 MW), and microturbines (rated 30 to 600 kW).

Figure 4.5.1 New York Landfill Gas to Electricity Potential Summary



The base case is projected to increase by about 240 % from 48 MW of installed capacity in 2002 to 116 MW in 2022, reflecting the known expansion of existing landfill facilities and the fact that substantially all existing landfills are now sufficiently large enough to support economical energy facilities.
As shown in the figure, LFGTE is projected to increase in the base case from 734 GWh in 2007 to 967 GWh by 2022.

Currently planned initiatives should increase the base case to 137 MW in 2022. As shown in the figure, under the CPI case LFGTE is projected to increase from 852 GWh in 2007 to 1,100 GWh in 2022.

Similarly, if GHG-reduction targets are achieved, an increase to 156 MW in 2022 is possible. As shown in the figure, under the GHG case, LFGTE is projected to increase from 734 GWh to 967 GWh by 2022 (under low avoided costs) and to 1,400 GWh by 2022 (under high avoided costs). At high avoided costs in the GHG-reduction case, LFGTE production is projected to reach 98 % of overall technical potential.

This study indicates that LFGTE production will continue to increase at a steady rate over the next two decades, reflecting the continued development of landfills of sufficient size to support energy facilities and paralleling the projected estimates of solid waste that will be landfilled in New York State. Overall, LFGTE will remain a growing and important, but small, percentage of renewable power.

TECHNOLOGY DESCRIPTION

Landfill Gas Resource

Landfill gas is a product of natural decomposition of organic waste materials in an anaerobic environment. Municipal solid waste deposited in landfills is covered on a daily basis with additional amounts of waste and some form of "cover material" to prevent windblown litter and entry of vectors. Under normal conditions, an anaerobic environment (without oxygen) is developed in the waste below the surface of the landfill within a short time, and substantial microbial activity begins the process of decomposition. This anaerobic microbial activity proceeds in the presence of waste, (the carbon source), water, and suitable nutrient conditions, and eventually forms landfill gas.

As noted, landfill gas is generally composed of about 50% methane and 50% carbon dioxide, with trace amounts of a variety of non-methane organic compounds (NMOC) in the parts per million range. Thus, LFG has approximately one-half the heating value of a typical natural gas and can be used for a variety of energy production purposes if collected for this use. The lower heating value of LFG is about 450 Btu per cubic foot at 50% methane.

Traditionally, the EPA Landfill Methane Outreach Program (LMOP) has considered that it is necessary to have a landfill with a minimum of 1 million tons of MSW in place as the minimum economically sized landfill for development of a LFGTE project. This has precluded many older, small landfills from interest in LFGTE. However, as most all small MSW landfills are now closed in New York — and because of current regulations most all new landfills are likely to be larger than 1 million tons — all future landfills will likely have the potential for LFGTE development.

LFGTE Technologies

Landfill gas has been collected and used to produce electric power for more than 30 years in the U.S. and elsewhere. Technologies that produce electric power from LFG include:

- internal combustion engine-generator sets (widely used for many years);
- combustion turbines (widely used for many years, at larger installations);
- steam cycle or combined cycle combustion/steam turbine power facilities (used only at a few of the largest facilities);
- microturbines (recently commercialized for smaller size applications);
- fuel cells (currently in research and development [R &D] and not economically or commercially available for LFGTE).

Other technologies use landfill gas as a fuel or upgraded fuel product. Medium-Btu gas can be collected from landfills and used in boilers, for co-firing and/or for pipeline blending. High-Btu gas can be produced by raising LFG to pipeline-quality gas, similar to natural gas. From fuel-quality landfill gas a number of derivative processes are possible, including: ethanol production (for an MTBE substitute); methanol production (for commercial applications); high grade carbon dioxide production (for greenhouses); pipeline quality gas (for commercial sales); LNG (liquid landfill gas for vehicle fuel); and CLG (compressed landfill gas).

In addition, other technologies are available for disposal and management of solid waste. Accordingly, SCS Engineering Inc. researched probable disposal volumes and options available in New York, including recycling, landfilling, waste-to-energy, export, and digestion. This information was used to estimate the amount of solid waste currently in landfills and likely to be landfilled in the future. The landfilled portion of MSW disposed represents the resource base available for current and future electricity generation from landfill gas. MSW that otherwise is being diverted for recycling or used as feedstock in waste-to-energy facilities is not considered potentially available for LFGTE.

In general, the direct use of LFG as a medium-Btu fuel is the most efficient use of landfill gas. However, this seldom occurs because a reliable customer base for LFG is usually not located near landfills and/or available for long-term contracts. For very large landfills, high-quality gas may be produced and sold to the local gas utility. This is currently done at Fresh Kills Landfill on Staten Island and is planned to continue in the future.

SCS recently completed conceptual feasibility evaluations for technologies that could use LFG to produce products other than electricity for the Rhode Island Resource Recovery Corporation. None were found to be economically feasible compared to electric-power production, primarily because of the scale and lack of proximity to a major energy (i.e., thermal) customer. Fresh Kills Landfill and an ethanol facility presently

under development in Orange County are the only significant projects SCS is aware of in New York that use (or will use) LFG to produce a product other than electricity.

Potentially feasible applications for direct LFG use in New York in the future may include some direct heating for small boiler applications at landfill sites, nearby greenhouses, or occasional industrial customers. However, SCS believes these applications are within the probable margin of error of this study; thus, such end uses are not included in the quantitative analysis completed for this report.

For purposes of this study, it is assumed that all future LFG production (excluding Fresh Kills) could be utilized for electric-power production within the margin of error of the technical potential assessment and within the parameters explored for practical and economic use.

Internal Combustion (I/C) Engines. I/C engines are widely available in sizes ranging from 200 kW to around 1.2 MW for LFG applications. The industry workhorse is an 800 kW unit available from several manufacturers, with many installations existing in the 450 to 600 kW range as well. I/C engines are typically direct coupled to synchronous electric generators at 4,160 volt, 60 Hertz, 3-phase power. Engines are installed in banks of two or more units, with up to 20 units (or more occasionally) as needed. Several suppliers have made a concerted effort to develop engines specifically for LFG applications. I/C engines are widely used presently and in the future will likely account for aboiut 85% of all applications.

I/C engines are commercially available from at least four or five reputable vendors, there is extensive practical operating experience with them, they are cost-effective within the range of uses usually planned, are reliable, and are accepted in the market by users and owners. There are presently no major regulatory or permitting obstacles to their use (although NOx control is slightly more favorable for large turbines and microturbine technologies). Some opportunities exist for secondary heat capture through jacket water systems and/or exhaust exchangers.

A typical facility includes spark-ignited internal combustion engines, lean burn, turbo-charged and suitable for low-pressure landfill gas. The engines operate simultaneously from a common LFG collection and pre-conditioning system. Routine maintenance is scheduled during low demand periods. The following equipment comprises a typical facility:

- One common LFG pre-conditioning skid, including filters;
- LFG engines, Caterpillar G3516, or equal;
- Synchronous generators, 800 kW, 1.0 power factor, 4,160 volts, 60 Hertz, 3 phase, equipped with protective relays;
- Radiators, each capable of handling an engine at full load;
- Exhaust systems with silencers;

- Combustion air supply and filters;
- Ventilation fans and exhaust louvers;
- Plumbing including lubrication oil, waste oil, LFG and jacket water;
- Ancillary items, including engine starters, engine sensors, jacket water heaters and performance monitors;
- All necessary electrical equipment, motor controls, breakers and computer control systems

Landfill gas is drawn under negative pressure to the powerhouse by an electric driven booster/blower package, passing first through a filter/separator to remove condensate carryover from the landfill. The LFG blower compresses the gas to 5- to 15-psig and directs the gas to an air-cooled heat exchanger, if necessary. At higher pressure and with additional cooling, the gas passes through a second, coalescing filter to remove additional moisture. It is typically not necessary to dry the gas for engine applications, but some developers prefer this approach.

The majority of the gas train is constructed of stainless steel up to the flex connections to the engine carburetors. A typical power plant design calls for internal combustion engines to be located within an enclosed building, for ease of maintenance.

The gas engines are typically equipped with twin turbo chargers and after coolers to improve engine performance and efficiency. The engines are usually classified as lean burn with a high air-to-fuel ratio to reduce cylinder engine temperatures and thereby reduce NOx emissions. Each engine is equipped with dedicated controls including auto ignition timing adjustment, air/fuel ratio control, safety shutdowns and auto electrical synchronizing control.

Engine exhaust gases are routed through a water/glycol cooled exhaust manifold to a rooftop exhaust silencer to the atmosphere. The engines are cooled with dedicated, closed circuit, air-cooled radiators circulating a conventional 50/50 water-glycol mixture. Coolant temperature is controlled with a combination of engine-mounted thermostats and radiator-mounted fans.

An electrical switchgear and control room is provided to house the synchronizing switchgear and other engine control/monitoring equipment. Each engine/generator has a dedicated breaker panel complete with voltage, amperage and power indications. Engines are typically started locally, at an engine-mounted panel. Once up to operating speed, synchronization with the electrical grid is initiated by the operator in the electrical switchgear room at the switchgear panel. The engine-mounted generators typically have three phases and operate at 4,160 volts.

Combustion Turbines. Combustion turbines are prime mover devices that combust LFG directly in the turbine, causing a driving motion. The turbine is connected to a synchronous electric generator. Turbines are available for LFG applications in nominal 3.0 and 5.0 MW sizes from one major manufacturer. The Solar Division of Caterpillar offers the Centaur model at 3 MW and the Taurus Model at 5 MW. This size range of combustion turbine has been commercially available for some time and is used in numerous LFG applications. However, the required heat rate to drive a turbine is higher than for internal combustion engines, which limits their application to sites where lower emissions from the turbines are required. Caterpillar Solar equipment has an excellent reputation in the LFG industry. Other combustion turbine manufacturers have virtually no market share.

The extensive operating experience and reliability of solar turbines have helped stimulate turbine use, and re-builds are available on a fast turnaround (making redundancy unnecessary at most sites). Turbines are considered cost-effective within the range of uses in place or planned for larger installations, although their fuel use efficiency is not as high as is desirable. The turndown efficiency is lower than I/C engines; hence the turbines should run at full load. Turbines are more readily permitted under Best Available Control Technology (BACT) or Lowest Achievable Emissions Rate (LAER) air emissions regulations because of lower NOx concentrations. At some locations where their larger size is feasible, turbines are selected over I/C engines partially because of their lower NOx emissions. This has not been a significant trend in the State of New York, however. SCS is aware of one 3 MW combustion turbine LFGTE installation in New York, and a few others in the Northeast.

LFG-combustion turbine installations are quite similar to those for I/C engines, with a few exceptions. Turbines require a significant inlet pressure from the LFG fuel and a major compressor installation to achieve that pressure. Thus, the in-plant parasitic load is higher. Turbine exhaust gasses can be captured for additional heat recovery (as noted below) to improve efficiency for larger installations.

Steam Cycle or Combined-Cycle Generation Systems. In selected situations, heat-recovery steam generators (HRSG) are added to combustion turbine installations to improve fuel efficiency and generate additional power. Usually, the captured steam is run through a steam turbine-generator for separate, secondary power generation (referred to as “combined cycle”). To make the installation economical, it is usually desirable to have sufficient LFG to fire the HRSG directly (in addition) for more steam production. Operation and maintenance (O&M) costs for steam systems are higher because of pressure-code requirements during operation.

Stand-alone steam turbine-generators (steam cycle) are also occasionally installed, sometimes with used equipment if available.

SCS is aware of two LFG steam turbine plants operating in the U.S. (in New Jersey and California) at 10 MW or greater. SCS is also aware of two LFG combined cycle plants using solar gas turbines, HRSG units and steam turbine secondary units. Used (re-built) steam turbines were installed at two of the plants because of the cost advantage of purchasing re-built equipment.

GE and Westinghouse both offer medium-sized steam turbines suitable for these applications. Similarly, HRSG and auxiliary equipment for this type of power plant have wide historic use in many industrial, military and commercial applications.

It is usually required that a licensed steam engineers be present 24 hours a day at facilities that use a steam turbine, making O&M costs higher than for facilities that use combustion turbines. In addition, auxiliary equipment is more complex for steam turbines. Accordingly, steam turbines or combined cycle technology are usually only selected for larger plants (greater than 10 MW) or in specific circumstances that require such technology.

Steam turbine and combined cycle plants are proven and quite reliable. Permitting is relatively straightforward and has recently been accomplished in New Jersey for both steam cycle and combined cycle plants. Overall efficiency is improved with combined cycle operation because the "waste heat" is utilized.

Prime Mover Selection. Reciprocating engines are by far the most widely used prime movers for LFG (on the basis of number of individual units installed). The principal advantage of reciprocating engines compared to combustion turbines is their better heat rate at lower capacities. A typical net heat rate for a reciprocating engine-based plant is 12,000 Btu/kWh. An additional advantage is that the units are available in many different increments of capacity, making it easy to tailor the size of the plant to the specific rate of LFG production.

While a combustion turbine has lower air emissions on a brake-horsepower basis, a principal drawback is its high net heat rate of about 15,000 Btu/kWh. This results in higher air emissions on a net output basis. The poor heat rate stems from two factors:

- The station power for a combustion turbine is about 15% of gross power output, compared to around 7-8% for a reciprocating engine-based plant.
- A combustion turbine requires a higher gas pressure, which increases the power consumption of the fuel gas compressors.

In addition, combustion turbines used in landfill gas electric power production are small and are not as efficient as larger units commonly employed in the independent power utility markets.

Microturbines. Microturbines are a small combustion turbine recently offered for LFG applications. Current size ranges are 30 kW to 80 kW range. However, some manufacturers have units in the 125 kW to 200 kW range in design. The first commercial applications on LFG were installed in 2001 and many installations are under way, particularly in California. SCS installed units at 10 landfills in 2002, indicating the rapidly expanding interest in the use of microtubines for LFGTE installations. Units can be combined to a practical total of around four to six in total, or up to 300 kW to500 kW of installed capacity. Installations up to 800 kW are potentially possible.

There are presently several commercial manufacturers of microturbines, including Ingersol-Rand, Capstone, Elliott Energy, and NREC Energy. Two of them, Capstone and Ingersoll-Rand, have installations operating at landfills. Units are also being installed on digester gas at wastewater treatment facilities and for other waste-related installations.

Feasibility studies conducted for the installations in place indicate the cost-effectiveness of these units is best where local power costs are higher than 6 cents/kWh. Installed cost per kW is higher than for I/C engines. All indications thus far suggest turnkey installations can be done reliably, and five-year warranties are available.

The use of microturbines for LFGTE can be considered commercially established, but long-term reliability has not been confirmed because the technology is new. Concerns exist about the lower quality of LFG (compared to natural gas) and the possible build-up over time of trace compounds (such as siloxanes) on turbine blades. However, it appears that these concerns can be addressed. Air emissions (NOx especially) appear to be lower than for I/C engines, and air permits have been received in southern California, where the most stringent regulations are in effect. Microturbines can meet state-of-the-art (SOTA) emissions requirements. This will likely favor the permitting and use of microturbines in other locations, such as New York.

SCS expects the use of microturbines for LFGTE to become quite significant in the future, particularly at smaller or older closed landfills where gas is flared and where the power produced could be used on-site or at nearby commercial facilities.

Fuel Cells. Fuel cells are being tested in pilot facilities at a few landfills in the 100 to 200 kW size range through R&D efforts sponsored by USEPA, DOE, NYSERDA, and others. However, there are no commercial installations of fuel cells that use LFG as feedstock.

The primary barrier to increased use of LFG with fuel cells is the significant effort (and cost) required to pre-treat the gas to remove sulfides and other trace compounds that could otherwise foul the fuel cell.

Technologies available to clean landfill gas are comprised of readily available components such as membrane separation, carbon absorption, condensing and filtering. However, the cost of pre-treating the gas doubles (approximately) the total cost of the installation. Overall, it currently costs about three times as much to clean landfill gas and use fuel cells to produce electricity from the gas as it does to use internal combustion engines (even when existing subsidies from DOE are taken into account). Due to these technical and cost issues, SCS does not anticipate fuel cells will be widely used in LFGTE applications during the next 20 years.

Technologies Included in This Study. The LFGTE technologies included in this study are summarized in Table 4.5.1. They were selected based on the information presented above and are the major technologies expected to be commercially available for application during the study period.

Table 4.5.1 Landfill Gas-To-Electricity Technologies Included in This Study

Technology Type	Scale to be Analyzed	Rationale for Including
Large Combustion Systems *	3.0 MW to 15 MW	Proven, reliable, cost effective
Internal Combustion Engines	400 kw to 5.0 MW	Proven, reliable, cost effective Captures mid-range of production
Microturbines	30 kw to 600 kw	Very promising, commercially available, captures low range of production
* Includes combustion turbines, steam turbines & combined cycle.		

MANUFACTURING AND SERVICE INFRASTRUCTURE

Manufacturing, Distribution, and Service Infrastructure

The infrastructure for I/C engines and large combustion systems is well-established nationwide and in service in New York. A number of U.S. and European equipment manufacturers are in the LFGTE market using technology originally established for other purposes. Major manufacturers include:

- Caterpillar (US)
- Waukesha (US)
- Jenbacher (Germany)
- Dietz (Germany)
- Solar Turbine (Caterpillar)
- GE (steam turbines)
- Westinghouse (steam turbines)

These manufacturers are well established, do not depend exclusively on the LFG business (which is a relatively small part of overall operations), and can sell or service readily to any location in New York for the foreseeable future. There should be no problem in serving a larger LFG market in New York from these sources in the future.

Microturbine manufacturers include:

- Capstone (over 1,000 shipped)
- Ingersol-Rand (shipped their first units in 11/01)
- Honeywell (300 shipped), now out of business
- Elliott Energy (early 2002)
- Turbec (ABB + Volvo) (planned for 2002)
- DTE Energy (2002)

As noted above, the use of microturbines for LFGTE is relatively recent. However, microturbines have been used on fossil fuel, oil field flare gas and digester gas for many years. The recent withdrawal of Honeywell from microturbine sales appears to be unrelated to the market, but more a corporate decision by GE after purchasing Honeywell. SCS has experienced no problems in securing equipment, service contracts or interest by several microturbine manufacturers, particularly as markets for distributed energy increase.

The existing manufacturing and service infrastructure for LFGTE technologies is adequate to meet future demand for LFG in New York State and should not be a barrier to development.

Key Market Barriers and Issues

Key issues affecting future LFGTE opportunities are not technical but primarily include tax credit issues, the lack of financial incentives for using LFG for energy, power sales restructuring, education and the need to reduce standby service rates. During the period through 1998 (after which federal tax credits for LFGTE expired), LFGTE installations were installed at hundreds of landfills across the country, including many in New York. At that time, PURPA "qualifying facilities" were entitled to power purchase contracts of some length of time with the regulated utility in the area. Such contracts provided a basis for financing LFGTE projects.

With the deregulation of power markets in many states (including New York), such long -term power purchase contracts are no longer available and new LFGTE projects must now bid into the NYISO program on a daily basis (without the security of a fixed floor price). This is not a desirable situation for base load plants and prevents current and future investment in new LFGTE facilities. More favorable contract

conditions may emerge when renewable energy credits can be marketed and in response to Governor Pataki's Executive Order I11 establishing renewable energy (and efficiency) goals for all state agencies.

At the same time, the New York Power Authority (NYPA) is assisting counties and other public entities who wish to enter the LFGTE business, and is offering municipal landfill owners the option of entering into a Customer Installation Commitment (CIC) for development of projects on a turnkey basis, including the provision of negotiated energy sales agreements. This is a very important initiative for municipal owners, who would otherwise find it difficult to develop projects without federal tax credits.

In many instances, the capital and O&M costs for a LFGTE project coupled with the uncertainty of energy sales prices represent a key barrier to development because the margin of profit for such projects remains small and economic feasibility uncertain.

At the present time, most LFG facilities are privately owned, in response to IRS requirements to receive tax credits under Federal Tax Code, Section 29. As vested LFG wells expire in years 2002 to 2008, it is anticipated that some of these facilities may consider shutting down unless additional tax credits or other marketing and economic incentives become available.

REGULATORY, PERMITTING AND SITING ISSUES

Environmental Impacts

LFGTE facilities are typically considered to have a low environmental impact and a positive impact on landfills with respect to collection and use of landfill gas, which otherwise may cause odor or migration problems at landfills. Federal New Source Performance Standards (NSPS) together with NYSDEC Air and Solid Waste permit requirements govern LFGTE installations. The study finds no significant issues of concern beyond conformance with existing air regulations.

LFG engines or turbines can be considered control devices that control emissions of methane, NMOCs, and odiferous compounds from landfills. By utilizing the energy in LFG to generate electricity, the engines offset air-pollutant emissions from the production of an equivalent amount of electricity at other facilities.

However, the combustion of LFG does result in secondary air pollutant emissions due to the combustion process (NOx and SOx), incomplete combustion (CO), and the LFG itself (particulates). To minimize secondary emissions, many sites use low-emission engines. These engines include lean-burn combustion engines with automatic air-to-fuel ratio control. SO2 removal can become an issue if the landfill receives construction wastes.

Collection and combustion of LFG also results in a significant reduction in greenhouse gas via the destruction of methane, which is 21 times stronger a greenhouse gas than carbon dioxide.

Siting and Permitting Issues

Siting a LFGTE facility is not typically a huge issue since it is usually located at an existing landfill site and provides a variety of positive impacts (mentioned above). The need to flare LFG is reduced or eliminated, and potential odors from the gas are eliminated.

The air impacts of LFGTE facilities are known and positive (in that methane is destroyed). The facilities offset reductions in pollutants from other power facilities. For up-to-date facilities, the air emissions produced are typically below regulatory requirements. As such, LFGTE facilities in New York State have not encountered major permitting problems with the EPA NSPS program or the NYSDEC Air and Solid Waste programs.

In summary, SCS does not expect siting or permitting issues to be significant barriers to future development of LFGTE facilities in New York during the study period.

COST AND RELATED INFORMATION

Cost Elements and Parameters

LFGTE facilities have typically been developed and operated by private companies that are in a position to utilize the federal tax credits that were available for plants that installed collection systems, before June 1998. As a result of NYPA involvement, several new municipal facilities may be developed in response to Executive Order 111. LFGTE facilities consist of two separate entities:

- LFG collection wells and related piping with flare
- LFGTE power generation plant with utility interconnection

While regulations, odor control, or other site conditions may require construction of a collection system and flare without a LFGTE facility, it has usually been possible for landfill owners to recover these costs as part of the agreement for payment by the LFGTE developer. Therefore, it is reasonable to include the cost of both the collection system and the energy facility as part of the total installed cost and the annualized O&M cost for the study. If the collection costs are not included, the economics are more favorable. Table 4.5.2 indicates specific items that are typically part of an electric power project and would be included in a financing pro forma analysis.

Table 4.5.2 Landfill Gas to Electricity Facility Costs — Items Included and Excluded

INSTALLATION	
Collection	**Generation**
Wells and Piping	Development & Engineering
Blower/Flare*	Legal
Permits and Fees	Equipment, Building & Site Work
Condensate System	Interconnection
Gas Measurement & Miscellaneous	Permits & Fees
LEVELIZED ANNUAL OPERATIONS & MAINTENANCE	
Collection	**Generation**
General & Administration	General & Administration
Insurance	Insurance
Routine O&M	Utilities/Fees/Licenses
Power Costs	Routine O&M
Major Maintenance	Major Maintenance
Contractors profit	Contractors profit
NOT INCLUDED	
Royalties-*	Site Lease Payments
Tax Credits or other incentives	Financing Costs (20 year term)

Installation and Operating Costs

Table 4.5.3, Landfill Gas-to-Electricity Costs (2003 $ per kW), lists the SCS estimate of costs for all technologies considered. While some minor improvements to LFG engines may be achieved, it appears that costs for engines and large systems will remain constant over the study period. On the other hand, the price of micorturbines will decrease somewhat over time, as more units are sold.

For this study, SCS used representative cost factors from actual LFGTE facilities constructed near Albany, Hartford, northern New Jersey and other Northeast locations, as well as SCS recent experience with microturbines in California. Costs from projects constructed in the years 1998 to 2000 have been escalated at 2.5% per year to 2003 dollars. Estimated variations from statewide pricing in particular load zones have been adjusted in the screening tool inputs template to reflect regional differences.

Table 4.5.3 Landfill Gas-To-Electricity Costs (2003 $ Per kW)

		Installed Cost (4.) 2003 $/Kw			Levelized O & M Cost (4.) 2003 $/Kw/Year		
Technology	Year	Collect.	Gen.	Total	Collect.	Gen.	Total
Large Systems (1.)	All	650	2,200	2,850	90	180	270
Engines (2.)	All	650	1,650	2,300	90	160	250
Microturbines (3.)	2003	650	2,900	3,550	90	150	240
Microturbines (3.)	2007	650	2,700	3,350	90	150	240
Microturbines (3.)	2012	650	2,500	3,150	90	150	240
Microturbines (3.)	2022	650	2,300	2,950	90	150	240

* See Table 4.5.2 for items included. Does not include financing, gas royalty payments or site lease payments. Does include contractor profit in O & M costs

1. Estimated by SCS based on data from 1-10 MW steam cycle and 1-17 Mw combined cycle plant, built in New Jersey in 1998 and 2001.

2. Estimated by SCS based on data from 1.9 to 3.8 Mw size engine plants constructed in various locations in NY, CT and NJ.

3. Estimated by SCS based on 2000-2001 facilities installed by SCS Energy. Costs are for installations in the 150-200 Kw range, and will vary with size.

4. Costs are for typical installations, statewide. Zone variation estimates are shown in the screening Tool Inputs.

TECHNICAL POTENTIAL

Existing and Planned LFGTE Facilities

There are 21 existing or planned LFGTE facilities in New York. Table 5.4 summarizes the status of these facilities and provides data available for power production in 1999 and 2000. Six of the facilities had not come on line yet in 2000. Of these, four are on line in 2002 and two more are scheduled for late 2002 or 2003.

SCS notes the significant difference between the electrical capacity (56 MW) from EPA Landfill Methane Outreach Program data and the more accurate rated capacity (35 MW) calculated by SCS based on actual power production. This discrepancy is caused by the fact that installed equipment is seldom fully utilized for many reasons related to gas recovery at any particular time. Accordingly, SCS has determined through numerous LFGTE analyses that the best method for predicting future electric production is to relate power production to estimated LFG recovery based on future waste disposal. Appropriate assumptions on the percent utilization of recovered gas can then be estimated.

Table 4.5.4 Existing and Planned Landfill Gas-to-Electricity Facilities in New York State (2002)

Load Control Zone	Landfill Name	Operating or Closed/yr.	MSW Received Tons 2,000	Tons (3) in Place (MM)	Elec.(3) Capacity MW	LFG(4) Recovered MMCF/Yr. 2000	Electricity (4) Generated MWH 2000	Rated Capacity MW (7) 2000	KWH/MCF	Operating Hours		1999 (6) MWH Gen.
A	Modern (5.)	O	550,000	5.1	5.2	-	-	0.0				
A	Lancaster	C/85	-	2.4	5.2	901	38,434	4.6	42.7	8,735		35,500
A	Tonawanda	C	-	1.0	0.9	(1)	(1)	0.0				
Total A			550,000	9	11	901	38,434	4.6				35,500
F	Albany	O	273,000	4.1	1.9	562	13,870	1.7	24.7	8,784		
F	Colonie (5.)	O	148,700	1.5	2.5	-	-	0.0				
F	Saratoga	C/91	-	2.1	1.0	18	1,131	0.1	62.8	6,000		1,100
Total F			421,700	8		580	15,001	1.8				1,100
G	Al Turi	C	0	4.0	5.0	1560	30,000	3.6	19.3			37,400
G	Orange County	C	-			567	9,058	1.1	16.0			16,700
Total G			0	4	5	2,127	39,058	4.7				54,100
K	Oceanside	C/88	-	6.5	3.0	317	9,866	1.2	31.1	19,908	*	11,700
K	E. Northport	C/91	-	3.8	1.0	-	-	0.0				
K	Blydenburgh (2)	C/85	-	8.0	4.0	-	-	0.0				
K	Old Bethpage	C/86	-	2.8	1.2	112	1,605	0.2	14.3			2,600
K	Smithtown	C/90	-	1.7	1.2	124	2,079	0.2	16.8	4,936	*	2,000
K	Brookhaven	C/96	-	8.0	5.0	765	21,802	2.6	28.5	8,748		25,200
Total K			0	31	15	1,318	35,352	4.2				41,500
	Mohawk Valley	C/92	-	1.2	1.6	110	6,855	0.8	62.3	8,760		
	High Acres	O	686,800	6.4	3.2	574	27,556	3.3	48.0	8,784		24,800
	Tripoli	C/85	-	1.7	1.2	317	9,866	1.2	31.1			
	Seneca Meadows	O	1,153,000	19.0	11.2	1,958	93,233	11.2	47.6	8,733		88,100
	Broome	O	104,600	3.1	2.3	-	-	1.2 (8)			*	
	Monroe/Liv.	C/89	-	5.2	3.2	(1)	(1)	2.4 (8)				22,300
	Madison (5)	O	47,700	1.2	1.2	-	-	0.0				
Statewide Total			2,963,800	89	56	7,885	265,355	35	189			267,400

* Engine total hours

Notes:
1. Data not available
2. Accident destroyed facility; energy contract lapsed.
3. Source, EPA-LMOP Database 12/21/01
4. Source, NYSDEC Annual Reports
5. Planned
6. NY State SW Management Plan 1999-2000 Update
7. Rated Capacity or "Installed Capacity" = MWH Generated/(365 x 24 x 0.95)
8. NYSERDA March 5, 2002 working document

Estimating Methodology

The technical potential for producing electricity from landfill gas is defined for this study as the upper limit theoretically possible for years 2003, 2007, 2012, and 2022. To determine LFGTE potential statewide and in the five load control zones, SCS developed a methodology for determining the amount of municipal solid waste (MSW) that will be landfilled during the study period. This involved reviewing data published by NYSDEC, reviewing data published by the Legislative Commission on Solid Waste Management reports and conducting the study's research. Results are presented in Table 4.5.5, Municipal Solid Waste Management in New York State. This table indicates the disposition of remaining municipal waste tonnage (in addition to what is landfilled and potentially available for LFGTE). Overall, SCS estimates current municipal solid waste generation to be about 24 million tons per year. In addition, SCS assumes total MSW generation will remain flat in the future, although the portion that is recycled is projected to increase and the portion that is exported is expected to decrease. Data in the table are also used for the analysis of municipal solid waste-to-electricity potential.

Table 4.5.5 Municipal Solid Waste Management in New York State (1000 Tons)

	1999		2000		2001(3)	2002(3)	2007(3)	2012(3)	2022(3)
Recycling	5,903	(2)	6,000	(3)	6,100	6,200	6,600	7,000	7,500
Export	5,095		5,378	(3)	6,300	7,000	6,300	4,600	2,700
WTE (4)	3,680	(1,2)	3,638	(1)	3,700	3,700	3,700	4,800	6,000
Digestion								200	400
Landfills:									
Fresh Kills	2,389	(2)	1,800	(3)	900	0	0	0	0
Non-MSW (5)	800	(2)	800	(3)	800	800	800	800	800
MSW (6)	5,717	(2)	6,084	(1)	6,200	6,300	6,600	6,600	6,600
Totals	23,584		23,700		24,000	24,000	24,000	24,000	24,000

Notes:

1. NYSDEC letter to SCS 2/20/2002
2. Legislative Commission on Solid Waste Management, "Where will the Garbage Go," 2000
3. SCS estimate, based on level total waste projections, indicating tonnage estimates to various management options.
4. Reflects existing and new Waste-to-Energy facilities
5. Dedicated non-MSW landfills
6. MSW landfill projections

Many factors affect MSW generation and management, and it is beyond the scope of this analysis to complete sophisticated projections of future MSW generation, disposal and management. The projections of future waste presented in Table 5.5 represents best professional estimates based on SCS' understanding of the waste industry, the New York City Draft Long Term Waste Management Plans and related issues. Key factors considered by SCS when projecting future solid waste trends are summarized below:

- While the overall population of New York has remained fairly constant over the past 20 years, solid waste generation increased by about 24% from 1990 to 1999, according to the Legislative Commission on Solid Waste Management report, "Where Will the Garbage Go? 2000." This report concludes that a significant portion of the increase is due to better accounting practices and an improved economy.
- Recycling increased by a factor of almost 5, from 5.6% in 1990 to 25% in 1999.
- Waste exports increased by almost 2 million tons per year from 1990 to 1999 but are known to have resulted in sharp increases in disposal fees in New York City. It is assumed more cost-effective solid waste management options will be investigated in the future.
- The use of MSW in waste-to-energy facilities remained substantially level from 1900 to 1999 (when reported as a percentage of the total).

Although the population in New York may vary over the 20-year study period, there is no clear correlation between a potential population increase and an increase in MSW generation. Economic factors may have a significant impact on MSW generation, but projecting such impacts are beyond the scope of this

assessment. At the policy level, NYSDEC emphasizes waste reduction and reuse over landfilling and waste-to-energy.

The recycling fraction shown in Table 4.5.5 increases at a 20% rate during the study period. Given the current difficulty in marketing recyclables, this may be optimistic in the short-term but seems reasonable in the long-term. SCS projects that existing municipal waste-to-energy plants will not expand prior to 2012. This seems reasonable given the costs of WTE facilities, the impact of PURPA power contracts that are expiring and negative public perception about the environmental impacts of such plants.

Estimates of the amount of solid waste disposed of in landfills are shown in Table 4.5.6, MSW Landfill Projections in New York State. The table accounts for future capacity planned at known sites (reported by NYSDEC) as well as seven new landfills assumed by SCS to be developed over the study period somewhere in New York by either the public or private sector. Given the present and probable future waste disposal climate, SCS believes it is reasonable to assume that landfills will continue to be the option of choice for waste that is not reduced or reused. Nevertheless, as shown in Table 4.5.6, waste export is expected to continue, including being the option of choice for New York City for at least another decade.

Table 4.5.6 MSW Landfill Projections in New York State(1000 Tons)

	2000	2002	2007	2012	2022
Present operating landfills	6,081	6,303	6,053	3,091	1,585
Existing capacity closed	—	—	(250)	(2,962)	(2,036)
Future planned landfills added (2)	—	—	500	950	—
Future unknown landfills added (3)	—	—	—	2,559 (3)	5,015 (3)
Totals (1)	6,081	6,303	6,553	6,600	6,600

Notes:
1. See Table 5.5 for basis of total MSW landfill projections.
2. Existing or entitled capacity known to NYSDEC (See letter to SCS 2/20/02).
3. Future new landfills to be added for years 2008 - 2012, estimated by SCS.

SCS also assumes that landfills will continue to be operated as anaerobic reactors that produce LFG. New aerobic technologies are available. However, SCS anticipates that any increase due to use of alternative technologies will be offset by implementation of anaerobic “bioreactor” technology at landfills, which produce substantially more LFG per ton.

LFG Models and Potential LFG Recovery

SCS used the EPA LandGem model to develop reasonable projections of LFG recovery rates at the variety of existing and future landfills in New York. Data for MSW in-place and future tonnage was derived from EPA LMOP database information, NYSDEC landfill projections and SCS estimates of future landfill construction. The LandGem model is the recognized regulatory vehicle for developing LFG generation information. SCS has used the model parameters for many years to review actual LFG generation at dozens of sites.

The LandGEM is a simplistic, first order, single-stage model with only two input parameters other than waste receipts and LFG composition. It assumes that the gas generation rate is at its peak upon initial waste placement, after a short lag time during which anaerobic conditions are established in the landfill. The gas generation rate is then assumed to decrease exponentially (i.e., first order decay) as the organic fraction of the landfill refuses decreases.

The model equation is as follows:

$$Q = \sum_{i=1}^{n} 2\, k\, L_0\, M_i \left(e^{-kt_i}\right)$$

where: Q = Methane generation rate from the landfill in the ith year, cf/yr

k = Methane generation rate constant, 1/yr

L_0 = Methane generation potential, cf/ton

M_i = Mass of refuse in the ith section, ton

t_i = Age of the ith section, yrs

i = Section number

The theoretical value for potential methane generation capacity of refuse, L_0, depends on the type of refuse only. The higher the cellulose content is of refuse, the higher the theoretical methane generation capacity. The theoretical methane generation capacity is determined by a stoichiometric method, is based on a gross empirical formula representing the chemical composition of composite refuse (or individual refuse type). The methane generation rate constant, k, determines how quickly the methane generation rate decreases, once it reaches the peak rate upon placement. The higher the value of k, the faster the methane generation rate from each sub-mass decreases over time. The value of k is a function of the following major factors: (1) refuse moisture content, (2) availability of the nutrients for methanogens, (3) pH, and (4) temperature. In general, increasing moisture content increases the rate of methane generation rate.

Typical values for L_0 and k are published by the U.S. EPA's Office of Air Quality Planning and Standards, which develops emission factors for various industries, including landfills. SCS's New York office has

analyzed LFG recovery (not generation) from many MSW landfill sites in the northeast. The k and L_0 values for each of these landfills were estimated using actual collection rates measured at sites over multiple years. These model inputs were used for this study.

Landfill Categories

The technical potential for recovering LFG for electricity production in New York is presented in Tables 4.5.7 through 4.5.10 for the following categories:

- Existing or expanded LFGTE facilities at operating or closed landfills (Table 4.5.7). These landfills already have LFGTE plants, which may continue operation, be expanded, or close in the future.
- Potential new facilities at operating or future landfills (Table 4.5.8). These operating landfills do not have presently have LFGTE and are prime candidates for new facilities.
- Potential new facilities at larger closed landfills (Table 4.5.9). These closed landfills do not have LFGTE but have over 1 million tons of waste in place and have technical potential, given the available landfill gas, for five to 10 years.

Potential new facilities at smaller closed landfills are noted in Table 4.5.10. These closed landfills also have close to 1 million tons of waste in place but are unlikely to be developed without significant incentives beyond those currently being contemplated in New York.

It is noted that each individual landfill shown on these tables was modeled for LFG production based on estimates of tons of waste disposed per year and estimated closure dates. The model takes into account the operating years (from opening to closure) of the site and the average estimated tons per year landfilled during this period. Information used to establish this data was obtained from the latest USEPA LMOP database dated Dec. 21, 2001, and from NYSDEC Annual Reports from operating facilities. NYSDEC also provided June 2001 official landfill-capacity data, including annual permit limits (tons), existing and proposed future capacity at existing and certain future sites. This information was used to calculate the rate of filling and to model LFG recovery for each project year. This methodology represents a reasonably accurate assessment of present and future LFG recovery, and includes recovery from future new landfills at unknown locations.

For modeling purposes, SCS used an 80% gas-collection system efficiency factor. This factor is representative of the maximum amount of LFG that can typically be captured from operating landfills.

Table 4.5.11, Total Potential Landfill Gas Recovery in New York State, summarizes the potentially recoverable LFG statewide and in five load control zones for the study period. Year 2002 includes only existing or planned LFGTE (in the short term) facilities from Table 4.5.7. The 2002 landfill gas recovery estimate of 12,408 MMCF (57 MW) in Table 4.5.7 is similar to the NYSERDA March 5, 2002 Working

Document Tier 1 totals (53 MW), which is assumed to be "nameplate capacity." On the other hand, actual 2000 production was only 35 MW, and the Table 4.5.7-B Base Case estimate is 48 MW for 2003.

Table 4.5.8 includes seven "future landfills" that will need to be sited and developed starting in year 2008 to year 2019 in order to maintain the total statewide landfill tonnage of 6.6 million tons of municipal solid waste disposed by landfilling, as shown in Table 4.5.6. The locations and exact sizes of these landfills is unknown. For this study, SCS theoretically placed the landfills in locations consistent with present and probable future locations.

Table 4.5.7 Technical Potential Landfill Gas Recovery from Existing or Expanded Landfill Gas-To-Electricity Facilities in New York State

Load Control Zone	Landfill Name	Operating or Closed/yr.	MSW Received 2000 Tons	Tons (3.) in Place (MM)	Existing & Proposed LF Capacity (4) MM tons	Yr Open		Year Closed		Estimated Tons Per Year		Potential LFG Recovery MMCF 2002 (5)	Potential LFG Recovery MMCF 2007 (5)	Potential LFG Recovery MMCF 2012 (5)	Potential LFG Recovery MMCF 2022 (5)
A	Modern	O	550,000	5.1	3.9	1983		2007	*	550,000		1,056	1,320	1,075	377
A	Lancaster	C/85	-	2.4	-	1950		1985		68,000	(8)	500	350	150	50
A	Tonawanda (9)	C	-	1.0	-	1975	*	1995	*	50,000	*	-	-	-	-
Total A			550,000	9	4					668,000		1,556	1,670	1,225	427
F	Albany	O	273,000	4.1	2.9	1969		2011	*	275,000		770	898	837	294
F	Saratoga Spr (7)	C/91	-	2.1	-	1937		1991		40,000		143	103	71	0
F	Colonie	O	148,700	1.5	4.0	1969		2018	*	150000		305	385	393	173
Total F			421,700	8	7					465,000		1,219	1,385	1,301	466
G	Al Turi (1)	C/00	(1)	4.0	2.6	1968		2000	*	125,000		607	556	453	159
G	Orange County	C	-									636	582	474	166
Total G			0	4	3					125,000		1,244	1,138	927	325
K	Oceanside	C/88	-	6.5	-	1964		1988		270,000		487	317	14	5
K	E. Northport	C/91	-	3.8	-	1961	*	1991		120,000		379	271	188	5
K	Blydenburgh (2)	C/85	-	8.0	-	1963		1985		360,000		322	16	14	5
K	Old Bethpage	C/86	-	2.8	-	1968		1986		150,000		113	16	14	5
K	Smithtown	C/90	-	1.7	-	1979		1990		155,000		157	110	75	5
K	Brookhaven	C/96	-	8.0	-	1974		1996		360,000		750	600	450	190
Total K			0	31	0					1,415,000		2,207	1,331	755	215
	Mohawk Valley	C/92	-	1.2	-	1972		1992		60,000		127	93	65	0
	High Acres	O	686,800	6.4	8.4	1972		2012	*	680,000		1,322	1,689	1,725	605
	Tripoli	C/85	-	1.7	-	1964		1985		155,000		68	0	0	0
	Seneca Meadows	O	1,153,000	19.0	11.0	1981		2009	*	1,200,000		3,529	4,071	3,503	1,228
	Broome	O	104,600	3.1	9.5	1969		1995	*	100,000		487	445	363	127
	Monroe/Liv.	C/89	-	5.2	-	1964		1989		208,000		438	298	199	0
	Madison (6)	O	47,700	1.2	1.4	1974		2024		50,000		211	228	211	93
Statewide Total			2,963,800	89								12,408	12,348	10,273	3,486

* SCS Estimate

Notes:
1. Temporarily shutdown in 2001
2. Accident destroyed facility; energy contract lapsed. Facility shutdown in 2000.
3. Source, EPA-LMOP Database 12/21/01
4. Source, NYSDEC, Existing and Proposed Capacity
5. Potential LFG recovery calculations performed by EPA LandGem Model. Model inputs for tonnages prior to 2000 were based on in-place tonnages divided by the years in operation. Where applicable, received tonnages for 2000 were used and future tonnages were projected out to the anticipated closing year. 80% collection system coverage is assumed.
6. Planned
7. Direct Use
8. Gas flow based on reported 2000 estimates.
9. Mostly ash per NYSDEC survey

Table 4.5.8 Technical Potential Landfill Gas Recovery from Existing and Future Landfills in New York State

Load Control Zone	Landfill Name	MSW Received Tons (3)	Tons (2) in Place (MM)	Existing/ (3) Proposed LF Capacity MM tons	Year Opened (2)	Projected Closure Year (2)	Estimated Future Tons Per Year *	Potential (1) LFG Recovery MMCF 2002	Potential (1) LFG Recovery MMCF 2007	Potential (1) LFG Recovery MMCF 2012	Potential (1) LFG Recovery MMCF 2022
A	Mill Seat	239,000	1.2	7.7	1993	2014	380,000	792	1,296	1,687	1,557
A	Chautauqua	253,700	3.2	5.1	1988 *	2020 *	250,000	1,424	1,646	1,815	1,947
A	Niagara Rec.	565,200	2.6	4.9	1995	2009	550,000	1,536	2,219	2,069	1,869
A	WMI-Albion	-	-	7.4	2005 *	2022 *	500,000 *	-	474	1,125	2,073
A	CID	493,500	4.0	26.7	1992 *	2052 *	500,000	1,978	2,528	2,952	3,754
A	Farmersville	-	-	16.8	2012 *	2033	800,000 *	-	-	225	2,132
A	Future-1				2008 *	2025 *	500,000 *	-	-	703	1,817
A	Future-6				2015 *	2025 *	1,000,000 *	-	-	-	1,938
Total A		1,551,400	11	69			3,480,000	5,729	8,163	10,577	17,089
F	Saratoga	-	-	1.4	2004 *	2032	50,000 *	-	63	127	230
F	Fulton	87,500	0.4	2.4	1989	2016	85,000	237	342	424	426
F	Future-2				2012 *	2025 *	300,000 *	-	-	84	800
F	Future-7				2019 *	2025 *	500,000 *	-	-	-	485
Total F		87,500	0.4	3.8			435,000	237	406	635	1,940
	DANC	245,000		8.5	1992	2017	265,000 *	985	1,284	1,515	1,546
	Auburn (4)	27,000		0.6	1995 *	2017 *	27,000 *				
	Chenango	21,000		1.6	1980 *	2050 *	21,000	174	186	195	219
	Cortland	24,200		0.4	1995 *	2012 *	24,000	70	99	110	100
	Bristol Hill	43,000	0.1	2.5	1997	2033	45,000	84	145	192	275
	Chemung	99,500	2.7	2.4	1973	2024 *	100,000	1,080	1,107	1,125	1,211
	Ontario	265,600	1.5	1.0	1975	2004 *	250,000	276	368	323	292
	Steuben	80,200	0.6	1.6	1988	2020	80,000	303	392	461	525
	Alleghany	32,800	0.4	0.7	1987	2011	32,000	268	286	263	238
	Oneida/Herk	-	-	12.9	2010 *	2094 *	150,000 *	-	-	127	472
	Hyland	180,500		2.0	1996	2011	180,000	455	684	735	664
	Sullivan	191,500	1.4	5.5	1994	2025	190,000	710	924	1,089	1,398
	Delaware	49,300	0.8	0.7	1984	2014	50,000	342	379	408	357
	Clinton	175,000	0.4 *	2.2	1998 *	2010	175,000	333	569	593	536
	Franklin	45,000		0.9	2000 *	2020 *	45,000	49	114	165	218
	Future-3				2010 *	2025 *	1,000,000	-	-	844	3,150
	Future-4				2010 *	2025 *	500,000	-	-	422	1,575
	Future-5				2011 *	2025 *	380,000	-	-	214	1,105
Statewide Total		3,118,500	19.3	115.9				11,092	15,106	19,991	32,908

Notes:
* SCS Estimate
1. Potential LFG recovery calculations performed by EPA LandGem Model. Model inputs for tonnages prior to 2000 were based on in-place tonnages divided by the years in operation. Where applicable, received tonnages for 2000 were used and future tonnages were projected out to the anticipated closing year. 80% collection system coverage is assumed.
2. Source, EPA-LMOP Database 12/21/01
3. Source, NYSDEC
4. Direct Use. No Power Potential.

Table 4.5.9 Technical Potential Landfill Gas Recovery from Existing and Future Landfills in New York State

Load Control Zone	Landfill Name	LFG Col. Sys Y or N	Tons (1) in Place (MM)	Year (1) Open		Year (1) Closed	Est. Tons* Per Year		Potential LFG Recovery (2) MMCF 2002	Potential LFG Recovery (2) MMCF 2007	Potential LFG Recovery (2) MMCF 2012	Potential LFG Recovery (2) MMCF 2022
A	Orleans	N	1.7	1983		1993	170,000		281	154	85	0
F	Queensbury	N	1.6	1962		1993	51,000		156	86	47	0
F	Troy	Y	1.5	1969		1993	62,000		146	80	44	0
TOTAL F			3				113,000		302	166	91	1
G	Haverstraw	N	1.2	1970		1996	46,000		126	69	38	11
J	Edgemere	N	2.0 *	1981	*	1991	200,000	*	175	96	53	0
K	East Hampton	N	1.0	1942		1993	20,000		74	41	22	0
K	Pt. Washington	Y	2.1	1983		1991	260,000		217	119	65	20
K	Riverhead	Y	2.0	1963		1993	66,000		206	113	62	19
K	North Sea	Y	1.1	1963		1995	34,000		113	62	34	10
K	Bablyon	N	6.0 *	1950		1990	75,000		279	153	84	25
TOTAL K			12.2				455,000		890	488	268	74
	Clifton Park	N	1.5	1963		1991	53,000		155	85	47	14
	Croton Pt.	Y	10.0	1966	*	1996	330,000	*	1,032	566	311	94
	Tomkins Cty.	N	1.0 *	1977	*	1997	50,000	*	103	57	31	9
	MOSA	N	1.0	1974		1993	52,000		103	57	31	9
	Laidlaw	N	1.4	1970		1992	63,000		144	79	44	13
	Austro Bros.	N	1.4	1972		1994	58,000		144	79	44	13
Statewide Total			36.5						3,456	1,897	1,041	240

Notes:

* Estimated by SCS

1. Source, EPA-LMOP Database
2. Potential LFG recovery calculations performed by EPA LandGem Model. Model inputs for tonnages prior to 2000 were based on in-place tonnages divided by the years in operation. Where applicable, received tonnages for 2000 were used and future tonnages were projected out to the anticipated closing year. 80% collection system is assumed.

Table 4.5.10 Technical Potential Landfill Gas Recovery from Smaller, Closed Landfills in New York State, NYSDEC Database > 20 Acres

Load Control Zone	Landfill Name	LFG Col. Sys (Y or N)	Size Acres	Tons in Place(1) (MM)	Year Open (2)	Year Closed	Estimated Tons per year *	Potential (3) LFG Recovery MMCF 2002	Potential (3) LFG Recovery MMCF 2007	Potential (3) LFG Recovery MMCF 2012	Potential (3) LFG Recovery MMCF 2022
F	Niskayuna	N	25	1.25	1970	1995	50,000	247	113	62	19
F	Moriah	N	20	1.00	1976	2001	40,000	197	91	50	15
F	Moreau	N	37	1.85	1974	1999	74,000	365	168	92	28
F	Hudson	Y	20	1.00				0	0	0	0
Total F								809	371	204	61
G	New Paltz	Y	21	1.05	1974	1999	42,000	207	95	52	16
G	Ulster	Y	33	1.65	1975	2000	66,000	326	149	82	25
G	Woodstock	N	19	0.95	1973	1998	38,000	187	86	47	14
G	Phillipstown	N	20	1.00	1972	1997	40,000	197	91	50	15
Total G								917	421	231	70
J	Bronx, Oak Pt.	N	20	1.00	1971	1996	40,000	197	91	50	15
J	Richmond, A & A	N	30	1.50	1971	1996	60,000	296	136	75	22
Total J								493	226	124	37
Total K	Merrick	N	50	2.50	1975	2000	100,000	493	226	124	37
	Monticello	N	50	2.00	1975	2000	100,000	493	226	124	37
	Schuyler Falls	Y	31	1.50	1972	1997	62,000	306	140	77	23
	Altamont	N	25	1.25	1971	1996	50,000	247	113	62	19
	Malone	N	25	1.25	1971	1996	50,000	247	113	62	19
	Chenango Rd. #3	N	20	1.00	1973	1998	40,000	197	91	50	15
Statewide Total								4,202	1,929	1,059	319

Notes

* SCS Estimate

1. SCS Estimate @ 50,000 tons per acre average.
2. SCS estimates 25 year operating life.
3. Potential LFG recovery calculations performed by EPA LandGem Model. Model inputs for tonnages prior to 2000 were based on in-place tonnages divided by the years in operation. Where applicable, received tonnages for 2000 were used and future tonnages were projected out to the anticipated closing year. 80% collection system coverage is assumed.

Table 4.5.11 Total Potential Landfill Gas Recovery in New York State

Existing or Expanded LFG to Electric Plants at operating and closed Landfills Table 4.5.4	Potential LFG Recovery MMCF 2002	Potential LFG Recovery MMCF 2007	Potential LFG Recovery MMCF 2012	Potential LFG Recovery MMCF 2022
Statewide	12,408	12,348	10,273	3,486
A	1,556	1,670	1,225	427
F	1,219	1,385	1,301	466
G	1,244	1,138	927	325
J				
K	2,207	1,331	755	215
Potential new LFG to Elec. Plants at Operating and future Landfills Table 4.5.5				
Statewide		15,106	19,991	32,908
A		8,163	10,577	17,089
F		406	635	1,940
G				
J				
K				
Potential new LFG to Elec. Plants at Larger closed landfills Table 4.5.6				
Statewide		1,897	1,041	240
A		154	85	0
F		166	91	1
G		69	38	11
J		96	53	0
K		488	268	74
Potential new LFG to Elec. Plants at Smaller closed Landfills Table 4.5.7				
Statewide		1,929	1,059	319
A				
F		371	204	61
G		421	231	70
J		226	124	37
K		226	124	37
Total Statewide	12,408	31,280	32,364	36,952
Total A	1,556	9,987	11,887	17,516
Total F	1,219	2,328	2,231	2,468
Total G	1,244	1,628	1,196	406
Total J	-	323	177	38
Total K	2,207	2,046	1,147	326

Electric Power Conversion Factors

Electric-power generation technical potential is estimated by determining LFG gas output in MMCF for each study year (as shown in Table 4.5.11), developing appropriate electricity conversion ractors, and estimating the amount of power to be produced by each technology statewide and for each of five load control zones. Table 4.5.12, Landfill Gas Technology Electric Conversion Factors, and Table 4.5.13, Landfill Gas Utilization Efficiency Factors, provide the basis for determining the net power production capability of the three technologies being assessed.

Heat rates from selected manufacturers data are used, together with equipment load factors and subtractions for plant parasitic loads, to arrive at a net electric production in kWh/ MMCF of LFG collected at 50% methane for year 2002, as shown in Table 4.5.12. An overall collection and utilization efficiency of 95% was used, as shown in Table 4.5.13.

Table 4.5.12 Landfill Gas Technology Electric Conversion Factors (2002)

Technology	Heat Rate(1) LHV(3) Btu/kWh	Elec. Conv (2) kWh/MMCF	Net Elec. Prod (4) kWh/MMCF
Large Systems	14,600 Btu/kWh	29,300	23,500
Engines	9600 Btu/kWh	44,500	38,700
Microturbines	14,000 Btu/kWh	30,500	24,400

Notes:
1. Average full load rating from Caterpillar, Jenbacher Waukesha, Capstone, Solar, Ingersoll-Rand.
2. Assumes 95% of full-load rating for average conditions.
3. LHV of LFG = 450 Btu/cf.
4. Assumes parasitic load of 15% for turbines and microturbines, 8% for engines, and a 95% gas-utilization efficiency factor (Table 4.5.10) for all technologies.

Table 4.5.13 Landfill Gas Utilization Efficiency Factors

Factor	% Reduction
Equipment to Gas Matchup (1)	95%
Mechanical/Elec. Availability (2)	95%
Maximum Utilization Efficiency	95%

Notes:
1. Economical equipment selection can usually only capture about 95% of the gas available, at best.
2. Maintenance and normal outages reduce output by 5%.

After 2002, SCS assumes small incremental increases in net electrical production efficiency of 3-6% will be achieved over 20 years for the technologies.

Technical Potential for Selected Technologies

SCS selected technology use factors based on estimates of the percentage of each technology listed (large systems, I/C engines or microturbines). For each study year, these percentages are adjusted to reflect SCS's estimate of factors impacting changes, as follows:

- In early years I/C engines will dominate, accounting for over 95% of all installations.
- As microturbines become more known and incentives are implemented, use of this technology may increase at smaller and closed sites. However, microturbines will never be a major producer when measured in kW or kWh, because of the small size of the technology.
- As existing and new landfills become larger, larger-scale technologies may be favored over banks of I/C engines. Similarly, NYSDEC regulators may view the lower NOx emissions from such systems as more desirable than they do today.

Tables 4.5.14 to 4.5.17 (Landfill Gas-to-Electricity Technical Potential Capacity and Generation for the years 2002, 2007, 2012 and 2022) provide a breakdown of estimated power production and rated capacity by year, technology, load control zone and statewide. Rated capacity or "installed capacity" is defined as 95% of the potentially convertible electricity based on full utilization of potentially recoverable gas. In practice, it is seldom possible to achieve full utilization of potentially recoverable gas, as discussed below. Comparing the base case in 2002 of 48 MW with the technical potential of 57 MW illustrates this.

Table 4.5.14 Landfill Gas-To-Electricity Technical Potential Capacity and Generation — 2002

Load Control Zone	Total Potential LFG Recovery MMCF	Technology / % Use (1)		Elec. (2) Conversion Rate Kwh/MMCF	Elec. Technical Potential Kwh (1000)	Rated or "Installed" Capacity kW (3)
Statewide	12,408	T	3%	23,500	8,748	1,051
		E	95%	38,700	456,197	54,818
		M	2%	24,400	6,055	728
A	1,556	T	3%	23,500	1,097	132
		E	95%	38,700	57,217	6,875
		M	2%	24,400	759	91
F	1,219	T	3%	23,500	859	103
		E	95%	38,700	44,804	5,384
		M	2%	24,400	595	71
G	1,244	T	3%	23,500	877	105
		E	95%	38,700	45,721	5,494
		M	2%	24,400	607	73
J	-	T	3%	23,500	-	0
		E	95%	38,700	-	0
		M	2%	24,400	-	0
K	2,207	T	3%	23,500	1,556	187
		E	95%	38,700	81,157	9,752
		M	2%	24,400	1,077	129

Notes:
1. Technologies: T=Large System: E=Internal Combustion engine; M=Microturbine;
2. Converstion rates from manufacturers data. See Table 5.9.
3. Rated capacity (kW) = kWh(1000) generated/(365 x 24 x 0.95)

Table 4.5.15 Landfill Gas-To-Electricity Technical Potential Capacity and Generation — 2007

Load Control Zone	Total Potential LFG Recovery MMCF	Technology / % Use (1)		Elec. (2) Conversion Rate Kwh/MMCF	Elec. Technical Potential Kwh (1000)	Rated or "Installed" Capacity kW (3)
Statewide	31,280	T	4%	24,000	30,029	3,608
		E	93%	39,200	1,140,355	137,029
		M	3%	25,000	23,460	2,819
A	9,987	T	4%	24,000	9,587	1,152
		E	93%	39,200	364,085	43,750
		M	3%	25,000	7,490	900
F	2,328	T	4%	24,000	2,235	269
		E	93%	39,200	84,873	10,199
		M	3%	25,000	1,746	210
G	1,628	T	4%	24,000	1,563	188
		E	93%	39,200	59,356	7,132
		M	3%	25,000	1,221	147
J	323	T	4%	24,000	310	37
		E	93%	39,200	11,765	1,414
		M	3%	25,000	242	29
K	2,046	T	4%	24,000	1,964	236
		E	93%	39,200	74,584	8,962
		M	3%	25,000	1,534	184

Notes:

1. Technologies: T=Large System: E=Internal Combustion engine; M=Microturbine; percent use estimated by SCS.
2. Converstion rates from manufacturers data. Incremental increase above Table 5.11.
3. Rated capacity (kW) = kWh(1000) generated/(365 x 24 x 0.95)

Table 4.5.16 Landfill Gas-To-Electricity Technical Potential Capacity and Generation — 2012

Load Control Zone	Total Potential LFG Recovery MMCF	Technology / % Use (1)		Elec. (2) Conversion Rate Kwh/MMCF	Elec. Technical Potential Kwh (1000)	Rated or "Installed" Capacity kW (3)
Statewide	32,364	T	5%	24,500	39,646	4,764
		E	91%	39,700	1,169,218	140,497
		M	4%	25,500	33,011	3,967
A	11,887	T	5%	24,500	14,561	1,750
		E	91%	39,700	429,428	51,602
		M	4%	25,500	12,124	1,457
F	2,231	T	5%	24,500	2,733	328
		E	91%	39,700	80,601	9,685
		M	4%	25,500	2,276	273
G	1,196	T	5%	24,500	1,465	176
		E	91%	39,700	43,207	5,192
		M	4%	25,500	1,220	147
J	177	T	5%	24,500	217	26
		E	91%	39,700	6,399	769
		M	4%	25,500	181	22
K	1,147	T	5%	24,500	1,405	169
		E	91%	39,700	41,440	4,980
		M	4%	25,500	1,170	141

Notes:

1. Technologies: T=Large System: E=Internal Combustion engine; M=Microturbine; percent use estimated by SCS.

2. Converstion rates from manufacturers data. See Table 4.9.

3. Rated capacity (kW) = kWh(1000) generated/(365 x 24 x 0.95)

Table 4.5.17 Landfill Gas-To-Electricity Technical Potential Capacity and Generation — 2022

Load Control Zone	Total Potential LFG Recovery MMCF	Technology / % Use (1)		Elec. (2) Conversion Rate Kwh/MMCF	Elec. Technical Potential Kwh (1000)	Rated or "Installed" Capacity kW (3)
Statewide	36,952	T	6%	25,000	55,429	6,660
		E	89%	40,000	1,315,507	158,076
		M	5%	26,000	48,038	5,772
A	17,516	T	6%	25,000	26,274	3,157
		E	89%	40,000	623,568	74,930
		M	5%	26,000	22,771	2,736
F	2,468	T	6%	25,000	3,702	445
		E	89%	40,000	87,863	10,558
		M	5%	26,000	3,208	386
G	406	T	6%	25,000	609	73
		E	89%	40,000	14,454	1,737
		M	5%	26,000	528	63
J	38	T	6%	25,000	57	7
		E	89%	40,000	1,344	162
		M	5%	26,000	49	6
K	326	T	6%	25,000	489	59
		E	89%	40,000	11,616	1,396
		M	5%	26,000	424	51

Notes:

1. Technologies: T=Large System: E=Internal Combustion engine; M=Microturbine; percent use estimated by SCS.

2. Converstion rates from manufacturers data. Incremental increase above Table 5.13.
3. Rated capacity (kW) = kWh(1000) generated/(365 x 24 x 0.95)

Energy and Capacity Coincidence Factors

SCS reviewed actual LFG and power-production data from existing LFGTE facilities in New York as well as data from other facilities nationwide to develop energy- and capacity coincidence factors for average, seasonal, and hourly production. Based on this research, SCS concludes it is not reasonable or realistic to propose such factors for several reasons, as follows.

Actual New York and national production from 1999, 2000, and 2001 for both gas production (MMCF) and power production (kWh) are quite variable. Such variations are due to many factors other than the season or time of day, including:

- Collection system blockages or well failures.
- Miscellaneous outages for maintenance or landfill operations.
- Power plant maintenance or off-line conditions.
- Failure to install adequate collection system components.

Landfill status is a more important factor than season and varies between sites:

- A closed landfill always has a declining gas/power production over a six-month period, no matter the season.
- An operating landfill tends to have increasing gas production until closure, if the collection system keeps up with the expansion.
- Gas collection systems are expanded periodically, not seasonally.
- Power plant engines or turbines are installed to meet demand or are removed from service at random times. This has more to do with financial/budget considerations than issues related to power production. Therefore, equipment nameplate rating is not an accurate measure of electric production capability.

Actual operating data indicate a seasonal variation of approximately plus or minus 3% of the annual average for both summer and winter for a well-run facility. However, this variation can be greater for individual sites. On a statewide basis, SCS estimates that a plus or minus 3% coincidence factor for both energy and capacity is reasonable, *regardless of season*. Overall, SCS recommends that a 100% factor be used for all seasons. No hourly differences are meaningful. It is also noted that LFGTE facilities cannot readily be brought on- or off-line seasonally and therefore should be considered (and operated) as base load plants.

ECONOMIC POTENTIAL

Economic potential is defined in this study as the subset of technical potential that is cost-effective compared to the electricity supply it would replace. Economic potential is determined by removing from technical potential the portion of LFGTE that is not cost-effective under long-run estimates of avoided electricity costs. NYSERDA furnished projections of avoided electric generation and capacity costs for each load zone, which vary by year and within each year according to season and time of day. LFGTE technologies were "screened" (as were all efficiency measures and renewable technologies included in this study) to determine the portion that are projected to be economic from a societal cost perspective.

Of the technical potential identified for landfill gas, the portion represented by the engines is cost-effective in the screening analysis under the high set of statewide avoided costs. None of the LFGTE technologies is cost effective when low statewide avoided costs are applied. With high statewide avoided costs, the economic potential for incremental (over base case) energy production from LFGTE engines is projected to be 438 GWh in 2007, 406 GWh in 2012, and over 418 GWh in 2022. The decline in the level of economic resource is determined by the LFG recovery potential in each of the study time horizons.

ACHIEVABLE POTENTIAL

Base Case

In this study, the base case for LFGTE includes facilities that are already on-line, permitted or well along in planning as of late 2002. Existing LFGTE systems are expanded in some cases and approximately five new installations at large private sites and one municipal site are planned. Year 2003 estimates do not include any of the planned new facilities, which are reflected in the 2007 estimates. From the modeled gas recovery projections, it is estimated that approximately 95% of the normally recoverable gas will be utilized. As noted above, the gas recovery model assumes that only 80% of gas generation will be recovered and additionally a 95% generation availability factor is used. The total estimated gas recovery is based primarily on the selection of landfills known to be planning or highly likely to build new (or expanded) LFGTE facilities in the immediate future.

Since all new landfills in New York are large enough to be defined as "large" facilities by the federal EPA, they will be required to install LFG collection systems to conform to federal NSPS rules. Such facilities will therefore have gas available as soon as (or before) the rules are applicable. This regulatory requirement is expected to drive the process of LFG collection at virtually all New York landfills in the future. Tables 5.7-B through 5.11-B show landfill gas recovery for the base case in New York State and Tables 5.14-B to 5.17-B show the landfill gas-to-electricity base case capacity and generation for the base case in New York State by year and technology.

Table 4.5.7-B Landfill Gas Recovery from Existing or Expanded Landfill Gas-To-Electricity Facilities in New York State

Load Control Zone	Landfill Name	Operating or Closed/yr.	MSW Received 2000 Tons	Tons (3.) in Place (MM)	Existing & Proposed LF Capacity (4) MM tons	Yr Open		Year Closed		Estimated Tons Per Year		Potential LFG Recovery MMCF 2002 (5)	Potential LFG Recovery MMCF 2007 (5)	Potential LFG Recovery MMCF 2012 (5)	Potential LFG Recovery MMCF 2022 (5)
A	Modern	O	550,000	5.1	3.9	1983		2007	*	550,000		1,056	1,320	1,075	377
A	Lancaster	C/85	-	2.4	-	1950		1985		68,000	(8)	500	350	150	50
A	Tonawanda (9)	C	-	1.0	-	1975	*	1995	*	50,000	*	-	-	-	-
Total A			550,000	9	4					668,000	**	1,478	1,586	1,164	406
F	Albany	O	273,000	4.1	2.9	1969		2011	*	275,000		770	898	837	294
F	Saratoga Spr (7)	C/91	-	2.1	-	1937		1991		40,000		-	-	-	-
F	Colonie	O	148,700	1.5	4.0	1969		2018	*	150000		305	385	393	173
Total F			421,700	8	7					465,000	**	1,022	1,219	1,169	443
G	Al Turi (1)	C/00	(1)	4.0	2.6	1968		2000	*	125,000		607	556	453	159
G	Orange County	C	-									636	582	474	166
Total G			0	4	3					125,000	**	1,181	1,081	880	309
K	Oceanside	C/88	-	6.5	-	1964		1988		270,000		250	175	50	5
K	E. Northport	C/91	-	3.8	-	1961	*	1991		120,000		-	-	-	-
K	Blydenburgh (2)	C/85	-	8.0	-	1963		1985		360,000		-	-	-	-
K	Old Bethpage	C/86	-	2.8	-	1968		1986		150,000		-	-	-	-
K	Smithtown	C/90	-	1.7	-	1979		1990		155,000		157	110	75	5
K	Brookhaven	C/96	-	8.0	-	1974		1996		360,000		750	600	450	190
Total K			0	31	0					1,415,000	**	1,099	841	546	190
	Mohawk Valley	C/92	-	1.2	-	1972		1992		60,000		-	-	-	-
	High Acres	O	686,800	6.4	8.4	1972		2012	*	680,000		1,322	1,689	1,725	605
	Tripoli	C/85	-	1.7	-	1964		1985		155,000		68	0	0	0
	Seneca Meadows	O	1,153,000	19.0	11.0	1981		2009	*	1,200,000		3,529	4,071	3,503	1,228
	Broome	O	104,600	3.1	9.5	1969		1995	*	100,000		487	445	363	127
	Monroe/Liv.	C/89	-	5.2	-	1964		1989		208,000		400	298	199	0
	Madison (6)	O	47,700	1.2	1.4	1974		2024		50,000		211	228	211	93
Statewide Total			2,963,800	89							**	10,497	11,121	9,459	3,297

* SCS Estimate

** Total flows are estimated to be 95% of individual landfill modeled flows.

Notes:

1. Temporarily shutdown in 2001
2. Accident destroyed facility; energy contract lapsed. Facility shutdown in 2000.
3. Source, EPA-LMOP Database 12/21/01
4. Source, NYSDEC, Existing and Proposed Capacity
5. Potential LFG recovery calculations performed by EPA LandGem Model. Model inputs for tonnages prior to 2000 were based on in-place tonnages divided by the years in operation. Where applicable, received tonnages for 2000 were used and future tonnages were projected out to the anticipated closing year. 80% collection system coverage is assumed.
6. Planned
7. Direct Use
8. Gas flow based on reported 2000 estimates.
9. Mostly ash per NYSDEC survey

Table 4.5.8-B Landfill Gas Recovery from Operating and Future Landfills in New York State

Load Control Zone	Landfill Name	MSW Received Tons (3)	Tons (2) in Place (MM)		Existing/ (3) Proposed LF Capacity MM tons	Year Opened (2)		Projected Closure Year (2)		Estimated Future Tons Per Year *		Potential (1) LFG Recovery MMCF 2002	Potential (1) LFG Recovery MMCF 2007	Potential (1) LFG Recovery MMCF 2012	Potential (1) LFG Recovery MMCF 2022
A	Mill Seat	239,000	1.2		7.7	1993		2014		380,000		792	1,296	1,687	1,557
A	Chautauqua	253,700	3.2		5.1	1988	*	2020	*	250,000		1,424	1,646	1,815	1,947
A	Niagara Rec.	565,200	2.6		4.9	1995		2009		550,000		1,536	2,219	2,069	1,869
A	WMI-Albion	-	-		7.4	2005	*	2022	*	500,000	*	-	474	1,125	2,073
A	CID	493,500	4.0		26.7	1992	*	2052	*	500,000		1,978	2,528	2,952	3,754
A	Farmersville	-	-		16.8	2012	*	2033		800,000	*	-	-	225	2,132
A	Future-1					2008	*	2025	*	500,000	*	-	-	703	1,817
A	Future-6					2015	*	2025	*	1,000,000	*	-	-	-	1,938
Total A		1,551,400	11		69					3,480,000	**	4,870	6,938	8,990	14,525
F	Saratoga	-	-		1.4	2004	*	2032		50,000	*	-	-	-	-
F	Fulton	87,500	0.4		2.4	1989		2016		85,000		-	-	-	-
F	Future-2					2012	*	2025	*	300,000	*	-	-	84	800
F	Future-7					2019	*	2025	*	500,000	*	-	-	-	485
Total F		87,500	0.4		3.8					435,000	**	-	-	72	1,092
	DANC	245,000			8.5	1992		2017		265,000	*	-	1,284	1,515	1,546
	Auburn (4)	27,000			0.6	1995	*	2017	*	27,000	*	-	-	-	-
	Chenango	21,000			1.6	1980	*	2050	*	21,000		-	-	-	-
	Cortland	24,200			0.4	1995	*	2012	*	24,000		-	-	-	-
	Bristol Hill	43,000	0.1		2.5	1997		2033		45,000		-	-	-	-
	Chemung	99,500	2.7		2.4	1973		2024	*	100,000		-	-	-	-
	Ontario	265,600	1.5		1.0	1975		2004	*	250,000		-	-	-	-
	Steuben	80,200	0.6		1.6	1988		2020		80,000		-	-	-	-
	Alleghany	32,800	0.4		0.7	1987		2011		32,000		-	-	-	-
	Oneida/Herk	-	-		12.9	2010	*	2094	*	150,000	*	-	-	-	-
	Hyland	180,500			2.0	1996		2011		180,000		-	-	-	-
	Sullivan	191,500	1.4		5.5	1994		2025		190,000		-	-	-	-
	Delaware	49,300	0.8		0.7	1984		2014		50,000		-	-	-	-
	Clinton	175,000	0.4	*	2.2	1998	*	2010		175,000		-	-	-	-
	Franklin	45,000			0.9	2000	*	2020	*	45,000		-	-	-	-
	Future-3					2010	*	2025	*	1,000,000		-	-	844	3,150
	Future-4					2010	*	2025	*	500,000		-	-	422	1,575
	Future-5					2011	*	2025	*	380,000		-	-	214	1,105
Statewide Total		3,118,500	19.3		115.9						**	4,870	8,030	11,607	21,886

Notes:

* SCS Estimate

** Total flows are estimated to be 85% of individual landfill modeled flows.

1. Potential LFG recovery calculations performed by EPA LandGem Model. Model inputs for tonnages prior to 2000 were based on in-place tonnages divided by the years in operation. Where applicable, received tonnages for 2000 were used and future tonnages were projected out to the anticipated closing year. 80% collection system coverage is assumed.
2. Source, EPA-LMOP Database 12/21/01
3. Source, NYSDEC
4. Direct Use. No Power Potential.

Table 4.5.9-B Landfill Gas Recovery from Larger Landfills in New York State

Load Control Zone	Landfill Name	LFG Col. Sys Y or N	Tons (1) in Place (MM)	Year (1) Open		Year (1) Closed	Est. Tons* Per Year		Potential LFG Recovery (2) MMCF 2002	Potential LFG Recovery (2) MMCF 2007	Potential LFG Recovery (2) MMCF 2012	Potential LFG Recovery (2) MMCF 2022
A	Orleans	N	1.7	1983		1993	170,000		-	-	-	-
F	Queensbury	N	1.6	1962		1993	51,000		-	-	-	-
F	Troy	Y	1.5	1969		1993	62,000		146	80	44	0
TOTAL F			3				113,000		146	80	44	0
G	Haverstraw	N	1.2	1970		1996	46,000		-	-	-	-
J	Edgemere	N	2.0 *	1981	*	1991	200,000	*	-	-	-	-
K	East Hampton	N	1.0	1942		1993	20,000		-	-	-	-
K	Pt. Washington	Y	2.1	1983		1991	260,000		-	-	-	-
K	Riverhead	Y	2.0	1963		1993	66,000		-	-	-	-
K	North Sea	Y	1.1	1963		1995	34,000		-	-	-	-
K	Bablyon	N	6.0 *	1950		1990	75,000		-	-	-	-
TOTAL K			12.2				455,000		-	-	-	-
	Clifton Park	N	1.5	1963		1991	53,000		-	-	-	-
	Croton Pt.	Y	10.0	1966	*	1996	330,000	*	-	-	-	-
	Tomkins Cty.	N	1.0 *	1977	*	1997	50,000	*	-	-	-	-
	MOSA	N	1.0	1974		1993	52,000		-	-	-	-
	Laidlaw	N	1.4	1970		1992	63,000		-	-	-	-
	Austro Bros.	N	1.4	1972		1994	58,000		-	-	-	-
Statewide Total			36.5						146	80	44	0

Notes:

* Estimated by SCS

1. Source, EPA-LMOP Database
2. Potential LFG recovery calculations performed by EPA LandGem Model. Model inputs for tonnages prior to 2000 were based on in-place tonnages divided by the years in operation. Where applicable, received tonnages for 2000 were used and future tonnages were projected out to the anticipated closing year. 80% collection system is assumed.

Table 4.5.10-B Landfill Gas Recovery from Smaller, Closed Landfills in New York State

NYSDEC DATABASE > 20 ACRES

Load Control Zone	Landfill Name	LFG Col. Sys (Y or N)	Size Acres	Tons in Place(1) (MM)	Year Open (2)	Year Closed	Estimated Tons per year *	Potential (3) LFG Recovery MMCF 2002	Potential (3) LFG Recovery MMCF 2007	Potential (3) LFG Recovery MMCF 2012	Potential (3) LFG Recovery MMCF 2022
F	Niskayuna	N	25	1.25	1970	1995	50,000	-	-	-	-
F	Moriah	N	20	1.00	1976	2001	40,000	-	-	-	-
F	Moreau	N	37	1.85	1974	1999	74,000	-	-	-	-
F	Hudson	Y	20	1.00				-	-	-	-
Total F								0	0	0	0
G	New Paltz	Y	21	1.05	1974	1999	42,000	-	-	-	-
G	Ulster	Y	33	1.65	1975	2000	66,000	-	-	-	-
G	Woodstock	N	19	0.95	1973	1998	38,000	-	-	-	-
G	Phillipstown	N	20	1.00	1972	1997	40,000	-	-	-	-
Total G								0	0	0	0
J	Bronx, Oak Pt.	N	20	1.00	1971	1996	40,000	-	-	-	-
J	Richmond, A & A	N	30	1.50	1971	1996	60,000	-	-	-	-
Total J								0	0	0	0
Total K	Merrick	N	50	2.50	1975	2000	100,000	-	-	-	-
	Monticello	N	50	2.00	1975	2000	100,000	-	-	-	-
	Schuyler Falls	Y	31	1.50	1972	1997	62,000	-	-	-	-
	Altamont	N	25	1.25	1971	1996	50,000	-	-	-	-
	Malone	N	25	1.25	1971	1996	50,000	-	-	-	-
	Chenango Rd. #3	N	20	1.00	1973	1998	40,000	-	-	-	-
Statewide Total								0	0	0	0

Notes

* SCS Estimate

1. SCS Estimate @ 50,000 tons per acre average.
2. SCS estimates 25 year operating life.
3. Potential LFG recovery calculations performed by EPA LandGem Model. Model inputs for tonnages prior to 2000 were based on in-place tonnages divided by the years in operation. Where applicable, received tonnages for 2000 were used and future tonnages were projected out to the anticipated closing year. 80% collection system coverage is assumed.

Table 4.5.11-B Total Landfill Gas Recovery in New York State — Base Case

Existing or Expanded LFG to Electric Plants at operating and closed Landfills Table 5.4	Potential LFG Recovery MMCF 2002	Potential LFG Recovery MMCF 2007	Potential LFG Recovery MMCF 2012	Potential LFG Recovery MMCF 2022
Statewide	10,497	11,121	9,459	3,297
A	1,556	1,670	1,225	427
F	1,219	1,385	1,301	466
G	1,244	1,138	927	325
J				
K	2,207	1,331	755	215
Potential new LFG to Elec. Plants at Operating and future Landfills Table 5.5				
Statewide		8,030	11,607	21,886
A		8,163	10,577	17,089
F		406	635	1,940
G				
J				
K				
Potential new LFG to Elec. Plants at Larger closed landfills Table 5.6				
Statewide		1,897	1,041	240
A		154	85	0
F		166	91	1
G		69	38	11
J		96	53	0
K		488	268	74
Potential new LFG to Elec. Plants at Smaller closed Landfills Table 5.7				
Statewide		1,929	1,059	319
A				
F		371	204	61
G		421	231	70
J		226	124	37
K		226	124	37
Total Statewide	10,497	22,977	23,166	25,742
Total A	1,556	9,987	11,887	17,516
Total F	1,219	2,328	2,231	2,468
Total G	1,244	1,628	1,196	406
Total J	-	323	177	38
Total K	2,207	2,046	1,147	326

Table 4.5.14-B Landfill Gas-To-Electricity Base Case Capacity and Generation in New York State — 2002

Load Control Zone	Total Potential LFG Recovery MMCF	Technology / % Use (1)		Elec. (2) Conversion Rate Kwh/MMCF	Elec. Technical Potential Kwh (1000)	Rated or "Installed" Capacity kW (3)
Statewide	10,497	T	3%	23,500	7,400	889
		E	95%	38,700	385,913	46,373
		M	2%	24,400	5,122	616
A	1,556	T	3%	23,500	1,097	132
		E	95%	38,700	57,217	6,875
		M	2%	24,400	759	91
F	1,219	T	3%	23,500	859	103
		E	95%	38,700	44,804	5,384
		M	2%	24,400	595	71
G	1,244	T	3%	23,500	877	105
		E	95%	38,700	45,721	5,494
		M	2%	24,400	607	73
J	-	T	3%	23,500	-	0
		E	95%	38,700	-	0
		M	2%	24,400	-	0
K	2,207	T	3%	23,500	1,556	187
		E	95%	38,700	81,157	9,752
		M	2%	24,400	1,077	129

Notes:
1. Technologies: T=Large System: E=Internal Combustion engine; M=Microturbine; percent
2. Converstion rates from manufacturers data. See Table 5.9.
3. Rated capacity (kW) = kWh(1000) generated/(365 x 24 x 0.95)

Table 4.5.15-B Landfill Gas-To-Electricity Base Case Capacity and Generation in New York State — 2007

Load Control Zone	Total Potential LFG Recovery MMCF	Technology / % Use (1)		Elec. (2) Conversion Rate Kwh/MMCF	Elec. Technical Potential Kwh (1000)	Rated or "Installed" Capacity kW (3)
Statewide	22,977	T	4%	24,000	22,058	2,651
		E	93%	39,200	837,660	100,656
		M	3%	25,000	17,233	2,071
A	9,987	T	4%	24,000	9,587	1,152
		E	93%	39,200	364,085	43,750
		M	3%	25,000	7,490	900
F	2,328	T	4%	24,000	2,235	269
		E	93%	39,200	84,873	10,199
		M	3%	25,000	1,746	210
G	1,628	T	4%	24,000	1,563	188
		E	93%	39,200	59,356	7,132
		M	3%	25,000	1,221	147
J	323	T	4%	24,000	310	37
		E	93%	39,200	11,765	1,414
		M	3%	25,000	242	29
K	2,046	T	4%	24,000	1,964	236
		E	93%	39,200	74,584	8,962
		M	3%	25,000	1,534	184

Notes:

1. Technologies: T=Large System: E=Internal Combustion engine; M=Microturbine; percent use estimated by SCS.
2. Converstion rates from manufacturers data. Incremental increase above Table 4.5.11.
3. Rated capacity (kW) = kWh(1000) generated/(365 x 24 x 0.95)

Table 4.5.16-B Landfill Gas-To-Electricity Base Case Capacity and Generation in New York State — 2012

Load Control Zone	Total Potential LFG Recovery MMCF	Technology / % Use (1)		Elec. (2) Conversion Rate Kwh/MMCF	Elec. Technical Potential Kwh (1000)	Rated or "Installed" Capacity kW (3)
Statewide	23,166	T	5%	24,500	28,378	3,410
		E	91%	39,700	836,918	100,567
		M	4%	25,500	23,629	2,839
A	11,887	T	5%	24,500	14,561	1,750
		E	91%	39,700	429,428	51,602
		M	4%	25,500	12,124	1,457
F	2,231	T	5%	24,500	2,733	328
		E	91%	39,700	80,601	9,685
		M	4%	25,500	2,276	273
G	1,196	T	5%	24,500	1,465	176
		E	91%	39,700	43,207	5,192
		M	4%	25,500	1,220	147
J	177	T	5%	24,500	217	26
		E	91%	39,700	6,399	0.8
		M	4%	25,500	181	0.0
K	1,147	T	5%	24,500	1,405	169
		E	91%	39,700	41,440	4,980
		M	4%	25,500	1,170	141

Notes:

1. Technologies: T=Large System: E=Internal Combustion engine; M=Microturbine; percent use estimated by SCS.
2. Converstion rates from manufacturers data. Incremental increase above Table 4.5.11.
3. Rated capacity (kW) = kWh(1000) generated/(365 x 24 x 0.95)

Table 4.5.17-B Landfill Gas-To-Electricity Base Case Capacity and Generation in New York State — 2022

Load Control Zone	Total Potential LFG Recovery MMCF	Technology / % Use (1)		Elec. (2) Conversion Rate Kwh/MMCF	Elec. Technical Potential Kwh (1000)	Rated or "Installed" Capacity kW (3)
Statewide	25,742	T	6%	25,000	38,613	4,640
		E	89%	40,000	916,414	110,119
		M	5%	26,000	33,465	4,021
A	17,516	T	6%	25,000	26,274	3,157
		E	89%	40,000	623,568	74,930
		M	5%	26,000	22,771	2,736
F	2,468	T	6%	25,000	3,702	445
		E	89%	40,000	87,863	10,558
		M	5%	26,000	3,208	386
G	406	T	6%	25,000	609	73
		E	89%	40,000	14,454	1,737
		M	5%	26,000	528	63
J	38	T	6%	25,000	57	7
		E	89%	40,000	1,344	162
		M	5%	26,000	49	6
K	326	T	6%	25,000	489	59
		E	89%	40,000	11,616	1,396
		M	5%	26,000	424	51

Notes:
1. Technologies: T=Large System: E=Internal Combustion engine; M=Microturbine; percent use estimated by SCS.
2. Converstion rates from manufacturers data. Incremental increase above Table 4.5.11.
3. Rated capacity (kW) = kWh(1000) generated/(365 x 24 x 0.95)

Currently Planned Initiatives

Future LFGTE production is assessed under a scenario (or "case") referred to as the currently planned initiatives (CPI) scenario. In the CPI case, future LFGTE production is estimated based on the expected future impacts resulting from initiatives contemplated in the current New York State Energy Plan. The initiatives that impact future LFG projects include support of green power marketing, Executive Order III, renewable energy credit trading, and an unspecified amount of future support through NYSERDA solicitations. These initiatives, particularly Executive Order 111, could increase LFGTE in the future if overall economics are favorable. SCS projects that under the CPI case, a few more of the larger, publicly owned landfills may install LFGTE facilities.

Tables 4.5.7-C through 4.5.11-C show estimated LFG recovery in the CPI case. Tables 4.5.12-C to 4.5.17-C show LFGTE installed capacity and generation in the CPI case, by year and technology.

Table 4.5.7-C Landfill Gas Recovery from Existing or Expanded Landfill Gas-To-Electricity Facilities in New York State — CPI Case

Load Control Zone	Landfill Name	Operating or Closed/yr.	MSW Received 2000 Tons	Tons (3.) in Place (MM)	Existing & Proposed LF Capacity (4) MM tons	Yr Open		Year Closed		Estimated Tons Per Year		otential Recov MMC 2002	Potential LFG Recovery MMCF 2012 (5)	Potential LFG Recovery MMCF 2022 (5)
A	Modern	O	550,000	5.1	3.9	1983		2007	*	550,000		##	1,075	377
A	Lancaster	C/85	-	2.4	-	1950		1985		68,000	(8)	##	150	50
A	Tonawanda (9)	C	-	1.0	-	1975	*	1995	*	50,000	*	-	-	-
Total A			550,000	9	4					668,000	**	##	1,164	406
F	Albany	O	273,000	4.1	2.9	1969		2011	*	275,000		##	837	294
F	Saratoga Spr (7)	C/91	-	2.1	-	1937		1991		40,000		-	-	-
F	Colonie	O	148,700	1.5	4.0	1969		2018	*	150000		##	393	173
Total F			421,700	8	7					465,000	**	##	1,169	443
G	Al Turi (1)	C/00	(1)	4.0	2.6	1968		2000	*	125,000		##	453	159
G	Orange County	C	-									##	474	166
Total G			0	4	3					125,000	**	##	880	309
K	Oceanside	C/88	-	6.5	-	1964		1988		270,000		##	50	5
K	E. Northport	C/91	-	3.8	-	1961	*	1991		120,000		-	-	-
K	Blydenburgh (2)	C/85	-	8.0	-	1963		1985		360,000		-	-	-
K	Old Bethpage	C/86	-	2.8	-	1968		1986		150,000		-	-	-
K	Smithtown	C/90	-	1.7	-	1979		1990		155,000		##	75	5
K	Brookhaven	C/96	-	8.0	-	1974		1996		360,000		##	450	190
Total K			0	31	0					1,415,000	**	##	546	190
	Mohawk Valley	C/92	-	1.2	-	1972		1992		60,000		-	-	-
	High Acres	O	686,800	6.4	8.4	1972		2012	*	680,000		##	1,725	605
	Tripoli	C/85	-	1.7	-	1964		1985		155,000		68	0	0
	Seneca Meadows	O	1,153,000	19.0	11.0	1981		2009	*	1,200,000		##	3,503	1,228
	Broome	O	104,600	3.1	9.5	1969		1995	*	100,000		##	363	127
	Monroe/Liv.	C/89	-	5.2	-	1964		1989		208,000		##	199	0
	Madison (6)	O	47,700	1.2	1.4	1974		2024		50,000		##	211	93
Statewide Total			2,963,800	89							**	##	9,759	3,400

* SCS Estimate

** Total flows are estimated to be 95% of individual landfill modeled flows.

Notes:

1. Temporarily shutdown in 2001
2. Accident destroyed facility; energy contract lapsed. Facility shutdown in 2000.
3. Source, EPA-LMOP Database 12/21/01
4. Source, NYSDEC, Existing and Proposed Capacity
5. Potential LFG recovery calculations performed by EPA LandGem Model. Model inputs for tonnages prior to 2000 were based on in-place tonnages divided by the years in operation. Where applicable, received tonnages for 2000 were used and future tonnages were projected out to the anticipated closing year. 80% collection system coverage is assumed.
6. Planned
7. Direct Use
8. Gas flow based on reported 2000 estimates.
9. Mostly ash per NYSDEC survey

Table 4.5.8-C Landfill Gas Recovery from Operating and Future Landfills in New York State – CPI Case

Load Control Zone	Landfill Name	MSW Received Tons (3)	Tons (2) in Place (MM)		Existing/ (3) Proposed LF Capacity MM tons	Year Opened (2)		Projected Closure Year (2)		Estimated Future Tons Per Year *		otentia G Rec MMC ##	Potential (1) LFG Recovery MMCF 2012	Potential (1) LFG Recovery MMCF 2022
A	Mill Seat	239,000	1.2		7.7	1993		2014		380,000		#	1,687	1,557
A	Chautauqua	253,700	3.2		5.1	1988	*	2020	*	250,000		#	1,815	1,947
A	Niagara Rec.	565,200	2.6		4.9	1995		2009		550,000		#	2,069	1,869
A	WMI-Albion	-	-		7.4	2005	*	2022	*	500,000	*	#	1,125	2,073
A	CID	493,500	4.0		26.7	1992	*	2052	*	500,000		#	2,952	3,754
A	Farmersville	-	-		16.8	2012	*	2033		800,000	*	#	225	2,132
A	Future-1					2008	*	2025	*	500,000	*	#	703	1,817
A	Future-6					2015	*	2025	*	1,000,000	*	#	-	1,938
Total A		1,551,400	11		69					3,480,000	**	#	9,519	15,380
F	Saratoga	-	-		1.4	2004	*	2032		50,000	*	-	-	-
F	Fulton	87,500	0.4		2.4	1989		2016		85,000		-	-	-
F	Future-2					2012	*	2025	*	300,000	*	#	84	800
F	Future-7					2019	*	2025	*	500,000	*	#	-	485
Total F		87,500	0.4		3.8					435,000	**	#	76	1,156
	DANC	245,000			8.5	1992		2017		265,000	*	#	1,515	1,546
	Auburn (4)	27,000			0.6	1995	*	2017	*	27,000	*	-	-	-
	Chenango	21,000			1.6	1980	*	2050	*	21,000		-	-	-
	Cortland	24,200			0.4	1995	*	2012	*	24,000		-	-	-
	Bristol Hill	43,000	0.1		2.5	1997		2033		45,000		-	-	-
	Chemung	99,500	2.7		2.4	1973		2024	*	100,000		-	-	-
	Ontario	265,600	1.5		1.0	1975		2004	*	250,000		#	323	292
	Steuben	80,200	0.6		1.6	1988		2020		80,000		-	-	-
	Alleghany	32,800	0.4		0.7	1987		2011		32,000		-	-	-
	Oneida/Herk	-	-		12.9	2010	*	2094	*	150,000	*	#	127	472
	Hyland	180,500			2.0	1996		2011		180,000		-	735	664
	Sullivan	191,500	1.4		5.5	1994		2025		190,000		-	1,089	1,398
	Delaware	49,300	0.8		0.7	1984		2014		50,000		-	-	-
	Clinton	175,000	0.4	*	2.2	1998	*	2010		175,000		#	593	536
	Franklin	45,000			0.9	2000	*	2020	*	45,000		-	-	-
	Future-3					2010	*	2025	*	1,000,000		#	844	3,150
	Future-4					2010	*	2025	*	500,000		#	422	1,575
	Future-5					2011	*	2025	*	380,000		#	214	1,105
Statewide Total		3,118,500	19.3		115.9						**	##	14,869	26,199

Notes:
* SCS Estimate
** Total flows are estimated to be 90% of individual landfill modeled flows.
1. Potential LFG recovery calculations performed by EPA LandGem Model. Model inputs for tonnages prior to 2000 were based on in-place tonnages divided by the years in operation. Where applicable, received tonnages for 2000 were used and future tonnages were projected out to the anticipated closing year. 80% collection system coverage is assumed.
2. Source, EPA-LMOP Database 12/21/01
3. Source, NYSDEC
4. Direct Use. No Power Potential.

Table 4.5.9-C Landfill Gas Recovery from Larger Landfills in New York State — CPI Case

Load Control Zone	Landfill Name	LFG Col. Sys Y or N	Tons (1) in Place (MM)	Year (1) Open		Year (1) Closed	Est. Tons* Per Year		Potential LFG Recovery (2) MMCF 2002	Potential LFG Recovery (2) MMCF 2007	Potential LFG Recovery (2) MMCF 2012	Potential LFG Recovery (2) MMCF 2022
A	Orleans	N	1.7	1983		1993	170,000		-	-	-	-
F	Queensbury	N	1.6	1962		1993	51,000		-	-	-	-
F	Troy	Y	1.5	1969		1993	62,000		146	80	44	0
TOTAL F			3				113,000		146	80	44	0
G	Haverstraw	N	1.2	1970		1996	46,000		-	-	-	-
J	Edgemere	N	2.0 *	1981	*	1991	200,000	*	-	-	-	-
K	East Hampton	N	1.0	1942		1993	20,000		-	-	-	-
K	Pt. Washington	Y	2.1	1983		1991	260,000		-	-	-	-
K	Riverhead	Y	2.0	1963		1993	66,000		-	-	-	-
K	North Sea	Y	1.1	1963		1995	34,000		-	-	-	-
K	Bablyon	N	6.0 *	1950		1990	75,000		-	-	-	-
TOTAL K			12.2				455,000		-	-	-	-
	Clifton Park	N	1.5	1963		1991	53,000		-	-	-	-
	Croton Pt.	Y	10.0	1966	*	1996	330,000	*	-	-	-	-
	Tomkins Cty.	N	1.0 *	1977	*	1997	50,000	*	-	-	-	-
	MOSA	N	1.0	1974		1993	52,000		-	-	-	-
	Laidlaw	N	1.4	1970		1992	63,000		-	-	-	-
	Austro Bros.	N	1.4	1972		1994	58,000		-	-	-	-
Statewide Total			36.5						146	80	44	0

Notes:

* Estimated by SCS

1. Source, EPA-LMOP Database
2. Potential LFG recovery calculations performed by EPA LandGem Model. Model inputs for tonnages prior to 2000 were based on in-place tonnages divided by the years in operation. Where applicable, received tonnages for 2000 were used and future tonnages were projected out to the anticipated closing year. 80% collection system is assumed.

Table 4.5.10-C Landfill Gas Recovery from Smaller, Closed Landfills in New York State — CPI Case, NYSDEC Database > 20 Acres

Load Control Zone	Landfill Name	LFG Col. Sys (Y or N)	Size Acres	Tons in Place(1) (MM)	Year Open (2)	Year Closed	Estimated Tons per year *	Potential (3) LFG Recovery MMCF 2002	Potential (3) LFG Recovery MMCF 2007	Potential (3) LFG Recovery MMCF 2012	Potential (3) LFG Recovery MMCF 2022
F	Niskayuna	N	25	1.25	1970	1995	50,000	-	-	-	-
F	Moriah	N	20	1.00	1976	2001	40,000	-	-	-	-
F	Moreau	N	37	1.85	1974	1999	74,000	-	-	-	-
F	Hudson	Y	20	1.00				-	-	-	-
Total F								0	0	0	0
G	New Paltz	Y	21	1.05	1974	1999	42,000	-	-	-	-
G	Ulster	Y	33	1.65	1975	2000	66,000	-	-	-	-
G	Woodstock	N	19	0.95	1973	1998	38,000	-	-	-	-
G	Phillipstown	N	20	1.00	1972	1997	40,000	-	-	-	-
Total G								0	0	0	0
J	Bronx, Oak Pt.	N	20	1.00	1971	1996	40,000	-	-	-	-
J	Richmond, A & A	N	30	1.50	1971	1996	60,000	-	-	-	-
Total J								0	0	0	0
Total K	Merrick	N	50	2.50	1975	2000	100,000	-	-	-	-
	Monticello	N	50	2.00	1975	2000	100,000	-	-	-	-
	Schuyler Falls	Y	31	1.50	1972	1997	62,000	-	-	-	-
	Altamont	N	25	1.25	1971	1996	50,000	-	-	-	-
	Malone	N	25	1.25	1971	1996	50,000	-	-	-	-
	Chenango Rd. #3	N	20	1.00	1973	1998	40,000	-	-	-	-
Statewide Total								0	0	0	0

Notes

* SCS Estimate

1. SCS Estimate @ 50,000 tons per acre average.
2. SCS estimates 25 year operating life.
3. Potential LFG recovery calculations performed by EPA LandGem Model. Model inputs for tonnages prior to 2000 were based on in-place tonnages divided by the years in operation. Where applicable, received tonnages for 2000 were used and future tonnages were projected out to the anticipated closing year. 80% collection system coverage is assumed.

Table 4.5.11-C Total Landfill Gas Recovery in New York State — CPI Case

Existing or Expanded LFG to Electric Plants at operating and closed Landfills Table 5.4	Potential LFG Recovery MMCF 2002	Potential LFG Recovery MMCF 2007	Potential LFG Recovery MMCF 2012	Potential LFG Recovery MMCF 2022
Statewide	10,497	11,121	9,459	3,297
A	1,556	1,670	1,225	427
F	1,219	1,385	1,301	466
G	1,244	1,138	927	325
J				
K	2,207	1,331	755	215
Potential new LFG to Elec. Plants at Operating and future Landfills Table 5.5				
Statewide		8,030	11,607	21,886
A		8,163	10,577	17,089
F		406	635	1,940
G				
J				
K				
Potential new LFG to Elec. Plants at Larger closed landfills Table 5.6				
Statewide		1,897	1,041	240
A		154	85	0
F		166	91	1
G		69	38	11
J		96	53	0
K		488	268	74
Potential new LFG to Elec. Plants at Smaller closed Landfills Table 5.7				
Statewide		1,929	1,059	319
A				
F		371	204	61
G		421	231	70
J		226	124	37
K		226	124	37
Total Statewide	10,497	22,977	23,166	25,742
Total A	1,556	9,987	11,887	17,516
Total F	1,219	2,328	2,231	2,468
Total G	1,244	1,628	1,196	406
Total J	-	323	177	38
Total K	2,207	2,046	1,147	326

Table 4.5.14-C Landfill Gas-To-Electricity CPI Case Capacity and Generation in New York State — 2002

Load Control Zone	Total Potential LFG Recovery MMCF	Technology / % Use (1)		Elec. (2) Conversion Rate Kwh/MMCF	Elec. Technical Potential Kwh (1000)	Rated or "Installed" Capacity kW (3)
Statewide	10,497	T	3%	23,500	7,400	889
		E	95%	38,700	385,913	46,373
		M	2%	24,400	5,122	616
A	1,556	T	3%	23,500	1,097	132
		E	95%	38,700	57,217	6,875
		M	2%	24,400	759	91
F	1,219	T	3%	23,500	859	103
		E	95%	38,700	44,804	5,384
		M	2%	24,400	595	71
G	1,244	T	3%	23,500	877	105
		E	95%	38,700	45,721	5,494
		M	2%	24,400	607	73
J	-	T	3%	23,500	-	0
		E	95%	38,700	-	0
		M	2%	24,400	-	0
K	2,207	T	3%	23,500	1,556	187
		E	95%	38,700	81,157	9,752
		M	2%	24,400	1,077	129

Notes:

1. Technologies: T=Large System: E=Internal Combustion engine; M=Microturbine; percent
2. Converstion rates from manufacturers data. See Table 5.9.
3. Rated capacity (kW) = kWh(1000) generated/(365 x 24 x 0.95)

Table 4.5.15-C Landfill Gas-To-Electricity CPI Case Capacity and Generation in New York State — 2007

Load Control Zone	Total Potential LFG Recovery MMCF	Technology / % Use (1)		Elec. (2) Conversion Rate Kwh/MMCF	Elec. Technical Potential Kwh (1000)	Rated or "Installed" Capacity kW (3)
Statewide	22,977	T	4%	24,000	22,058	2,651
		E	93%	39,200	837,660	100,656
		M	3%	25,000	17,233	2,071
A	9,987	T	4%	24,000	9,587	1,152
		E	93%	39,200	364,085	43,750
		M	3%	25,000	7,490	900
F	2,328	T	4%	24,000	2,235	269
		E	93%	39,200	84,873	10,199
		M	3%	25,000	1,746	210
G	1,628	T	4%	24,000	1,563	188
		E	93%	39,200	59,356	7,132
		M	3%	25,000	1,221	147
J	323	T	4%	24,000	310	37
		E	93%	39,200	11,765	1,414
		M	3%	25,000	242	29
K	2,046	T	4%	24,000	1,964	236
		E	93%	39,200	74,584	8,962
		M	3%	25,000	1,534	184

Notes:

1. Technologies: T=Large System: E=Internal Combustion engine; M=Microturbine; percent use estimated by SCS.
2. Converstion rates from manufacturers data. Incremental increase above Table 5.11.
3. Rated capacity (kW) = kWh(1000) generated/(365 x 24 x 0.95)

Table 4.5.16-C Landfill Gas-To-Electricity CPI Case Capacity and Generation in New York State — 2012

Load Control Zone	Total Potential LFG Recovery	Technology / % Use (1)		Elec. (2) Conversion Rate Kwh/MMCF	Elec. Technical Potential Kwh (1000)	Rated or "Installed" Capacity kW (3)
Statewide	23,166	T	5%	24,500	28,378	3,410
		E	91%	39,700	836,918	100,567
		M	4%	25,500	23,629	2,839
A	11,887	T	5%	24,500	14,561	1,750
		E	91%	39,700	429,428	51,602
		M	4%	25,500	12,124	1,457
F	2,231	T	5%	24,500	2,733	328
		E	91%	39,700	80,601	9,685
		M	4%	25,500	2,276	273
G	1,196	T	5%	24,500	1,465	176
		E	91%	39,700	43,207	5,192
		M	4%	25,500	1,220	147
J	177	T	5%	24,500	217	26
		E	91%	39,700	6,399	769
		M	4%	25,500	181	22
K	1,147	T	5%	24,500	1,405	169
		E	91%	39,700	41,440	4,980
		M	4%	25,500	1,170	141

Notes:

1. Technologies: T=Large System: E=Internal Combustion engine; M=Microturbine; percent use estimated by SCS.
2. Converstion rates from manufacturers data. See Table 4.9.
3. Rated capacity (kW) = kWh(1000) generated/(365 x 24 x 0.95)

Table 4.5.17-C Landfill Gas-To-Electricity CPI Case Capacity and Generation in New York State — 2022

Load Control Zone	Total Potential LFG Recovery MMCF	Technology / % Use (1)		Elec. (2) Conversion Rate Kwh/MMCF	Elec. Technical Potential Kwh (1000)	Rated or "Installed" Capacity kW (3)
Statewide	25,742	T	6%	25,000	38,613	4,640
		E	89%	40,000	916,414	110,119
		M	5%	26,000	33,465	4,021
A	17,516	T	6%	25,000	26,274	3,157
		E	89%	40,000	623,568	74,930
		M	5%	26,000	22,771	2,736
F	2,468	T	6%	25,000	3,702	445
		E	89%	40,000	87,863	10,558
		M	5%	26,000	3,208	386
G	406	T	6%	25,000	609	73
		E	89%	40,000	14,454	1,737
		M	5%	26,000	528	63
J	38	T	6%	25,000	57	7
		E	89%	40,000	1,344	162
		M	5%	26,000	49	6
K	326	T	6%	25,000	489	59
		E	89%	40,000	11,616	1,396
		M	5%	26,000	424	51

Notes:
1. Technologies: T=Large System: E=Internal Combustion engine; M=Microturbine; percent use estimated by SCS.
2. Converstion rates from manufacturers data. Incremental increase above Table 5.13.
3. Rated capacity (kW) = kWh(1000) generated/(365 x 24 x 0.95)

Potential Contributions to Greenhouse-Gas Reduction Targets

This study also assesses future LFGTE production also assessed under a greenhouse gas (GHG) reduction scneario. Additional initiatives above and beyond those considered in the CPI case are evaluated in order to estimate the amount of LFGTE that could be produced under those initiatives. Initiatives included in the GHG case that will impact LFG power production include additional marketing and green power purchase options, implementation of mandatory renewables targets for state agencies, federal tax credits (if enacted) and renewable energy production incentives (REPI) rebates. A reduction or elimination of standby charges and exit fees to utilities are also very important, since these costs are a clear disincentive at the present time. Of these, the most significant initiative would be enactment of federal tax credits, since such credits would provide direct financial support for future facilities.

Tables 4.5.7-G through 4.5.11-G show LFG recovery estimated for the GHG-reduction case. Tables 4.5.14-G to 4.5.17-G show LFGTE installed capacity and generation for the GHG-reduction case by year and technology.

Table 4.5.7-G Landfill Gas Recovery from Existing or Expanded Landfill Gas-to-Electricity Facilities in New York State — GHG-Reduction Case

Load Control Zone	Landfill Name	Operating or Closed/yr.	MSW Received 2000 Tons	Tons (3.) in Place (MM)	Existing & Proposed LF Capacity (4) MM tons	Yr Open		Year Closed		Estimated Tons Per Year		Potential LFG Recovery MMCF 2002 (5)	Potential LFG Recovery MMCF 2007 (5)	Potential LFG Recovery MMCF 2012 (5)	Potential LFG Recovery MMCF 2022 (5)
A	Modern	O	550,000	5.1	3.9	1983		2007	*	550,000		1,056	1,320	1,075	377
A	Lancaster	C/85	-	2.4	-	1950		1985		68,000	(8)	500	350	150	50
A	Tonawanda (9)	C	-	1.0	-	1975	*	1995	*	50,000	*	-	-	-	-
Total A			550,000	9	4					668,000	**	1,478	1,586	1,164	406
F	Albany	O	273,000	4.1	2.9	1969		2011	*	275,000		770	898	837	294
F	Saratoga Spr (7)	C/91	-	2.1	-	1937		1991		40,000		-	-	-	-
F	Colonie	O	148,700	1.5	4.0	1969		2018	*	150000		305	385	393	173
Total F			421,700	8	7					465,000	**	1,022	1,219	1,169	443
G	Al Turi (1)	C/00	(1)	4.0	2.6	1968		2000	*	125,000		607	556	453	159
G	Orange County	C	-									636	582	474	166
Total G			0	4	3					125,000	**	1,181	1,081	880	309
K	Oceanside	C/88	-	6.5	-	1964		1988		270,000		250	175	50	5
K	E. Northport	C/91	-	3.8	-	1961	*	1991		120,000		-	-	-	-
K	Blydenburgh (2)	C/85	-	8.0	-	1963		1985		360,000		-	-	-	-
K	Old Bethpage	C/86	-	2.8	-	1968		1986		150,000		-	-	-	-
K	Smithtown	C/90	-	1.7	-	1979		1990		155,000		157	110	75	5
K	Brookhaven	C/96	-	8.0	-	1974		1996		360,000		750	600	450	190
Total K			0	31	0					1,415,000	**	1,099	841	546	190
	Mohawk Valley	C/92	-	1.2	-	1972		1992		60,000		-	-	-	-
	High Acres	O	686,800	6.4	8.4	1972		2012	*	680,000		1,322	1,689	1,725	605
	Tripoli	C/85	-	1.7	-	1964		1985		155,000		68	0	0	0
	Seneca Meadows	O	1,153,000	19.0	11.0	1981		2009	*	1,200,000		3,529	4,071	3,503	1,228
	Broome	O	104,600	3.1	9.5	1969		1995	*	100,000		487	445	363	127
	Monroe/Liv.	C/89	-	5.2	-	1964		1989		208,000		400	298	199	0
	Madison (6)	O	47,700	1.2	1.4	1974		2024		50,000		211	228	211	93
Statewide Total			2,963,800	89							**	10,497	11,121	9,459	3,297

* SCS Estimate

** Total flows are estimated to be 95% of individual landfill modeled flows.

Notes:

1. Temporarily shutdown in 2001
2. Accident destroyed facility; energy contract lapsed. Facility shutdown in 2000.
3. Source, EPA-LMOP Database 12/21/01
4. Source, NYSDEC, Existing and Proposed Capacity
5. Potential LFG recovery calculations performed by EPA LandGem Model. Model inputs for tonnages prior to 2000 were based on in-place tonnages divided by the years in operation. Where applicable, received tonnages for 2000 were used and future tonnages were projected out to the anticipated closing year. 80% collection system coverage is assumed.
6. Planned
7. Direct Use
8. Gas flow based on reported 2000 estimates.
9. Mostly ash per NYSDEC survey

Table 4.5.8-G Landfill Gas Recovery from Operating and Future Landfill Gas-to-Electricity Facilities in New York State — GHG-Reduction Case

Load Control Zone	Landfill Name	MSW Received Tons (3)	Tons (2) in Place (MM)		Existing/ (3) Proposed LF Capacity MM tons	Year Opened (2)		Projected Closure Year (2)		Estimated Future Tons Per Year *		Potential (1) LFG Recovery MMCF 2002	Potential (1) LFG Recovery MMCF 2007	Potential (1) LFG Recovery MMCF 2012	Potential (1) LFG Recovery MMCF 2022
A	Mill Seat	239,000	1.2		7.7	1993		2014		380,000		792	1,296	1,687	1,557
A	Chautauqua	253,700	3.2		5.1	1988	*	2020	*	250,000		1,424	1,646	1,815	1,947
A	Niagara Rec.	565,200	2.6		4.9	1995		2009		550,000		1,536	2,219	2,069	1,869
A	WMI-Albion	-	-		7.4	2005	*	2022	*	500,000	*	-	474	1,125	2,073
A	CID	493,500	4.0		26.7	1992	*	2052	*	500,000		1,978	2,528	2,952	3,754
A	Farmersville	-	-		16.8	2012	*	2033		800,000	*	-	-	225	2,132
A	Future-1					2008	*	2025	*	500,000	*	-	-	703	1,817
A	Future-6					2015	*	2025	*	1,000,000	*	-	-	-	1,938
Total A		1,551,400	11		69					3,480,000	**	5,443	7,755	10,048	16,234
F	Saratoga	-	-		1.4	2004	*	2032		50,000	*	-	-	-	-
F	Fulton	87,500	0.4		2.4	1989		2016		85,000		-	342	424	426
F	Future-2					2012	*	2025	*	300,000	*	-	-	84	800
F	Future-7					2019	*	2025	*	500,000	*	-	-	-	485
Total F		87,500	0.4		3.8					435,000	**	-	325	483	1,624
	DANC	245,000			8.5	1992		2017		265,000	*	985	1,284	1,515	1,546
	Auburn (4)	27,000			0.6	1995	*	2017	*	27,000	*	-	-	-	-
	Chenango	21,000			1.6	1980	*	2050	*	21,000		-	-	-	-
	Cortland	24,200			0.4	1995	*	2012	*	24,000		-	-	-	-
	Bristol Hill	43,000	0.1		2.5	1997		2033		45,000		84	145	192	275
	Chemung	99,500	2.7		2.4	1973		2024	*	100,000		1,080	1,107	1,125	1,211
	Ontario	265,600	1.5		1.0	1975		2004	*	250,000		276	368	323	292
	Steuben	80,200	0.6		1.6	1988		2020		80,000		303	392	461	525
	Alleghany	32,800	0.4		0.7	1987		2011		32,000		-	-	-	-
	Oneida/Herk	-	-		12.9	2010	*	2094	*	150,000	*	-	-	127	472
	Hyland	180,500			2.0	1996		2011		180,000		455	684	735	664
	Sullivan	191,500	1.4		5.5	1994		2025		190,000		710	924	1,089	1,398
	Delaware	49,300	0.8		0.7	1984		2014		50,000		342	379	408	357
	Clinton	175,000	0.4	*	2.2	1998	*	2010		175,000		-	569	593	536
	Franklin	45,000			0.9	2000	*	2020	*	45,000		-	-	-	-
	Future-3					2010	*	2025	*	1,000,000		-	-	844	3,150
	Future-4					2010	*	2025	*	500,000		-	-	422	1,575
	Future-5					2011	*	2025	*	380,000		-	-	214	1,105
Statewide Total		3,118,500	19.3		115.9						**	9,464	13,640	18,175	30,309

Notes:

* SCS Estimate

** Total flows are estimated to be 95% of individual landfill modeled flows.

1. Potential LFG recovery calculations performed by EPA LandGem Model. Model inputs for tonnages prior to 2000 were based on in-place tonnages divided by the years in operation. Where applicable, received tonnages for 2000 were used and future tonnages were projected out to the anticipated closing year. 80% collection system coverage is assumed.
2. Source, EPA-LMOP Database 12/21/01
3. Source, NYSDEC
4. Direct Use. No Power Potential.

Table 4.5.9-G Landfill Gas Recovery from Larger Landfills in New York State — GHG-Reduction Case

Load Control Zone	Landfill Name	LFG Col. Sys Y or N	Tons (1) in Place (MM)	Year (1) Open		Year (1) Closed	Est. Tons* Per Year		Potential LFG Recovery (2) MMCF 2002	Potential LFG Recovery (2) MMCF 2007	Potential LFG Recovery (2) MMCF 2012	Potential LFG Recovery (2) MMCF 2022
A	Orleans	N	1.7	1983		1993	170,000		-	-	-	-
F	Queensbury	N	1.6	1962		1993	51,000		-	-	-	-
F	Troy	Y	1.5	1969		1993	62,000		146	80	44	0
TOTAL F			3				113,000		146	80	44	0
G	Haverstraw	N	1.2	1970		1996	46,000		-	-	-	-
J	Edgemere	N	2.0 *	1981	*	1991	200,000	*	-	-	-	-
K	East Hampton	N	1.0	1942		1993	20,000		-	-	-	-
K	Pt. Washington	Y	2.1	1983		1991	260,000		-	119	65	20
K	Riverhead	Y	2.0	1963		1993	66,000		-	113	62	19
K	North Sea	Y	1.1	1963		1995	34,000		-	-	-	-
K	Bablyon	N	6.0 *	1950		1990	75,000		279	153	84	25
TOTAL K			12.2				455,000		279	385	211	64
	Clifton Park	N	1.5	1963		1991	53,000		-	-	-	-
	Croton Pt.	Y	10.0	1966	*	1996	330,000	*	600	400	200	100
	Tomkins Cty.	N	1.0 *	1977	*	1997	50,000	*	-	-	-	-
	MOSA	N	1.0	1974		1993	52,000		-	-	-	-
	Laidlaw	N	1.4	1970		1992	63,000		-	-	-	-
	Austro Bros.	N	1.4	1972		1994	58,000		-	-	-	-
Statewide Total			36.5						1,025	865	455	164

Notes:

* Estimated by SCS

1. Source, EPA-LMOP Database
2. Potential LFG recovery calculations performed by EPA LandGem Model. Model inputs for tonnages prior to 2000 were based on in-place tonnages divided by the years in operation. Where applicable, received tonnages for 2000 were used and future tonnages were projected out to the anticipated closing year. 80% collection system is assumed.

Table 4.5.10-G Landfill Gas Recovery from Smaller Closed Landfills in New York State — GHG-Reduction Case, NYSDEC Database > 20 Acres

Load Control Zone	Landfill Name	LFG Col. Sys (Y or N)	Size Acres	Tons in Place(1) (MM)	Year Open (2)	Year Closed	Estimated Tons per year *	Potential (3) LFG Recovery MMCF 2002	Potential (3) LFG Recovery MMCF 2007	Potential (3) LFG Recovery MMCF 2012	Potential (3) LFG Recovery MMCF 2022
F	Niskayuna	N	25	1.25	1970	1995	50,000	-	-	-	-
F	Moriah	N	20	1.00	1976	2001	40,000	-	-	-	-
F	Moreau	N	37	1.85	1974	1999	74,000	-	-	-	-
F	Hudson	Y	20	1.00				-	-	-	-
Total F								0	0	0	0
G	New Paltz	Y	21	1.05	1974	1999	42,000	-	95	52	16
G	Ulster	Y	33	1.65	1975	2000	66,000	-	149	82	25
G	Woodstock	N	19	0.95	1973	1998	38,000	-	-	-	-
G	Phillipstown	N	20	1.00	1972	1997	40,000	-	-	-	-
Total G								0	245	134	40
J	Bronx, Oak Pt.	N	20	1.00	1971	1996	40,000	-	-	-	-
J	Richmond, A & A	N	30	1.50	1971	1996	60,000	-	-	-	-
Total J								0	0	0	0
Total K	Merrick	N	50	2.50	1975	2000	100,000	493	226	124	37
	Monticello	N	50	2.00	1975	2000	100,000	-	-	-	-
	Schuyler Falls	Y	31	1.50	1972	1997	62,000	-	140	77	23
	Altamont	N	25	1.25	1971	1996	50,000	-	-	-	-
	Malone	N	25	1.25	1971	1996	50,000	-	-	-	-
	Chenango Rd. #3	N	20	1.00	1973	1998	40,000	-	-	-	-
Statewide Total								493	611	336	101

Notes

* SCS Estimate

1. SCS Estimate @ 50,000 tons per acre average.
2. SCS estimates 25 year operating life.
3. Potential LFG recovery calculations performed by EPA LandGem Model. Model inputs for tonnages prior to 2000 were based on in-place tonnages divided by the years in operation. Where applicable, received tonnages for 2000 were used and future tonnages were projected out to the anticipated closing year. 80% collection system coverage is assumed.

Table 4.5.11-G Total Landfill Gas Recovery in New York State — GHG-Reduction Case

Existing or Expanded LFG to Electric Plants at operating and closed Landfills Table 5.4	Potential LFG Recovery MMCF 2002	Potential LFG Recovery MMCF 2007	Potential LFG Recovery MMCF 2012	Potential LFG Recovery MMCF 2022
Statewide	10,497	11,121	9,459	3,297
A	1,556	1,670	1,225	427
F	1,219	1,385	1,301	466
G	1,244	1,138	927	325
J				
K	2,207	1,331	755	215
Potential new LFG to Elec. Plants at Operating and future Landfills Table 5.5				
Statewide		8,030	11,607	21,886
A		8,163	10,577	17,089
F		406	635	1,940
G				
J				
K				
Potential new LFG to Elec. Plants at Larger closed landfills Table 5.6				
Statewide		1,897	1,041	240
A		154	85	0
F		166	91	1
G		69	38	11
J		96	53	0
K		488	268	74
Potential new LFG to Elec. Plants at Smaller closed Landfills Table 5.7				
Statewide		1,929	1,059	319
A				
F		371	204	61
G		421	231	70
J		226	124	37
K		226	124	37
Total Statewide	10,497	22,977	23,166	25,742
Total A	1,556	9,987	11,887	17,516
Total F	1,219	2,328	2,231	2,468
Total G	1,244	1,628	1,196	406
Total J	-	323	177	38
Total K	2,207	2,046	1,147	326

Table 4.5.14-G Landfill Gas-To-Electricity GHG-Reduction Case Capacity and Generation in New York State — 2002

Load Control Zone	Total Potential LFG Recovery MMCF	Technology / % Use (1)		Elec. (2) Conversion Rate Kwh/MMCF	Elec. Technical Potential Kwh (1000)	Rated or "Installed" Capacity kW (3)
Statewide	10,497	T	3%	23,500	7,400	889
		E	95%	38,700	385,913	46,373
		M	2%	24,400	5,122	616
A	1,556	T	3%	23,500	1,097	132
		E	95%	38,700	57,217	6,875
		M	2%	24,400	759	91
F	1,219	T	3%	23,500	859	103
		E	95%	38,700	44,804	5,384
		M	2%	24,400	595	71
G	1,244	T	3%	23,500	877	105
		E	95%	38,700	45,721	5,494
		M	2%	24,400	607	73
J	-	T	3%	23,500	-	0
		E	95%	38,700	-	0
		M	2%	24,400	-	0
K	2,207	T	3%	23,500	1,556	187
		E	95%	38,700	81,157	9,752
		M	2%	24,400	1,077	129

Notes:
2. Converstion rates from manufacturers data. Incremental increase above Table 4.5.13.
2. Converstion rates from manufacturers data. See Table 4.5.9.
3. Rated capacity (kW) = kWh(1000) generated/(365 x 24 x 0.95)

Table 4.5.15-G Landfill Gas-To-Electricity GHG-Reduction Case Capacity and Generation in New York State — 2007

Load Control Zone	Total Potential LFG Recovery MMCF	Technology / % Use (1)		Elec. (2) Conversion Rate Kwh/MMCF	Elec. Technical Potential Kwh (1000)	Rated or "Installed" Capacity kW (3)
Statewide	22,977	T	4%	24,000	22,058	2,651
		E	93%	39,200	837,660	100,656
		M	3%	25,000	17,233	2,071
A	9,987	T	4%	24,000	9,587	1,152
		E	93%	39,200	364,085	43,750
		M	3%	25,000	7,490	900
F	2,328	T	4%	24,000	2,235	269
		E	93%	39,200	84,873	10,199
		M	3%	25,000	1,746	210
G	1,628	T	4%	24,000	1,563	188
		E	93%	39,200	59,356	7,132
		M	3%	25,000	1,221	147
J	323	T	4%	24,000	310	37
		E	93%	39,200	11,765	1,414
		M	3%	25,000	242	29
K	2,046	T	4%	24,000	1,964	236
		E	93%	39,200	74,584	8,962
		M	3%	25,000	1,534	184

2. Converstion rates from manufacturers data. Incremental increase above Table 4.5.13.

1. Technologies: T=Large System: E=Internal Combustion engine; M=Microturbine; percent use estimated by SCS.
2. Converstion rates from manufacturers data. Incremental increase above Table 4.5.11.
3. Rated capacity (kW) = kWh(1000) generated/(365 x 24 x 0.95)

Table 4.5.16-G Landfill Gas-To-Electricity GHG-Reduction Case Capacity and Generation in New York State — 2012

Load Control Zone	Total Potential LFG Recovery	Technology / % Use (1)		Elec. (2) Conversion Rate Kwh/MMCF	Elec. Technical Potential Kwh (1000)	Rated or "Installed" Capacity kW (3)
Statewide	23,166	T	5%	24,500	28,378	3,410
		E	91%	39,700	836,918	100,567
		M	4%	25,500	23,629	2,839
A	11,887	T	5%	24,500	14,561	1,750
		E	91%	39,700	429,428	51,602
		M	4%	25,500	12,124	1,457
F	2,231	T	5%	24,500	2,733	328
		E	91%	39,700	80,601	9,685
		M	4%	25,500	2,276	273
G	1,196	T	5%	24,500	1,465	176
		E	91%	39,700	43,207	5,192
		M	4%	25,500	1,220	147
J	177	T	5%	24,500	217	26
		E	91%	39,700	6,399	1
		M	4%	25,500	181	0
K	1,147	T	5%	24,500	1,405	169
		E	91%	39,700	41,440	4,980
		M	4%	25,500	1,170	141

Notes:
2. Converstion rates from manufacturers data. Incremental increase above Table 4.5.13.
2. Converstion rates from manufacturers data. See Table 4.4.9.
3. Rated capacity (kW) = kWh(1000) generated/(365 x 24 x 0.95)

Table 4.5.17-G Landfill Gas-To-Electricity GHG-Reduction Case Capacity and Generation in New York State — 2022

Load Control Zone	Total Potential LFG Recovery MMCF	Technology / % Use (1)		Elec. (2) Conversion Rate Kwh/MMCF	Elec. Technical Potential Kwh (1000)	Rated or "Installed" Capacity kW (3)
Statewide	36,952	T	6%	25,000	55,429	6,660
		E	89%	40,000	1,315,507	158,076
		M	5%	26,000	48,038	5,772
A	17,516	T	6%	25,000	26,274	3,157
		E	89%	40,000	623,568	74,930
		M	5%	26,000	22,771	2,736
F	2,468	T	6%	25,000	3,702	445
		E	89%	40,000	87,863	10,558
		M	5%	26,000	3,208	386
G	406	T	6%	25,000	609	73
		E	89%	40,000	14,454	1,737
		M	5%	26,000	528	63
J	38	T	6%	25,000	57	7
		E	89%	40,000	1,344	162
		M	5%	26,000	49	6
K	326	T	6%	25,000	489	59
		E	89%	40,000	11,616	1,396
		M	5%	26,000	424	51

Notes:
1. Technologies: T=Large System: E=Internal Combustion engine; M=Microturbine; percent use estimated by SCS.

2. Converstion rates from manufacturers data. Incremental increase above Table 5.13.
3. Rated capacity (kW) = kWh(1000) generated/(365 x 24 x 0.95)

Summary of Results

Table 4.5.18, Statewide Summary of Total Installed Capacity LFGTE Projections, indicates the overall summary of future estimates by scenario. Base case projections are estimated to capture over 65% of technical potential by year 2022. The CPI scenario should result in over 75% of technical potential by 2022. The GHG scenario should result in about 90% of technical potential by 2022 (if federal tax credits are enacted). Most LFG power will be generated from facilities at large landfills, which are required to install LFG collection systems under NSPS rules.

Table 4.5.18 Statewide Summary of Total Installed Capacity LFGTE Projections

Case	MW			
	2002	2007	2012	2022
Technical Potential	57	143	149	171
Base Case	48	88	97	116
Currently Planned	48	102	114	137
Greenhouse Gas	48	120	131	156

Cost Effectiveness

LGTE technologies under the CPI scenario are cost-effective when high statewide avoided costs are applied to the analysis. Through 2022, LFGTE technologies provide cumulative net benefits (in 2003 $) of $6.2 million for all technologies scales combined. However, certain scales of technology are not cost-effective; large LFGTE systems and microturbines have cumulative net benefits of $600,000. These negative net benefits are more than offset by the positive net benefits from the expected deployment of engine-based LFGTE systems.

STRATEGIES FOR ACCELERATING MARKET DEVELOPMENT

The most effective strategies for accelerating market development involve economic incentives to install the initial LFGTE facilities, either by providing financial support in the form of tax credits or direct buy-down incentives. Particularly in the case of smaller or closed landfills, where considerable untapped LFG still is available, existing LFG resources will not be developed without assistance. California and New Jersey have opted to initiate buy-down programs for facilities up to 1 MW size, with up to 40% of the installation cost paid through a "societal benefit charge." These programs have created the possibility of installing microturbines at many sites that otherwise would not be able to afford them. Once installed, systems will continue to be upgraded to collect as much gas as possible into the future.

Similarly, the initiation of a Renewable Portfolio Standard (RPS) statewide would accelerate and increase LFGTE development by mandating the purchase of renewables. In his State of the State Address on Jan 9, 2003, Governor Pataki indicated that he will "ask the PSC to implement an RPS positive development for renewables." The development of a viable renewables energy credit trading system will be of considerable value, as will the Executive Order 111. Similarly, a very important element for municipal landfill gas development will be continued strong support for NYPA assistance in project development

Section 6:
MUNICIPAL SOLID WASTE TO ELECTRICITY

SUMMARY RESULTS

Municipal solid waste-to-electricity, or "waste-to-energy" (WTE) facilities, as they are commonly called, have been operating in the United States for the past 25 years. After regional solid waste planning was mandated by the New York State Department of Environmental Conservation (DEC) in the late 1970s, WTE plants became a significant option for municipal solid waste (MSW) disposal throughout New York State. At that time, local landfills were rapidly reaching capacity, and "long haul" alternatives to more distant landfills were not economical. Between from 1980 and 1994, 13 WTE facilities came on-line in New York State; of these, three no longer operate.

Several types of technologies for waste combustion exist, based initially on successful installations in Europe and Japan. By the late 1980s, "mass burn" systems that process waste "as received" on a moving stoker with integral water-wall boilers and steam generating systems had become the favored and most competitive method for WTE facilities in the U.S. While stoker systems remain largely of European design, the boilers, air pollution control system, ash system, and power-generating systems are constructed of standard U.S. power-plant components and are developed or modified for WTE plants. All recently constructed WTE plants have excellent on-line reliability and successfully meet New York State and federal regulatory requirements for environmental performance.

During the peak period of WTE construction, landfill costs and tipping fees were escalating rapidly, air-pollution control requirements were strict but affordable, and higher electricity prices and contracts were projected to provide sufficient revenues to enable WTE to remain economical well into the future. However, the solid-waste market, private industry's response to waste market conditions, the electric-power regulatory climate, and pricing for electricity generated by independent power producers changed dramatically during the 1980s and 1990s. These changes included a reduction in landfill costs, repeal of minimum electricity prices under Public Utilities Regulatory and Policy Act (PURPA), and public concern about emissions and possible health risks associated with WTE plants

From the beginning, WTE plants drew significant public concern, based principally on emissions created by combustion of waste materials. While WTE facilities have successfully met or exceeded increasingly stringent emissions requirements mandated by the U.S. Environmental Protection Agency (EPA) and DEC, and exceeded State Department of Health requirements, the costs to do so have increased, and the public's generally negative perception of siting new WTE facilities has not abated. Since the cost for new WTE plants has increased in comparison to a landfill-disposal options in most areas of New York State (except New York City), most project developers do not find it lucrative to build new WTE plants. Expansion of

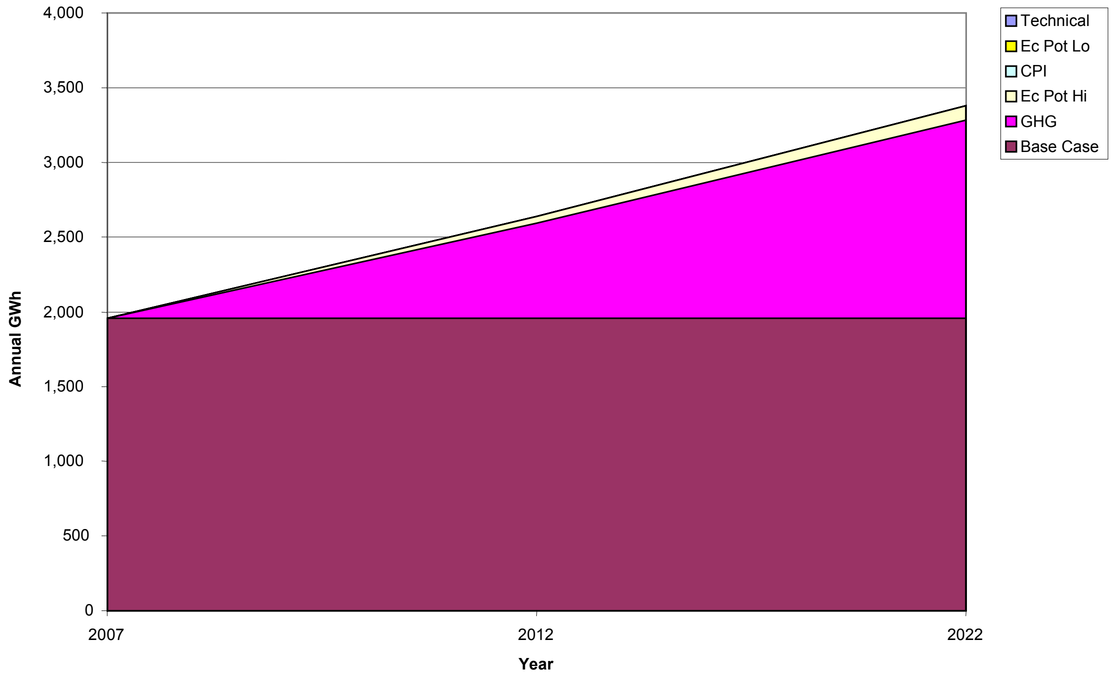
existing WTE facilities remains viable on a site-specific basis, and development of new WTE may be stimulated by the EPA's recent support for inclusion of WTE technologies in states' Resource Portfolio Standards (RPS). In addition, technologies that anaerobically digest MSW may become commercially and economically viable during the next 10 to 15 years.

In New York City and other metropolitan areas with high solid-waste disposal costs and uncertainty about long- term disposal options, WTE facilities could be an attractive alternative. Several potential benefits could accrue to New York City — includng, for example, retaining control over waste disposal, job retention, economic certainty, and flexibility in waste delivery. Similarly, it is possible that anaerobic digestion processes could develop to the point where intermediate-sized facilities could be viable for certain areas of New York City.

This study estimates future waste-to-energy electricity capacity and generation through 2022 under six cases: technical potential, economic potential (assuming high statewide avoided cost), economic potential (assuming low statewide avoided cost), currently planned initiatives (CPI), greenhouse gas (GHG) reduction targets, and the base case. Technical potential is defined as the upper limit for WTE capacity and generation theoretically possible from the MSW resource without regard to cost, market barriers, or market acceptability. Economic potential is the subset of technical potential that is cost-effective from a societal perspective compared to the cost of electric supply the WTE would replace. Economic potential is assessed separately for both high and low statewide avoided cost rates (provided by NYSERDA). The CPI case is defined as the future impacts expected from currently planned initiatives included in the 2002 Energy Plan. The GHG-reduction case identifies WTE potential under an expanded set of policy and program supports above and beyond those analyzed in the CPI case. The policy and program supports are intended to assist in achieving greenhouse-gas reduction targets established by the State using a least-cost portfolio of efficiency and renewable energy options. The base case includes WTE already on-line, already permitted, or well-along in planning as of late 2002.

In each of the cases, WTE potential was assessed for three technologies: large mass-burn steam generators capable of handling 250 tons per day (TPD) or more of MSW, small mass burn steam generators capable of handling up to 250 TPD of MSW, and anaerobic digestors capable of handling about 250 TPD of MSW. These technologies are believed to be the most likely for development in New York State during the study period.

Figure 4.6.1 New York Municipal Waste to Electricity Potential Summary



As shown in Figure 4.6.1, the technical potential for WTE ranges from just under 2,000 GWh/yr in 2007 to nearly 3,400 GWh/yr in 2022. This is an increase of 73% from the base case of 235 MW of net installed capacity, or 2,000 GWh/yr projected for the entire study period. All of this capacity is cost-effective from a societal perspective from 2007 through 2022, assuming both high and low avoided cost rates.

Currently planned initiatives are unlikely to result in any new WTE or digestion plants. However, under a GHG-reduction target scenario, it is possible that installed capacity could increase by 170 MW to 405 MW in 2022, if WTE and digester facilities are included under power plant siting regulations, are included as RPS designated facilities, and a combination of economics, power needs, and public concerns are effectively balanced. Output under this scenario could increase to 3,300 GWh/yr by 2022.

TECHNOLOGY DESCRIPTION AND COMMERCIALIZATION STATUS

Overview of Municipal Solid Waste Resource and Technologies

Municipal Solid Waste Resource. Municipal solid waste (MSW) is collected and processed or handled in a variety of ways. MSW is a finite resource, with collected amounts being dependent upon the habits and proclivities of the population, businesses and industries. While historic MSW generation rates have been projected into the future based on population, this is only an approximate mechanism for predicting future generation.

Historically, MSW has been partially recycled, landfilled, exported out of state, or processed in waste-to-energy (WTE) facilities in New York. This section of the report is concerned with that MSW fraction which can potentially be processed to generate electrical power directly or indirectly, but does not include landfill gas production.

MSW is considered to have a combustible fraction and a non-combustible fraction, or an organic and inorganic fraction. Typically about 75 to 80% of MSW is combustible or organic by weight, consisting of paper, plastic, food and yard waste, wood, rubber, textiles and leather. About 20 to 25% is non-combustible, or inorganic, consisting of metal, glass, sand, brick, dirt, ash and other materials. The Higher Heating Value (HHV) of MSW is typically between 4,500- 6,200 Btu per pound, with an average HHV of about 5,300 to 5,500 Btu per pound. Potential power production in kWh per ton will vary directly with the HHV. An ash or inorganic residue remains after processing, either from WTE or Digester facilities, which must be disposed.

Direct Electric Power Technologies. "Waste-to-energy" or "resource recovery" facilities are terms used to describe the incineration of municipal solid waste (MSW) and generation of steam, which is usually converted to electric power through a turbine generator for use on-site and sale to the power grid. Technologies used for this process vary by manufacturer, but can be generally placed in the following categories:

- Mass burn systems, large units
- Mass burn systems, small units
- Refuse derived fuel (RDF) systems, large and small units
- Small modular combustors (usually do not produce electricity from the steam)

All of these systems are well established and commercially available, although RDF units have become less attractive over time, because of the significant cost to handle, shred and separate RDF prior to burning.

Emerging Technologies for Future Development and Older Technologies. Of interest for future MSW application is anaerobic digestion, a method of processing MSW to produce methane that is then used to generate electric power. Full-scale pilot units are in operation in Canada and other locations.

Older research applications, such as pyrolysis and/or waste gas generation from MSW have been attempted many times at the pilot level, but never overcame significant technical and economic difficulties. The U.S. Department of Energy and others sponsored numerous Research Development and Demonstration (RD&D) projects for these applications during the past 20 or 30 years. One of the objectives was to produce a

combustible off-gas, which could be used to make electricity. The study authors are not aware of systems or technologies of this type that could become commercially available in the near term.

Another process under development is plasma arc processing, whereby a very high voltage arc furnace dissociates waste to its elemental forms and produces significant amounts of hydrogen. The U.S. Army selected this process for demonstrating alternatives to incineration system for destroying chemical weapons. This process is also being investigated for MSW and hazardous waste applications. However, the process is reasonably complex and plasma arc systems are not anticipated to be economically viable for MSW in the foreseeable future.

In -Vessel Anaerobic Digestion of Solid Waste Overview, Anaerobic digestion of MSW involves three steps:

- Sorting incoming material and separating recyclables;
- Enhanced in-vessel anaerobic digestion of the waste and recovery of peat products and methane;
- Electric power production from digester-derived methane.

Various systems for MSW digestion were attempted in the past and are currently being implemented at the pilot scale. The heart of the system is a series of vessels or tanks, similar to sludge digesters, with the capability to rapidly break down the organic fraction of MSW and produce large quantities of methane. Questions exist about whether regular MSW (containing a significant inorganic fraction) can be used as feedstock, or whether it is necessary to separately collect the organic fraction prior to digestion. Systems using both methods are offered. Whichever method is selected, the remaining fraction must be dealt with through recycling or disposal.

A Canadian firm (Super Blue Box Recycling Corporation or SUBBOR) recently completed construction and operation of a large-scale (25,000 tons per year) pilot application of this technology north of Toronto, with financial assistance from the Ministry of Industry. U S and European firms are also developing anaerobic systems.

The future need to reduce dependence on landfills while increasing recycling and energy production increases the perceived need for alternatives to waste incineration. Accordingly, this technology merits additional review as a viable future candidate. While some attempts have been made in the U.S. in the past to develop anaerobic digestion, various obstacles to commercialization prevented this from happening. Key points favoring potential development of anaerobic digestion are:

- MSW processing occurs in a compact fully enclosed system, with less residue than incineration.
- Production of three times the amount of methane is possible from landfills.
- Production of marketable recyclable products is possible.
- Emissions are the same as from landfill gas or sewage sludge digesters.
- Economic viability is supported by renewable energy sales.

Priority of Competing Solid Waste Technologies

Overview. Within the range of disposal and/or recycling options available to the New York public and private solid waste industry, recycling, waste- to-energy and landfill technologies have a semi-competitive relationship for the finite amount of solid waste generated. The hierarchy of solid waste processing options determined by the Department of Environmental Conservation (DEC) places the following priorities on these activities:

- Waste reduction
- Waste reuse and recycling
- Waste disposal

Options available include:

- Recycling, materials or energy
- Composting
- Landfill
- Waste-to-energy
- Ethanol production (there is currently one proposed project)
- Out-of-state disposal

Several factors have had and will continue to have a significant impact on New York's solid waste industry, including:

- Energy prices (the repeal of PURPA price supports for energy from waste was a negative impact);
- Legal (the "Carbone" decision and the recent "Oneida" decision upholding municipal flow control could have a positive impact);
- The closure of small landfills, and relatively lower costs to landfill than any other option;
- Emissions controls (with stricter requirements in place now than in the past or expected in the future); and
- Closure of the Fresh Kills landfill and significant increases in costs for New York City waste as a result of out-of-state disposal.

These factors have dramatically changed the waste landscape in recent years. Since they are continually in a state of flux, it is difficult to determine which MSW management and disposal options will be dominant role in the future and that amount of electricity that could be produced by WTE facilities. For this study, the authors made a reasonable assessment of the probable split between recycling, landfill, waste to energy and other technologies for purposes of evaluating potential electricity production from MSW.

New York City Opportunities and Issues. New York City (NYC) recently closed the Fresh Kills landfill and is currently exporting most MSW to out-of-state landfills. The costs of export have driven the cost of NYC disposal to historic highs. This situation offers a potential opportunity to implement WTE or some smaller amount of anaerobic digestion facilities in the City. While a Long Term Plan for NYC MSW disposal has been under way for some time, the City is presently reconsidering its options. WTE plants have been defeated due to local opposition in the past and previous administrations have declined to pursue WTE further. Nonetheless, it could make technical and economic sense to reconsider WTE or digestion options in the future for the following reasons:

- WTE and digestion would provide significant waste disposal self-sufficiency (as opposed to reliance on private out of state landfills);
- Significant quantities of electricity could be generated;
- The economic benefit of disposal would remain in the New York State economy;
- WTE and digestion could be fully compliant with all EPA/DEC requirements.

Municipal Solid Waste-to-Electricity Technology Selection. During the past 20 years, a variety of technologies were investigated for MSW reduction, incineration, processing and disposal. Of these, "mass burn" systems emerged as the most favorable, reliable and economical method for producing electricity from solid waste. A few locations successfully used refuse-derived fuel (RDF) systems, which involve shredding and separation prior to introduction into a furnace/boiler system. However, RDF systems have proven to be more difficult to operate, have slightly higher operating costs and are typically replaced by mass burn systems, when practical.

Mass burn systems are available in "process trains" or unit sizes that are substantially independent operating units. They include a basic feed or shred system, a furnace or stoker system, a boiler and downstream heat recovery, air pollution controls, exhaust stack and ash handling system. Typically, a plant consists of two or more "trains" or units, providing some redundancy and ability to keep running if one unit is down for repairs. The systems are proven, widely used, commercially available, have extensive operating experience, are reasonably cost effective, are reliable and are accepted in the market. A typical mass burn facility consists of the following elements:

- Receiving, storage and feeding system;
- Fuel combustion and steam generation system;
- Power generation equipment;
- Electrical systems;
- Turbine condensing and cooling system;
- Ash handling system; and
- Air pollution control system and stack.

The distinction between "large" and "small" WTE units at 250 tons per day rated capacity, is one of convenience, based on current EPA air pollution control regulatory definitions. Similarly, small systems tend to be somewhat different physically from large systems (as they have been installed in New York). Future installations would likely be reviewed and categorized on the basis of whether they are large (>250 TPD) or small (<250 TPD).

WTE plants typically contain two or three "trains" consisting of independent feed, stoker, boiler and air pollution control (APC) systems, often supplying steam to a common turbine generator and electrical substation. Combustion train size for plants in New York State ranges from 100 to 225 TPD for small plants, to 375 to 830 TPD per train for large plants. Because of site and logistical issues, a 3,000 TPD plant is the maximum practical size. Smaller plants are less economical now than in the past because of the significant cost of new air pollution control equipment required by the EPA.

The EPA has established air emissions guidelines for large municipal waste combustors (MWC). The guidelines were adopted in New York State by DEC in 1996 for units that process more than 250 tons per day. New York State has seven existing larger unit plants. The EPA proposed and recently finalized emissions guidelines for small MWC, processing less than 250 TPD per unit. Small plants will have an extended compliance period. The State has three existing small unit plants.

While anaerobic digestion of MSW does not have a significant "track record" and there is more work to be done in scaling this technology up to modular sizes where it could be considered viable for large installations, the study authors believe it offers promise and is, therefore, included in this study.

In summary, the technologies recommended for WTE in New York State in the future and therefore included in this study are presented in Table 4.6.1.

Table 4.6.1 MSW Technologies Selected for This Study

Technology Type	Scale to be Analyzed	Rationale for Including
Large mass burn steam generators	>250 TPD units	Proven, reliable, cost effective. Captures high range of production in EPA large facility category.
Small mass burn steam generators	<250 TPD units	Proven, reliable, cost effective Captures small range of production in EPA small facility category.
Anaerobic digesters	250 TPD units	Potentially promising technology.

MANUFACTURING AND SERVICE INFRASTRUCTURE

Manufacturing, Distribution and Service Infrastructure

The infrastructure for WTE plants is well established nationwide and in service in New York. A number of U.S. and European manufacturers of equipment are in the market. WTE plants are generally developed by turnkey bidders who offer design, construction and operation agreements (typically for a 20-year timeframe). Developers and major equipment manufacturers include:

- Ogden Martin
- Foster Wheeler
- Detroit Stoker
- Deutsche-Babcock
- Belco Pollution Control
- ABB Energy
- GE (steam turbines)
- Westinghouse (steam turbines)

These companies are well established, do not depend exclusively on the WTE business (which is a relatively small part of overall operations), and can sell or service readily to any location in New York State for the foreseeable future. There should be no problem serving a larger WTE market from these and other sources in New York State in the future.

Anaerobic digestion of MSW has only a limited number of participants currently, and is in need of additional support to make this technology commercially viable at the scale contemplated in this study. Such support need not be extensive, since the technology itself is proven. However, issues surrounding

waste handling, markets and feedstock collection are important elements that need to be investigated for applications in New York. On the other hand, the important issue of emissions from the process is relatively easily addressed (similar to sewage sludge digesters or landfill gas systems).

Key Market Barriers and Issues

WTE Facilities. Key market barriers associated with WTE technology development are not technical, but involve complex public acceptance issues in addition to potential tax credits, RPS designation, and power sales contract supports. As demonstrated during the period when PURPA $0.06/kWh power contracts were available, WTE installations were installed at dozens of sites across the country, including 10 in New York. At that time, PURPA "qualifying facilities" were entitled to minimum priced power purchase contracts of some length of time for these projects, providing a basis for financing.

With implementation of electric power deregulation in many states (including New York) such long-term power purchase contracts are no longer available. New WTE projects must bid into the New York Independent System Operator (NYISO) program on a daily basis, without the security of a fixed floor price.

Today, as landfill tip fees have dropped significantly, the capital and operations and maintenance (O&M) costs for a WTE project coupled with the uncertainty of energy sales prices represents a key issue for development. The margin of profit for such projects remains small and economic feasibility uncertain (unless local export prices are high, such as those experienced in NYC).

Moreover, while existing WTE facilities in New York State have installed complex air pollution control equipment in compliance with federal and state regulations (which are stricter than many fossil fuel plants), some public interest groups are not convinced of the long-term safety of WTE plants. Thus, considerable public opposition to new facilities in NYC could be anticipated. A change in public attitude towards WTE would be needed prior to the successful siting of new facilities in certain locations in New York.

Anaerobic Digestion. Certain technical, product marketing and economic issues need to be addressed for this technology to emerge at full scale. The limited number of firms who offer this technology are, in some cases, treating their technology as proprietary. While the basic elements consist of equipment that is readily fabricated or supplied by existing manufacturers, the digester itself (be it one-, two- or three-stages) will likely be patented, similar to WTE stoker technologies. Ideally, the technology could be supported through an initial major grant for a project in New York, and could emerge for full-scale applications in approximately five to seven years.

Regulatory, Permitting and Siting Issues

Environmental Impacts. WTE facilities are typically considered to have significant environmental impacts, primarily due to their being a "major source" of air pollution. Additional impacts of a large waste handling facility are also of concern, similar to landfills.

The 1991 Federal Clean Air Act and subsequent amendments are the governing body of air regulations for WTE facilities in New York State. New York State DEC adopted these regulations in 1996 and all WTE facilities in New York State must meet federal New Source Performance Standards (NSPS), Public Service Department (PSD), and National Ambient Air Quality Standards (NAAQS). All large WTE facilities in the State of New York were upgraded, as needed, to meet these regulations and amendments. Small WTE facilities have until 2004 to comply. All plants must comply, or they will be shut down. In addition, federal guidelines for municipal waste combustors, New York State DEC solid waste permit requirements, and State Environmental Quality Review Act (SEQR) procedures are required for WTE facilities in New York.

Overall, existing WTE facilities have complied with public health regulations and significant issues of concern raised by the New York Department of Health have been addressed under SEQR for existing facilities. Nevertheless, as noted above, some parties are not satisfied by the level of regulatory review and performance of WTE facilities, and remain opposed to any new WTE facilities in New York.

Air Emissions Impacts. To control air emissions, WTE facilities use boiler economizers (to control boiler temperature), acid gas control systems (scrubbers), NOx control systems, particulate control devices (bag houses), and a "good engineering practice" stack. Combustion of MSW results in the destruction at high temperature of most elements of concern. Air emissions due to the combustion process (NOx and SOx), incomplete combustion (CO), and particulate matter are minimized through control devices.

It is important to note that although WTE are usually thought of only as emissions producers, the collection and combustion of MSW also results in the offset of generation of greenhouse gas from MSW that would otherwise be decaying in landfills.

Siting and Permitting Issues. Siting WTE facilities can be difficult in New York State and some projects have not proceeded due to siting concerns. The permitting of facilities under EPA and DEC air and solid waste regulations has not revealed significant issues that are not resolvable. The air impacts are known, and have been further reduced by current federal standards. Health risks are known and health risk assessments approved by the Department of Health are conducted repeatedly in New York. Nevertheless, public opposition at several sites has been strong. Siting and public perception of health risks are expected to be significant barriers to development of new WTE facilities in New York State during the study period.

Implementation of power plant siting regulations for WTE facilities could facilitate future development in New York State.

COST AND RELATED INFORMATION

The development of cost factors for municipal solid waste to energy facilities is directly related to the municipal strategy for waste disposal and the method of collecting monies for that public service. A major source of WTE funding is in the form of tipping fees charged to customers for waste disposal. Such charges are used to directly offset capital and/or operating costs. Further, in New York, a sponsoring government entity may choose to partially offset costs by instituting some form of waste district fee or other general tax to assist in financing the facility.

For purposes of this study, the authors assumed that cost factors are for potential new facilities and are estimates of the cost to build existing facilities with a startup in year 2003. To be uniform, both land and extended environmental study costs are not included, since it is difficult to determine such costs and their impact. Table 4.6.2 indicates the cost items included and excluded. Table 4.6.3 includes Installation and Levelized Operating Costs, which provides cost factors for large systems, and would typically be considered more viable because of the substantial economies of scale.

Table 4.6.2 Waste-to-Energy Facility Costs — Items Included and Excluded

INSTALLATION	LEVELIZED ANNUAL OPERATIONS & MAINTENANCE	NOT INCLUDED
Development & Engineering	General & Administration	Tax Credits or Other Incentives
Legal	Insurance	Site Lease Payments
Equipment, Building & Site Work	Utilities/Fees/Licenses	Financing Costs
Interconnection	Ash Disposal	
Permits & Fees	Routine O&M	
Contractors Profit	Major Maintenance	
Siting and Environmental Studies	Contractors Profit	
Land Cost	Tip Fee Revenues	

Table 4.6.3 Waste-to-Energy Facility Costs (2003 $ per kW)

Large Systems*	Year	Installed Cost 2003 $/Kw	O & M Cost (1.) 2003 $/Kw	Tip Fee (2.) 2003 $/Ton	Tip Revenue (3.) 2003 $/Kw	Net O &M Cost 2003 $/Kw
Statewide	All	8,500	650	65	(-983)	(-333)
Zone A	All	7,500	525	45	(-680)	(-155)
Zone F	All	7,500	550	60	(-908)	(-358)
Zone G	All	8,500	650	65	(-983)	(-333)
Zone J	All	11,500	825	75	(-1135)	(-310)
Zone K	All	9,500	725	65	(-983)	(-258)

* See Screening Input Template for cost variations by technology.
1. O&M cost includes ash disposal.
2. Estimated MSW tip fee charged, $/ton. Tip fees are assumed to increase by $1/ton/year above inflation.
3. Tip Fee x 8,322 hours/550 KWh/ton.

Tipping fee revenues are estimated in Table 4.6.3 and are generally representative of the current marketplace. While tip fees are used to offset capital costs as well, Table 3 assumes that tip fee revenue will result in a net negative O&M cost, which can then be applied to the financing method selected for the screening tool to reduce the overall cost per kW. It is noted that facility costs have been estimated based on information provided from several present WTE facility operators in New York, who were asked to estimate current replacement costs for their facilities. These costs varied considerably as a function of $/kW sold. All cost factors are in terms of net kW output sold from the facility.

It was further assumed that since there is generally expected to be a decrease availability of landfill space in the Northeast during the study period, that tip fees at WTE facilities will increase at a rate of $1/ton higher than projected inflation rates. This results in a net lower cost for power production over time.

Small WTE plant costs are estimated at approximately $2,000 per kW more than large plants for capital costs, and $200 per kW more for O&M costs. These cost factors are consistent with actual cost information received from a letter survey of existing facilities. Digestion costs are estimated to be similar to small WTE facilities.

TECHNICAL POTENTIAL

<u>Existing WTE Facilities</u>

There are 10 WTE facilities in operation in New York. Table 4.6.4 demonstrates Existing Waste-to-Energy Capacity and Generation in New York State, which shows the status of the facilities and electric power production as of 2000. All facilities came on line prior to 1994. Two facilities, Long Beach and Albany ANSWERS, were subsequently removed from service. It is interesting to note that smaller plants are typically (but not always) less efficient producers of energy per ton of waste processed.

Table 4.6.4 Existing Waste-to-Energy Capacity and Generation in New York State (2000 MW and GWh)

Load Control Zone	Facility	Nominal Design Capacity (TPD) (1)	Permit Limit Capacity (1) (1000 TPY)	MSW (1) Processed (1000 TPY) 2000	% of Permit Limit	Electricity Generated (GWH) (1) 2000	Rated Plant Capacity MW 2000 (4)	Electricity Sold (GWH) (1) 2000		Net Capacity MW (5) 2000	Elec. Gen. per ton Processed (KWH/Ton)	Elec. Sold per Ton Processed (KWH/Ton) (6)	
F	Hudson Falls	400	153	156	102%	100	12.0	89.0	(3)	10.7	642	571	S
G	Dutchess	450	137	153	112%	65.7	7.9	53.7		6.5	429	351	S
K	Islip	400	189	159	84%	56.2	6.8	50.0	(3)	6.0	356	314	S
	Oswego	200	61	60	98%	7.8	0.9	3.2		0.4	129	54	S*
Statewide Total "S" plants		1,450	540	528		229.7	27.6	196.0		23.6			
A	Niagara	2,250	821	710	86%	353.8	42.5	314.9	(3)	37.8	496	493	L*
K	Hempstead	2,500	914	889	97%	599.8	72.1	537.3		64.6	676	606	L
K	Huntington	750	315	313	99%	197.6	23.7	172.5		20.7	631	551	L
K	Babylon	750	274	217	79%	124.7	15.0	105.2		12.6	575	485	L
Total K		4,000	1,503	1,419	92%	922.0	110.8	815.0		98			
	Onandaga	990	336	335	100%	245.1	29.5	214.3		25.8	732	640	L
	Westchester	2,250	686	644	94%	409.6	49.2	385.0		46.3	636	598	L
Statewide Total "L" plants		9,490	3,346	3,108		1,930.6	232	1,729.2		208			
Tot./Avg. all plants		10,940	3,886	3,636	95%	2,160.2	260	1,925.2		231	585	515	(2)
										Avg. Large Plants (L)	624	576	
										Avg. Small Plants (S)	389	412	

*Biased low, due to large steam sales

Notes:
1. Source, NYSDEC Annual Reports
2. Does not include Oswego or Niagara
3. SCS Estimate based on average of 7 plants at 89% of MWH Generated
4. Rated Capacity=MWH Generated/365 x 24 x 0.95
5. Net Capacity = MWH Sold/(365 x 24 x 0.95)
6. Power sold per ton processed reflect the reduction due to in-plant parasitic load.

Estimating Methodology

In this study, technical potential is defined as the upper limit for electricity capacity and output theoretically possible from the MSW resource base within New York State, without regard to cost, market barriers, or market acceptability.

To estimate WTE potential statewide and in five load control zones, the authors developed a methodology for determining the amount of municipal solid waste that will potentially be used by waste-to-energy and digestion facilities during the study period. This estimate is shown in Table 4.6.5., Waste Solid Waste Management in New York State. The estimate is derived from published data from New York State DEC and/or the Legislative Commission on Solid Waste Management reports, together with SCS Engineering estimates of future tonnages. Table 4.6.5 indicates the disposition of municipal waste tonnage, by major option during the study period.

Table 4.6.5 Municipal Solid Waste Management in New York State (1000 Tons)

	1999		2000		2001(3)	2002(3)	2007(3)	2012(3)	2022(3)
Recycling	5,903	(2)	6,000	(3)	6,100	6,200	6,600	7,000	7,500
Export	5,095		5,378	(3)	6,300	7,000	6,300	4,600	2,700
WTE (4)	3,680	(1,2)	3,638	(1)	3,700	3,700	3,700	4,800	6,000
Digestion								200	400
Landfills:									
Fresh Kills	2,389	(2)	1,800	(3)	900	0	0	0	0
Non-MSW (5)	800	(2)	800	(3)	800	800	800	800	800
MSW(6)	5,717	(2)	6,084	(1)	6,200	6,300	6,600	6,600	6,600
Totals	23,584		23,700		24,000	24,000	24,000	24,000	24,000

Notes:
1. NYSDEC letter to SCS 2/20/2002
2. Legislative Commission on Solid Waste Management, "Where will the Garbage Go", 2000
3. SCS Estimate, based on level total waste projections, indicating tonnage estimates to various management options
4. Reflects existing and new Waste to Energy facilities
5. Dedicated Non-MSW landfills
6. MSW landfill projections

While the overall population of New York State has remained fairly constant over the past 20 years, solid-waste generation has risen by about 24% from 1990 to 1999, according to the Legislative Commission on Solid Waste Management report, "Where Will the Garbage Go? 2000." However, this report concludes that a significant portion of this increase is attributable to better accounting practices and a better economy. At the same time, the emphasis on recycling has increased this fraction by a factor of almost 5, or from 5.6% in 1990 to 25% in 1999. Similarly, waste export has increased by almost 2 million tons per year in this 10-year period, while waste-to-energy disposal has remained substantially level as a percentage.

As shown in Table 4.6.5, waste export is expected to continue as a major option for many New York State communities, including New York City, during the study period. However, it is estimated that the increased cost pressure on NYC from waste export will result in the construction of one new WTE plant in NYC by 2012 and a second plant by 2022. Similarly, it is anticipated that new anaerobic digester facilities could be on line starting in 2012 and expanded in 2022. These developments, if they occur, will reduce but not eliminate the export fraction.

<u>Electric Power Conversion Factors</u>: The technical potential for WTE in New York State is estimated by reviewing the experience of existing WTE plants in New York State and major facilities in other locations. The experience in New York State is diverse, and there is a track record of many years standing. Moreover, as indicated from data in Table 4, power production rates are reasonably consistent between

facilities. Variations in MSW fuel quality in HHV make a direct difference in power output. As the fuel value increases per pound of waste the MWH per ton increases.

WTE plant developers will offer a "guaranteed" kWh /ton for each increment of HHV. For example, the 1989 bond issue financing feasibility report for New York's Hudson Falls mass-burn facility offered a guaranteed power production of 554 kWh/ton @ HHV of 5,300 Btu/lb and 575 kWh/ton @ HHV of 5,500 Btu/lb.

The original facility design for Hudson Falls was based on an average HHV of 5,500 Btu/lb. In 2000, the plant achieved a net output of 571 kWh/ton, which suggests the HHV remained virtually constant over the past 10 years. While there may be some technical improvements in power production or heat-capture efficiency, this is likely to be small, given the mature state of development and the thermodynamic limits imposed by the technology itself. Similarly, it is not anticipated that the composition of the MSW waste stream and its HHV will change noticeably during the study period.

Accordingly, SCS assigned each existing WTE plant the same conversion factor recorded in year 2000 for future operations, and an average of the existing large plant factors for new facilities.

For anaerobic digester facilities, data from pilot plant operations at the SUBBOR facility in Canada indicate a net 10,000 cubic feet of landfill gas (LFG) can be produced per ton of MSW and that a net electric conversion rate of 30,000 kWh/million cubic feet (MMCF) of LFG can be achieved (after subtracting plant parasitic loads). This is consistent with the probable use of internal combustion (I/C) engines for power production and also assumes use of 100% of the MSW waste stream. For this study, the authors assumed 8,000 cubic feet of LFG will be produced per ton of MSW and that some residue disposal will be required.

Technical Potential by Technology

The authors selected technology-use factors based on the existing WTE plants for each technology listed above (large mass burn and small mass burn), and projected that future tonnage and output will be the same for all existing plants, with no expansions. While several plants could expand physically, it does not appear that the economic climate during the study period will enable competition with landfills to favor expansion of WTE plants.

However, the authors believe new WTE facilities and/or waste digestion plants could be economically constructed in New York City, so they were included for development in 2012 and 2022.

Tables 4.6.6 through 4.6.9 document waste-to-energy technical potential for the years 2002, 2007, 2012, and 2022 for both capacity and generation.

Table 4.6.6 Waste-to-Energy Technical Potential Capacity and Generation — 2002

Load Control Zone	Facility	MSW (1) Processed (1000 TPY)	Elec. Sold (2) per ton processed kWh/Ton	Net Electricity sold (GWH)	Net Rated Capacity kW	Technology Large/Small
F	Hudson Falls	153	571	87.4	10,498	S
G	Dutchess	140	351	49.1	5,905	S
K	Islip	180	314	56.5	6,792	S
	Oswego	60	54	3.2	389	S
Statewide Total "S" plants		533	1,290	196.3	23,583.6	
A	Niagara	720	443	318.9	38,327.3	L
K	Hempstead	910	606	551.5	66,265.3	L
K	Huntington	315	551	173.6	20,856.2	L
K	Babylon	240	485	116.4	13,987.0	L
Total K		1,465	1,642	841.4	101,108.5	
	Onandaga	336	640	215.0	25,839.9	L
	Westchester	646	598	386.3	46,420.1	L
Statewide Total "L" plants		3,167		1,761.7	211,695.9	
Tot./Avg. all plants		3,700		1,958.0	235,279.5	

Notes:

1. MSW processed in existing WTE plants is expected to remain substantially the same over the study period and reflects 2000 processing permit limit.
2. Power conversion rates for existing plants are estimated to be the same as current values. Rates for new large plants are an average of existing large plants (576 Kwh/ton net).
3. Net rated capacity (MW) = MWH sold/365 x 24 x 0.95.

Table 4.6.7 Waste-to-Energy Technical Potential Capacity and Generation — 2007

Load Control Zone	Facility	MSW (1) Processed (1000 TPY)	Elec. Sold (2) per ton processed kWh/Ton	Net Electricity sold (GWH)	Net Rated Capacity kW(3)	Technology Large/Small
F	Hudson Falls	153	571	87.4	10,497.8	S
G	Dutchess	140	351	49.1	5,904.8	S
K	Islip	180	314	56.5	6,791.6	S
	Oswego	60	54	3.2	389.3	S
Statewide Total "S" plants		533	1,290	196.3	23,583.6	
A	Niagara	720	443	319.0	38,327.3	L
K	Hempstead	910	606	551.5	66,265.3	L
K	Huntington	315	551	173.6	20,856.2	L
K	Babylon	240	485	116.4	13,987.0	L
Total K	0	1,465	1,642	841.4	101,108.5	
	Onandaga	336	640	215.0	25,839.9	L
	Westchester	646	598	386.3	46,420.1	L
Statewide Total "L" plants		3,167		1,761.7	211,695.9	
Tot./Avg. all plants		3,700		1,958.0	235,279.5	

Notes:

1. MSW processed in existing WTE plants is expected to remain substantially the same over the study period and reflects 2000 processing permit limit.
2. Power conversion rates for existing plants are estimated to be the same as current values. Rates for new large plants are an average of existing large plants (576 Kwh/ton net).
3. Net rated capacity (MW) = MWH sold/365 x 24 x 0.95.

Table 4.6.8 Waste-to-Energy Technical Potential Capacity and Generation — 2012

Load Control Zone	Facility	MSW (1) Processed (1000 TPY)	Elec. Sold (2) per ton processed kWh/Ton	Net Electricity sold (GWH)	Net Rated Capacity kW(3)	Technology Large/Small
F	Hudson Falls	153	571	87.4	10,497.8	S
G	Dutchess	140	351	49.1	5,904.8	S
K	Islip	180	314	56.5	6,791.6	S
	Oswego	60	54	3.2	389.3	S
Statewide Total "S" plants		533	1,290	196.3	23,584	S
A	Niagara	720	443	318.9	38,327.3	L
J	NYC Plant 1	1,100	576	633.6	76,135.5	L
K	Hempstead	910	606	551.5	66,265.3	L
K	Huntington	315	551	173.6	20,856.2	L
K	Babylon	240	485	116.4	13,987.0	L
Total K	0	1,465	1,642	841.4	101,109	
	Onandaga	336	640	215.0	25,839.9	L
	Westchester	646	598	386.3	46,420.1	L
Statewide Total "L" plants		4,267		2,395.3	287,831	L
Tot./Avg. all plants		4,800		2,591.6	311,415	

Notes:

1. MSW processed in existing WTE plants is expected to remain substantially the same over the study period and reflects 200 processing permit limit.

2. Power conversion rates for existing plants are estimated to be the same as current values. Rates for new large plants are an average of existing large plants (576 Kwh/ton net).

3. Net rated capacity (MW) = MWH sold/365 x 24 x 0.95.

Table 4.6.9 Waste-to-Energy Technical Potential Capacity and Generation — 2022

Load Control Zone	Facility	MSW (1) Processed (1000 TPY)	Elec. Sold (2) per ton processed kWh/Ton	Net Electricity sold (GWH)	Net Rated Capacity Capacity kW(3)	Technology Large/Small
F	Hudson Falls	153	571	87.4	10,497.8	S
G	Dutchess	140	351	49.1	5,904.8	S
K	Islip	180	314	56.5	6,791.6	S
	Oswego	60	54	3.2	389.3	S
Statewide Total "S" plants		533		196.3	23,584	
A	Niagara	720	443	319.0	38,327.3	L
J	NYC Plant 1	1,100	576	633.6	76,135.5	L
J	NYC Plant 2	1,200	576	691.2	83,057.0	L
Total J		2,300		1,324.8	159,193	
K	Hempstead	910	606	551.5	66,265.3	L
K	Huntington	315	551	173.6	20,856.2	L
K	Babylon	240	485	116.4	13,987.0	L
Total K		1,465		841.4	101,109	
	Onandaga	336	640	215.0	25,839.9	L
	Westchester	646	598	386.3	46,420.1	L
Statewide Total "L" plants		5,467		3,086.5	370,888	
Tot./Avg. all plants		6,000		3,282.8	394,472	

Notes:

1. MSW processed in existing WTE plants is expected to remain substantially the same over the study period and reflects 2000 processing permit limit.
2. Power conversion rates for existing plants are estimated to be the same as current values. Rates for new large plants are an average of existing large plants (576 Kwh/ton net).
3. Net rated capacity (MW) = MWH sold/365 x 24 x 0.95.

Energy and Capacity Coincidence Factors

MSW processing facilities must be open for processing 365 days per year and do not lend themselves to periodic shutdowns or outages for any reason, because trash must be disposed in accordance with public health regulations. Therefore, WTE plants should be considered base load facilities. However, the overall experience with MSW collection and delivery to WTE plants indicates that higher volumes of MSW are received in the summer than the winter. The seasonal difference varies with location, but overall it is reasonable to assume in New York State that the MSW received in the summer is 5-10% higher than the annual average, and the winter is correspondingly lower.

From a power-production viewpoint, steam-turbine condensing systems cause variable power output as a function of temperature differential. An air-cooled condenser produces more power in the winter (perhaps 2 to 3%) and less in the summer. A water-cooled condenser has less differential. There are both air- and water-cooled WTE systems in New York. The authors conclude that, on average, New York State WTE facilities will produce approximately 5% more power in the summer and 5% less in the winter. There is no noticeable hourly variation in power output at any time of year.

For capacity, a similar regime is applicable. WTE facilities typically achieve a 95% availability factor and are usually able to handle their summer waste load by running at full load (100%) during this period. Therefore, WTE plants can be said to have a 100% capacity coincidence year round.

ECONOMIC POTENTIAL

All of the WTE technical potential resources identified above pass the economic screening applied for this assessment and are cost-effective under both high and low statewide avoided costs. The values in Tables 4.6.6 to 4.6.9 represent technical potential, including what is expected to be developed under the base case scenario. The economic potential for incremental (over base case) energy production is projected to be over 681 GWh in 2012, and over 1,400 GWh in 2022. The economic summer-peak coincident capacity resource grows from 91 MW in 2012 to 190 MW in 2022.

ACHIEVABLE POTENTIAL

Base Case

This case reflects maintenance of the status quo, with existing plants continuing to be in operation throughout the study period. In consideration of the large financing costs of these facilities, it is unlikely that any existing facility will close (even under adverse energy price circumstances) because of the need to continue bond payments. Table 4.6.10 demonstrates Waste-to-Energy Technical Potential Capacity Summary, and Table 4.6.11 shows Waste-to-Energy Base Case Capacity Summary. These tables indicate the estimated projections. Base case estimates are substantially the same as what is currently produced from these facilities. No new facilities are planned.

Table 4.6.10 Waste-to-Energy Technical Potential Capacity Summary

Load Control Zone	Facility	MSW (1) Processed (1000 TPY)	Technology Large/Small	2002 kW	2007 kW	2012 kW	2022 kW
F	Hudson Falls	153	S	10,498	10,498	10,498	10,498
G	Dutchess	140	S	5,905	5,905	5,905	5,905
K	Islip	180	S	6,792	6,792	6,792	6,792
	Oswego	60	S	390	390	390	390
Statewide Total "S" plants		533	0	23,585	23,585	23,585	23,585
A	Niagara	720	L	38,327	38,327	76,136	76,136
J	NYC Plant 1	1,100	L				83,057
J	NYC Plant 2	1,200	L			76,136	159,193
Total J		2,300	0	0	0	76,136	242,250
K	Hempstead	910	L	66,265	66,265	66,265	66,265
K	Huntington	315	L	20,856	20,856	20,856	20,856
K	Babylon	240	L	13,987	13,987	13,987	13,987
Total K		1,465	0	101,108	101,108	101,108	101,108
	Onandaga	336	L	25,840	25,840	25,840	25,840
	Westchester	646	L	46,420	46,420	46,420	46,420
Statewide Total "L" plants		5,467	0	211,695	211,635	287,771	370,828
Tot./Avg. all plants		6,000	0	235,280	235,220	311,356	394,413

Table 4.6.11 Waste-to-Energy Base Case Capacity Summary

Load Control Zone	Facility	MSW (1) Processed (1000 TPY)	Technology Large/Small	2002 kW	2007 kW	2012 kW	2022 kW
F	Hudson Falls	153	S	10,498	10,498	10,498	10,498
G	Dutchess	140	S	5,905	5,905	5,905	5,905
K	Islip	180	S	6,792	6,792	6,792	6,792
	Oswego	60	S	390	390	390	390
Statewide Total "S" plants		533	0	23,585	23,585	23,585	23,585
A	Niagara	720	L	38,327	38,327	38,327	38,327
J	NYC Plant 1	1,100	L				
J	NYC Plant 2	1,200	L				
Total J		2,300	0	0	0	0	0
K	Hempstead	910	L	66,265	66,265	66,265	66,265
K	Huntington	315	L	20,856	20,856	20,856	20,856
K	Babylon	240	L	13,987	13,987	13,987	13,987
Total K		1,465	0	101,108	101,108	101,108	101,108
	Onandaga	336	L	25,840	25,840	25,840	25,840
	Westchester	646	L	46,420	46,420	46,420	46,420
Statewide Total "L" plants		5,467	0	211,695	211,635	211,635	211,635
Tot./Avg. all plants		6,000	0	235,280	235,220	235,220	235,220

Currently Planned Initiatives

It is not clear whether the CPI will impact WTE facilities or whether WTE will be included in the green-power marketing incentive support program. It is assumed that no NYSERDA solicitations will be directed to the WTE market. Therefore, no new facilities are anticipated and estimates of production are the same as the base case.

Potential Contributions to Greenhouse-Gas Reduction Targets

The one initiative that could impact WTE in the GHG-reduction case is the application of power-plant siting rules to WTE facilities. With the steadily increasing cost of MSW disposal at out-of-state landfills for New York City waste, it is anticipated that the City may attempt to site and build two new WTE facilities to handle a portion of city waste — one by 2012 and a second plant by 2022 (see Table 4.6.12). Digestion facilities shown in Table 4.6.13 are also a possibility. Construction of these facilities will depend on the probability of significant increases in cost for out-of-state facility disposal and transport costs during the next five years.

Table 4.6.12 Waste-to-Energy Greenhouse-Gas Reduction Case Capacity Summary

Load Control Zone	Facility	MSW (1) Processed (1000 TPY)	Technology Large/Small	2002 kW	2007 kW	2012 kW	2022 kW
F	Hudson Falls	153	S	10,498	10,498	10,498	10,498
G	Dutchess	140	S	5,905	5,905	5,905	5,905
K	Islip	180	S	6,792	6,792	6,792	6,792
	Oswego	60	S	390	390	390	390
Statewide Total "S" plants		533	0	23,585	23,585	23,585	23,585
A	Niagara	720	L	38,327	38,327	38,327	38,327
J	NYC Plant 1	1,100	L			76,136	76,136
J	NYC Plant 2	1,200	L				83, 057
Total J		2,300	0	0	0	76,136	76,136
K	Hempstead	910	L	66,265	66,265	66,265	66,265
K	Huntington	315	L	20,856	20,856	20,856	20,856
K	Babylon	240	L	13,987	13,987	13,987	13,987
Total K		1,465	0	101,108	101,108	101,108	101,108
	Onandaga	336	L	25,840	25,840	25,840	25,840
	Westchester	646	L	46,420	46,420	46,420	46,420
Statewide Total "L" plants		5,467	0	211,695	211,635	287,771	370,828
Tot./Avg. all plants		6,000	0	235,280	235,220	311,356	394,413

Table 4.6.13. Municipal Solid Waste Digestion Capacity and Generation 2012 and 2022

Load Control Zone	Facility	MSW Processed (1000 TPY)	LFG (1) Produced MMCF	Net (2) Elec. Conv. kWh/MMCF	Net Elec. Prod. GWH	Net Rated Capacity kW (3)
YEAR	2012	2012	2012	2012	2012	2012
J	Plant No. 1	200	1600	30,000	48.0	5,768
Statewide Total		200	1600		48.0	5,768
YEAR	2022	2022	2022	2022	2022	2022
J	Plant No. 1	200	1600	30,000	48.0	5,768
J	Plant No. 2	200	1600	30,000	48.0	5,768
Total J		400	3,200		96.0	11,536
Statewide Total		400	3,200		96.0	11,536

*Only applicable under Greenhouse Gas Reduction case.

1. LFG production is estimated to be 8,000 cf/ton of MSW processed.
2. Net electrical conversion rate assumes LFG engines with 30% parasitic load and a 95% utilization factor.
3. Net rated capacity (MW) = MWH sold/365 x 24 x 0.95.

STRATEGIES FOR ACCELERATING MARKET DEVELOPMENT

The construction of new WTE facilities in regions outside of the New York City metro area is unlikely during the study period because of the high capital costs and need for high tip fees for MSW when compared to landfill disposal. While some expansion of existing facilities is possible, it is not likely unless fees can be increased.

On the other hand, New York City is a potentially good candidate for WTE facilities based on costs, the potential for maintaining control over at least some disposal capacity within the City, and the ability to increase base load power-plant capacity locally. Application of power-plant siting rules could stimulate the development of new WTE facilities.

The most important initiatives for the continued viability and development of new WTE facilities would be inclusion of this technology as a renewable power source in Executive Order 111, in energy marketing and trading activities, and in a Renewable Portfolio Standard (RPS).

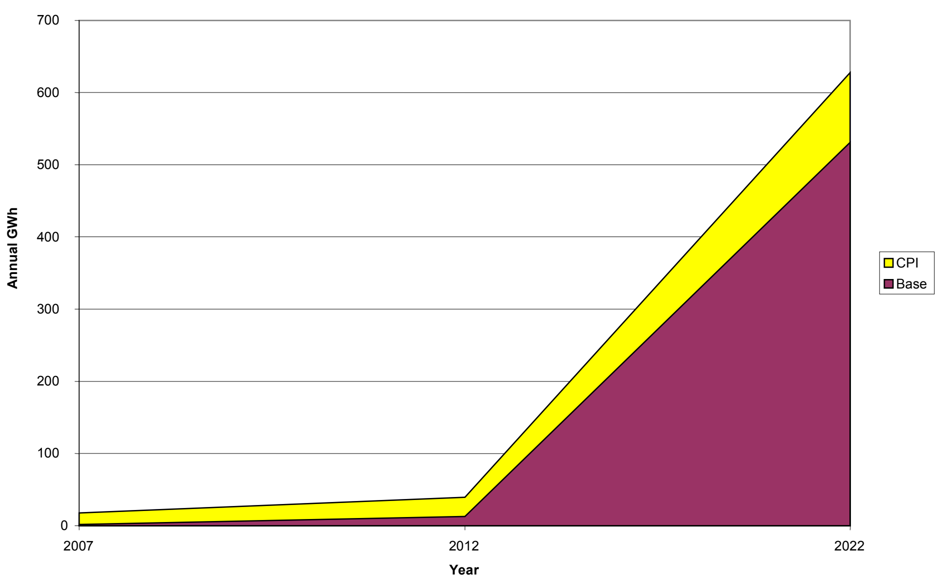
Section 7:
PHOTOVOLTAICS

SUMMARY RESULTS

There is tremendous technical potential for renewable electric generation in New York State using photovoltaic technologies. This study characterizes the amount of generation available from photovoltaics (PV) based on New York State's solar resource and continued rapid growth of global manufacturing capacity. However, by definition, technical potential estimates do not account for cost and other market barriers. Thus, for policy, program, and market planning, the projected levels of development under the base case and currently planned initiative (CPI) scenarios have more direct bearing.

Projected electric generation under these two scenarios is illustrated in Figure 4.7.1. This figure illustrates the anticipated exponential growth of photovoltaic generation, with particular acceleration expected after 2012. By 2022 the expected generation is more than 530 GWh in the base case and close to 640 GWh in the CPI scenario. This growth is driven by the two complementary factors of increased manufacturing capacity and decreasing costs. As a result, by 2022 PV installations are expected to have total levelized costs of <$0.15 per kWh, which should result in favorable customer economics in a number of applications. The cost declines and growth in manufacturing capacity projected in this analysis are consistent in trend but more conservative than industry projections.

Figure 4.7.1 New York Photovoltaic Base and CPI Scenario Potential Summary

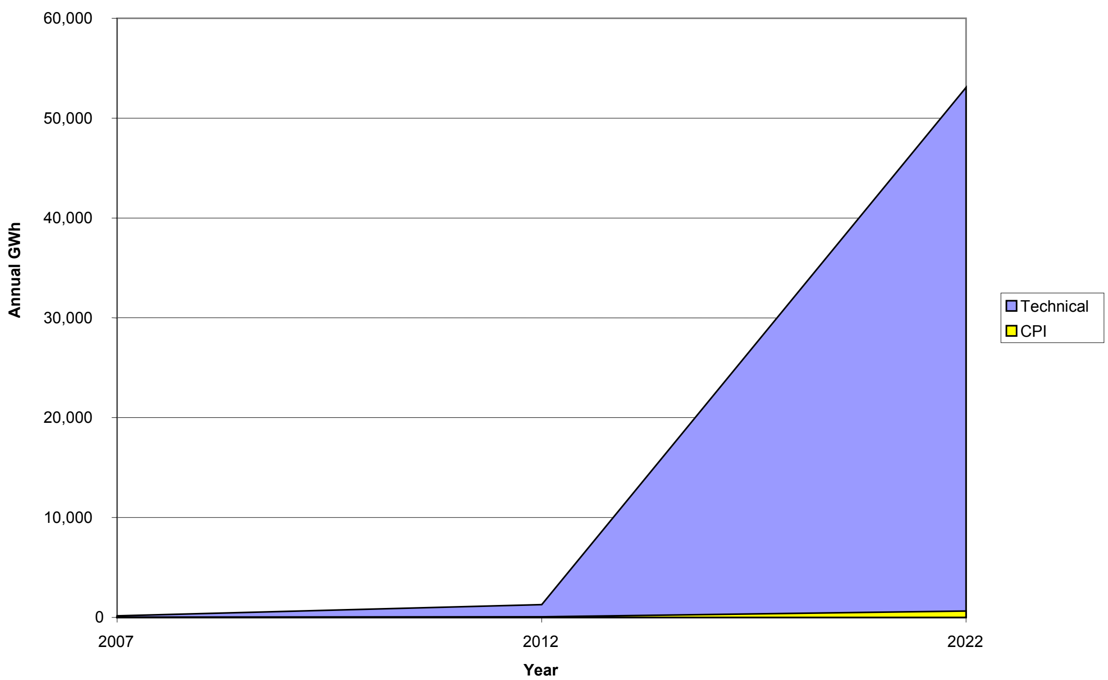


The differential between the expected generation in the base case and CPI scenarios is greatest early in the study's time horizon. The generation in the CPI scenario exceeds that in the base case by a factor of 11 in

2007, by a factor of approximately 3 in 2012, and by roughly 20% in 2022. This result is consistent with market conditions and program designs, which are based on declining incentives over time, increasing consumer awareness, and early program focus on the development of delivery infrastructure through training and certification.

The technical potential for photovoltaic generation is very large, exceeding the level of generation expected through the base case and CPI scenarios by a factor of more than 80 times by 2022. Figure 4.7.2 illustrates the magnitude of this technical potential by charting it in comparison to the expected generation in the CPI scenario from Figure 4.7.1. Of all the renewable resources included in this analysis, photovoltaics are characterized by the largest spread between the technical and CPI and base case scenarios. The magnitude of the technical potential resource, more than 53,000 GWh in 2022, makes PV a major component (roughly one-third) of the total renewable technical potential, and by its very size represents an important finding from this study.

Figure 4.7.2 New York State Photovoltaic Potential Summary



Photovoltaic generation does not pass the societal economic screening tests applied in this study. It also does not contribute to the least-cost integrated set of efficiency and renewable resources to attain greenhouse gas (GHG) reduction targets.

TECHNOLOGY DESCRIPTION

The photovoltaic effect converts light energy (photons) to electricity. Solar electric systems based on this effect are used to produce electricity for a wide variety of applications ranging from power supplies for small consumer products, such as watches and calculators, to installations with more than 1 MW of peak power output. PV systems provide reliable power for remote applications, such as off-grid homes, navigation buoys, and the international space station. Increasingly, over the last decade, they also provide power for end uses that are connected to the conventional electric power grid. This technology assessment is focused on PV applications that are grid-connected and provide power directly to New York State's electric-power system. The study also focuses on flat-plate PV collectors, including building-integrated applications.

Solar cells are composed of semi-conductor materials, carefully designed and manufactured so that when they are struck by light, electrons are freed to flow in an electrical circuit external to the solar cell. A number of different materials are used in the solar cells currently on the market, including single crystal silicon, polycrystalline silicon, amorphous silicon (no crystalline structure), copper indium diselenide, and cadmium telluride. Production techniques include the sawing of individual silicon wafers from pure crystalline ingots, the growth of thin crystalline ribbons, and the deposition of thin films (only a few microns thick) directly onto glass or other substrates. For panel or flat-plate photovoltaics, manufacturers typically combine a number of solar cells, wired in parallel or in series in a single unit (solar module) which is designed to produce specific voltage and current under full sun conditions.

Photovoltaics rely on available sunshine and therefore produce intermittent electric power. They will produce electricity any time the sun is shining, but more electricity is produced when the light is more intense (a sunny day) and is striking the PV modules directly (when the rays of sunlight are perpendicular to the PV modules). The efficiencies with which solar cell converts energy from sunlight to direct current electricity range from 7% to 17% depending on materials and cell type. In the State of New York, a photovoltaic system with a peak output of 1 kW will produce approximately 1,400 kW hours annually and contain of roughly 100 square feet of solar cells (12% cell efficiency).

Solar cells produce direct current electricity. Therefore, for grid-connected applications, an inverter is needed to convert the power produced by the solar cells to alternating current. Inverters are solid-state electronic power-conditioning devices designed and selected to match the current and voltage outputs of a particular PV system. Inverters also function to prevent PV systems from feeding electricity back to the utility grid when there is a power outage. Other "balance of system" components in the solar electric power systems being assessed in this study include wiring and connection devices, mounting structures and hardware.

Market Applications

Three applications of photovoltaic technologies were selected for inclusion in this assessment:

- **Residential systems**, installed in both new construction and existing homes. A typical residential system would average 3 kW installed capacity and take advantage of utility net metering. Net metering permits the customer to spin their meter backward when the solar electric system produces more power than is consumed at the home and receive retail credit for this power.[36]
- **Commercial- and industrial-sited systems** designed to maximize solar energy and capacity output. These systems, with an average installed capacity of 200 kW, will generally be sized so that they produce power "behind the meter" for the customer, without exporting any power to the utility grid since they are not eligible for retail net metering. Nevertheless, although they are not exporting power to the grid, the electric and capacity benefits produced by these systems reduce the customer load and, therefore, directly offset demands on the power grid. These applications are assumed to be a mix of horizontal and slightly sloping south-oriented applications. Also available are installations using solar load control designed to maximize the peak shaving capacity of PV systems by reducing demand whenever warranted by PV output and load demand. These would increase the demand-reduction benefits associated with PV. However, for consistency with the other portions of this resource assessment, in which load shifting and load management was explicitly excluded from the efficiency potential analyses, PV with load control is not included as an option under this category.
- **Building-integrated photovoltaic systems** that are typically vertically oriented on facades with orientations between east and west in the southerly direction. These systems, which in the study's analysis are assumed to average 50 kW in size, will typically provide lower levels of solar output due to orientation, but they can provide building-material cost reductions (for glazing or cladding materials) that can partially or wholly off set the power-production penalty. To take advantage of this benefit, building-integrated systems are therefore most likely to be installed in new-construction applications. These systems are primarily sized to meet loads on the customer's side of the meter.

Commercialization Status and Manufacturing /Delivery Infrastructure

The photovoltaic industry is growing rapidly, maintaining annual growth rates in total shipments over the past three years of >30% annually.[37] Government and industry targets for sustained growth rates in manufacturing and shipments of greater than 25% annually during the next 20 years indicate an expectation that this type of growth will continue.[38]

Sustained growth in manufacturing capacity is necessary if photovoltaics are to provide the potential electric resources identified in this study. Increasing the scale of manufacturing is also a key component to reducing PV costs and the long-term goal of providing competitively priced power.

---

[36] New York's Net Metering Law allows photovoltaic systems up to 10kW to net meter. Credit for excess power is rolled forward on a monthly basis, with any annual surplus production reimbursed by the utility at wholesale rates. Reference: NY Public Service Law sec. 66-j (1997 A.B. 8660, S.B. 5400)

[37] U.S. Department of Energy, Photovoltaics Overview FY 2001.

[38] *Photovoltaics: Energy for the New Millenium,* U.S. Department of Energy, National Photovoltaics Program Plan, 2002-2004.

Worldwide, the top 10 companies produced 336.24 MW of PV power in 2001, as listed in Table 4.7.1.[39]

Table 4.7.1 Global PV Production, 2001

Company	Country	MW Produced
1. Sharp	Japan	75.02
2. BP	Europe	54.2
3. Kyocera	Japan	54.0
4. Shell/Siemens	Europe	39.0
5. Astropower	US	26.0
6. RWE (was ASE)	Europe	23.0
7. Sanyo	Japan	19.0
8. Isophoton	Spain	18.02
9. Mitsubishi	Japan	14.0
10. Photowatt	Europe (France)	14.0
Remaining small producers	Worldwide	54.26
	TOTAL PRODUCTION	390.50

The top global markets for PV are Germany, Japan, and the United States. In 2001 Germany had 200 MW of installed solar power, trailing Japan's 400 MW. The U.S. was third with 175 MW of installed capacity.

In the United States, there have been dramatic changes in the patterns of PV cell and module shipments during the last several years. Domestic shipments shot up nearly 80% in 2001 to 36.3 peak megawatts, while exports declined 10%. This reverses a 10-year history of largely modest growth in domestic shipments and strong gains in exports. Overall, total PV cell and module shipments rose 11% in 2001 to 98 peak megawatts.

There were also substantial changes in the type of module produced. For example, thin-film silicon, which had never had more than 4 peak megawatts shipped in a single year, had almost 13 peak megawatts of cells and modules shipped in 2001. However, countering this trend, BP Solar announced in November 2002 that it was halting its activity in thin-film product manufacturing, focusing on crystalline technologies, which represent roughly 85% of BP's global production capacity.[40]

Module manufacturers, which do not manufacture their own cells, purchased substantially less product in 2001, receiving shipments of 14 peak megawatts of cells and modules, compared with 19 peak megawatts

[39] Paul Maycock, PV News, November 1/2002
[40] BP Solar Press Release, November 21, 2002 (See www.bpsolar.com).

in 2000. Despite this trend, total module shipments rose from 55,007 peak kilowatts to 67,033 peak kilowatts.

The total value of PV cell and module shipments rose to $305 million in 2001, a 13% gain over 2000. The average price per peak megawatt held fairly steady for both cells and modules during 2001 at $2.46 and $3.42 respectively.

A 34% surge in shipments to the residential market enabled this market to regain its ranking as the top market for PV cells and modules in 2001. Manufacturers shipped 33 peak megawatts of cells and modules to the residential market in 2001, compared with 25 in 2000. Shipments to the second-largest market sector, industrial, declined slightly from 29 to 28 peak megawatts.

Shipments for electricity generation rose sharply. Shipments for grid-interactive and remote application markets increased 25 and 43% respectively, to combine for a total of 49 peak megawatts in 2001. In contrast, sales to original equipment manufacturers dropped nearly 50% from levels the previous year.

The drop in exports was due mainly to decreased shipments to Japan (68%) and India (98%). Since 1999, exports to Japan have decreased 83%. Germany remained the leading importer of U.S. PV cells and modules during 2001 with nearly 35 peak megawatts, or 57% of total U.S. exports. [41]

In addition to manufacturing capacity, the commercialization of PV technologies depends on the development of marketing, installation, and servicing infrastructure. The New York State Solar Energy Industry Association (NYSEIA) lists 15 contractors and installers as members. Recognizing the need to build delivery and marketing capacity, the industry continues to expand training activity and has recently worked with stakeholders to implement a national certification standard and program.

Regulatory, Permitting and Siting Issues

Photovoltaics are a clean, modular, distributed-generation technology that provides significant environmental benefits over most other power-generating options. Although tremendous progress has been made in developing standardized requirements and processes over the past several years, the siting, permitting, and interconnection of PV installations can still, on occasion, raise significant barriers to specific installations and market development. Therefore, continuing efforts to standardize and streamline permitting, interconnection processes and requirements — as well as efforts to educate key stakeholders, such as local permitting agencies and inspectors — remain important strategies to help move markets forward.

---

[41] Renewable Energy Annual 2000, (See www.eia.doe.gov)

Most photovoltaic modules consist of the same types of silicon-based semi-conductor materials found in computers and other electronic products. Modules are very durable and have expected service lives of 20 to 25 years. Some photovoltaic modules contain toxic heavy metals, such as cadmium telluride, and thus require special handling at the time of recycling or disposal. The National Center for Photovoltaics has also worked with industry partners to reduce the potential for other material-disposal issues, such as the development of manufacturing techniques using lead-free solder in modules.[42]

Cost and Related Information

The cost for PV modules has declined significantly over the past 25 years, from more than $20 per peak watt in 1976[43] to less than $3.50 currently. The module cost typically accounts for 35 to 50% of the total installed system cost, with the remainder made up of installation, design labor and balance-of-system components (including inverter). Based on an informal survey of industry sources, the total turnkey projected costs are projected to evolve over the study period as demonstrated by Table 4.7.2.

Table 4.7.2 PV Cost Projections

Forecast Total Installed Cost — 2003$/Peak Watt		
Year	**Residential and BIPV**	**Commercial Industrial**
2003	$8.50	$7.00
2007	$6.00	$5.20
2012	$4.75	$4.20
2022	$3.50	$3.00

These estimates are consistent in trend, although they are more conservative than industry-established roadmap goals, which forecast total end-user costs, including operations and maintenance (O&M) of $3 per Watt in 2010, approaching $1.50 per Watt in 2020.

Operations and maintenance costs for photovoltaics are assumed to consist of an inverter replacement in year 10. Currently inverter costs are roughly $1 per Watt. These costs are projected to decline, so that systems installed in 2003 will experience, an average O&M expense of $0.50 per Watt in their 10th year. Improved reliability — delaying the average need for inverter maintenance to year 15, accompanied by further cost reductions to $0.37 and $0.10 per Watt — are forecast for systems installed in 2007 and 2012 respectively.

---

42 U.S. Department of Energy, Photovoltaic Energy Program Overview FY 2000.

TECHNICAL POTENTIAL

PV Category 1: Energy/Capacity-Maximizing, Grid-Connected, User-Sited

Commercial/Industrial PV

This broad user-sited category includes industrial as well as commercial applications:

Overall Resource Potential. The overall potential is based on an estimation of the space available to deploy PV. Potential spaces include commercial roof space, industrial roof space, parking lots, and exclusion zones.

Commercial Roof Space. The Energy Information Administration (EIA) provides detailed data on commercial building stock distribution as a function of square footage, number of floors, and region. The EIA information is a snapshot of the year 1997. An estimated 2% growth rate (based on 1980-1997 trend) was used to bring the 1997 information to 2002 levels. Using straightforward assumptions relating number of floors and office space, a 2002 total roof area of 3.8 billion m^2 in the U.S. and 625 million m^2 in the northeastern U.S. (including New England, New York State, Pennsylvania and New Jersey) was estimated. The New York State number is prorated down from the EIA's northeast U.S. number based on population distribution. Thus, total commercial roof space in New York is estimated at 230 million m^2. This number is further extrapolated down for each Independent System Operator (ISO) region based on population, with an exception for region J (New York City), where the population-estimated number is divided by 2 in an attempt to account for the greater building stock in Manhattan. This approach leads to the following numbers for 2003:[44]

- Statewide: 187 million m2
- Region A: 21 million m2
- Region F: 15 million m2
- Region G: 16 million m2
- Region J: 43 million m2
- Region K: 36 million m2

Industrial Roof Space. Unfortunately, the EIA does not provide information on industrial building square footage. However, a reasonable estimate of a potential solar-collection space comparable to the commercial building stock can be inferred based on two facts: (1) industrial energy usage in the Northeast is slightly

43 Kelly, Henry, Introduction to Photovoltaic Technology, In Renewable Energy: Sources for Fuels and Electricity, Island Press, 1993.

44 All deployable potential capacities presented in this report are, for conservative reasons, based on the 2003 space availability. These numbers could be increased by ~50% at the study's 2022 horizon if one assumes real estate space growth rate of 2% per year.

higher than commercial usage; (2) industrial buildings should be expected to have fewer floors than commercial buildings (hence a higher roof-to-occupancy space ratio).

Parking Lots and Exclusion Zones. Detailed and comprehensive information on the availability of such spaces is not available. However, three indirect sources of information can be accessed to generate an acceptable, conservative estimate. The three sources include (1) regional length of rural and urban roadways (Source: USDOT); (2) impervious ground coverage in sample rural, suburban, and urban environments (Source: NASA); and (3) building structure footprints (see above). A conservative estimate of parking lot and exclusion zone acreage equal to commercial/industrial building footprint corresponds to ~ 15% of estimated roadway acreage. Further, estimating impervious ground cover from the sum of estimated building acreage (including residential), estimated roadways acreage, and the above estimate of parking lot and exclusion zones acreage, leads to factors ranging from 1-2% in regions A, F and G, 14% in region K, and 60% in region J. This is well on the conservative side of NASA estimates in sample Northeastern regions.

Installed PV Capacity Potential. The following assumptions are used to determine potential PV capacity from available space:

- Effective PV conversion efficiency (solar to AC): 8%
- Utilizability of commercial roofs: 50%
- Utilizability of industrial roofs: 25%
- Utilizability of parking lots and exclusion zones: 25%

Based on these assumptions, deployable PV capacities given 2003 space availability[45] are:

- Statewide: 18.4 GW
- Region A: 2.1 GW
- Region F: 1.5 GW
- Region G: 1.6 GW
- Region J: 4.3 GW
- Region K: 3.6 GW

Energy and Energy Distribution. Nominal energy output as a function of season and time of day was derived from typical meteorological year (TMY) data representative of each region, using the calculation engine of the Clean Power Estimator program (itself patterned after a Photovoltaic System Simulation

45 Using a building space growth rate of 2%, the 2022 numbers should be ~ 50% higher.

Program [PVFORM] developed by Sandia National Laboratory). A mix of horizontal and lightly sloping arrays facing south and southwest was assumed. Overall energy potential[46] per region is:

- Statewide: 27 million GWh
- Region A: 3.0 million GWh
- Region F: 2.2 million GWh
- Region G: 2.5 million GWh
- Region J: 6.7 million GWh
- Region K: 5.6 million GWh

Energy/price coincidence factors are listed in Table 4.7.3.

Table 4.7.3 Commercial Industrial PV Energy Production by Costing Period

	Summer On-Peak %	Summer Off-Peak %	Summer Shoulder %	Non-Summer On-Peak %	Non-Summer Off- Peak %	Non-Summer Shoulder %
STATE	15%	10%	9%	6%	55%	5%
A	16%	11%	10%	5%	54%	4%
F	14%	10%	9%	6%	55%	6%
G	14%	10%	9%	6%	55%	6%
J	14%	10%	9%	6%	55%	6%
K	14%	10%	9%	6%	55%	6%

Effective Capacity. The numbers below were previously derived by the author based on detailed analysis of hourly regional New York State loads (1997-99) and time- and site-specific, satellite-derived insolation data. The numbers in Table 4.7.4 correspond to the selected array configuration and a PV-grid penetration of <5%. Note that with the exception of technical potential, PV generation under all of the study scenarios is well below this level.

Table 4.7.4 Commercial Industrial PV Capacity Coincidence Factors

	Summer Generation Capacity % of Max Output	Non-Summer Generation Capacity % of Max Output
STATE	43%	8%
A	36%	8%
F	33%	8%
G	41%	6%
J	49%	13%
K	47%	5%

46 These numbers are at the customer meter, the savings at the central generator are higher by 11.5% due to avoided

2003-2022 Potential. The technical potential determined above from deployment space availability is extremely large compared to the current size of the PV industry. Therefore, another approach was used to determine likely achievable PV deployment in the 2003-2020 timeframe. This approach consists of assuming New York State's markets will attract a fraction of the world PV production (present assumption = 3%) and that the PV industry will continue growing at a solid rate (present assumption = 25%). Under this assumption, the numbers remain well below the ultimate deployment potential described above even in 2020. Table 4.7.5 demonstrates Commercial and Industrial (C&I) PV Technical Potential.

Table 4.7.5 Commercial Industrial PV Technical Potential (25% Average Annual Industry Growth)

	Installed Capacity (kW) 2003	annual kWh2003	Installed Capacity (kW) 2007	annual kWh2007	Installed Capacity (kW) 2012	annual kWh2012	Installed Capacity (kW) 2022	annual kWh2022
STATE	4,569	6,799,000	33,000	49,002,000	147,000	219,293,000	1,562,000	2,325,000,000
A	525	736,000	4,000	5,306,000	17,000	23,745,000	179,000	252,000,000
F	368	545,000	3,000	3,931,000	12,000	17,593,000	126,000	187,000,000
G	402	610,000	3,000	4,397,000	13,000	19,676,000	138,000	209,000,000
J	1,071	1,661,000	8,000	11,973,000	35,000	53,580,000	366,000	568,000,000
K	900	1,396,000	6,000	10,061,000	29,000	45,026,000	308,000	477,000,000

For the purpose of estimating technical potential, the study also examined how a more aggressive 45% PV industry growth rate could fully meet the 2003 deployable potential over the study horizon. Table 4.7.6 reflects this more aggressive assumption.

Table 4.7.6 Commercial Industrial PV Technical Potential (45% Average Annual Industry Growth)

	Installed Capacity (kW) 2003	annual kWh2003	Installed Capacity (kW) 2007	annual kWh2007	Installed Capacity (kW) 2012	annual kWh2012	Installed Capacity (kW) 2022	annual kWh2022
STATE	4,569	6,799,000	50,000	74,938,000	402,000	598,852,000	17,125,000	25,482,000,000
A	525	736,000	6,000	8,114,000	46,000	64,844,000	1,967,000	2,759,000,000
F	368	545,000	4,000	6,012,000	32,000	48,043,000	1,378,000	2,044,000,000
G	402	610,000	4,000	6,724,000	35,000	53,732,000	1,507,000	2,286,000,000
J	1,071	1,661,000	12,000	18,310,000	94,000	146,317,000	4,014,000	6,226,000,000
K	900	1,396,000	10,000	15,387,000	79,000	122,958,000	3,373,000	5,232,000,000

PV Category 2: Residential PV

Overall Resource Potential. As above, the overall resource potential is based upon available deployment space. In this case, the available space consists of residential rooftops.

Residential Rooftop Determination. The EIA provides information on the number of households in New York State (~ 7 million). It also provides, at the regional level, information on the breakdown of these

transmission and distribution losses.

housing units as a function of housing type and ownership (single detached, single attached, 2-4 units, 5+ units and mobile homes). Selecting single attached and detached units for potential deployment, prorating the numbers from the regional to the New York State level and further down to the ISO-region level using population as a benchmark (and as explained above, using 1/2 of this value for region J), and assuming a 100 m^2 nominal size per unit, the residential roof space is:

- Statewide: 406 million m2
- Region A: 47 million m2
- Region F: 33 million m2
- Region G: 36 million m2
- Region J: 94 million m2
- Region K: 80 million m2

Installed Residential PV Capacity Potential. The following assumptions are used to determine potential PV capacity from available space:

- Effective PV conversion efficiency (solar to AC): 8%
- Utilizability of residential roofs: 50%

Deployable PV capacities for the considered categories are:

- Statewide: 16 GW
- Region A: 1.9 GW
- Region F: 1.3 GW
- Region G: 1.4 GW
- Region J: 3.8 GW
- Region K: 3.2 GW

Energy and Energy Distribution. The approach used for energy determination is similar to the commercial approach to the exception that the considered systems are all tilted and ~ south facing.

- Statewide: 23 million GWh
- Region A: 2.5 million GWh
- Region F: 1.8 million GWh
- Region G: 2.1 million GWh
- Region J: 5.6 million GWh
- Region K: 4.7 million GWh

Hourly data analysis leads to the energy availability distribution for residential systems as represented in Table 4.7.7.

Table 4.7.7 Residential PV Energy Production by Costing Period

	Summer On-Peak %	Summer Off-Peak %	Summer Shoulder %	Non-Summer On-Peak %	Non-Summer Off- Peak %	Non-Summer Shoulder %
STATE	14%	10%	9%	6%	55%	6%
A	16%	10%	9%	6%	55%	5%
F	14%	10%	9%	6%	55%	6%
G	14%	9%	9%	6%	56%	6%
J	14%	9%	8%	6%	56%	6%
K	14%	9%	8%	6%	56%	6%

Effective Capacity. The numbers are very similar to the commercial numbers; the small difference reflects the small change in prevailing array geometry. Table 4.7.8. details residential PV capacity-coincidence factors.

Table 4.7.8 Residential PV Capacity Coincidence Factors

	Summer Generation Capacity % of Max Output	Non-Summer Generation Capacity % of Max Output
STATE	41%	10%
A	34%	9%
F	31%	9%
G	38%	7%
J	46%	15%
K	45%	6%

2003-2022 Potential. Using the same approach as commercial and prorating New York markets based on their ultimate size, the possible deployment of residential PV in the 2003-2020 timeframe is reflected in Table 4.7.9.

Table 4.7.9 Residential PV Technical Potential (25% Annual Average Industry Growth)

	Installed Capacity (kW) 2003	annual kWh2003	Installed Capacity (kW) 2007	annual kWh2007	Installed Capacity (kW) 2012	annual kWh2012	Installed Capacity (kW) 2022	annual kWh202
STATE	4,024	5,702,000	29,000	41,093,000	130,000	183,899,000	1,376,000	1,950,000,000
A	462	610,000	3,000	4,396,000	15,000	19,673,000	158,000	209,000,000
F	324	458,000	2,000	3,303,000	10,000	14,782,000	111,000	157,000,000
G	354	513,000	3,000	3,698,000	11,000	16,550,000	121,000	175,000,000
J	943	1,399,000	7,000	10,081,000	30,000	45,115,000	323,000	478,000,000
K	793	1,175,000	6,000	8,472,000	26,000	37,912,000	271,000	402,000,000

As for commercial systems it should be noted that a more aggressive PV industry growth (45% instead of 25%) could meet the entire deployable residential PV potential by the year 2022, as shown in the following table. This aggressive growth assumption was used in estimating the technical potential values in Table 4.7.10.

Table 4.7.10 Residential PV Technical Potential (45% Average Annual Growth)

	Installed Capacity (kW) 2003	annual kWh2003	Installed Capacity (kW) 2007	annual kWh2007	Installed Capacity (kW) 2012	annual kWh2012	Installed Capacity (kW) 2022	annual kWh202
STATE	4,024	5,702,000	44,000	62,843,000	354,000	502,196,000	15,080,000	21,369,000,000
A	462	610,000	5,000	6,723,000	41,000	53,725,000	1,732,000	2,286,000,000
F	324	458,000	4,000	5,051,000	29,000	40,368,000	1,214,000	1,718,000,000
G	354	513,000	4,000	5,656,000	31,000	45,196,000	1,327,000	1,923,000,000
J	943	1,399,000	10,000	15,417,000	83,000	123,200,000	3,535,000	5,242,000,000
K	793	1,175,000	9,000	12,956,000	70,000	103,532,000	2,971,000	4,405,000,000

PV Category 3: Envelope-Cost-Tradeoff-Maximizing Grid-Connected, User-Owned Commercial/Industrial PV.

Overall Resource Potential. It is first assumed that the majority of these systems will consist of vertical array facing east, south or west. As above, the study looks at the ultimate achievable potential by gauging the space available on these surfaces. Since these applications are likely to focus on material tradeoffs/aesthetics, the study only considers the commercial building stock and not the industrial.

Available Vertical Space. Again, the EIA provides sufficient elements in terms of building type/regional/size distribution to infer a reasonable estimate of available vertical surfaces. As above, prorated region J numbers are reduced by 50%.

- Statewide: 82 million m2
- Region A: 9 million m2
- Region F: 7 million m2

- Region G: 7 million m2
- Region J: 19 million m2
- Region K: 16 million m2

Installed PV Capacity Potential. The following assumptions are used to determine potential PV capacity from available space. Note the lower PV efficiency reflecting the more likely utilization of thin film for these applications, and the effect of building integration on orientation and potential shading.

- Effective PV conversion efficiency (solar to AC) 4%
- Utilizability of vertical surfaces 50%

Based on these assumptions, deployable PV capacities for this PV category are:

- Statewide: 1.6 GW
- Region A: 0.2 GW
- Region F: 0.1 GW
- Region G: 0.1 GW
- Region J: 0.4 GW
- Region K: 0.3 GW

Energy and Energy Distribution. Using the same approach as above, the following overall energy potential per region was determined to be:

- Statewide: 1.6 million GWh
- Region A: 0.2 million GWh
- Region F: 0.1 million GWh
- Region G: 0.1 million GWh
- Region J: 0.4 million GWh
- Region K: 0.3 million GWh

Energy/price coincidence factors are included in Table 4.7.11:

Table 4.7.11 Building Integrated (BI) PV Energy Production by Period

	Summer On-Peak %	Summer Off-Peak %	Summer Shoulder %	Non-Summer On-Peak %	Non-Summer Off- Peak %	Non-Summer Shoulder %
STATE	11%	10%	8%	7%	57%	7%
A	12%	10%	8%	6%	57%	6%
F	10%	10%	8%	7%	56%	7%
G	10%	10%	8%	7%	57%	7%
J	10%	10%	8%	7%	57%	7%
K	10%	10%	8%	7%	57%	7%

Note that the vertical array configuration reduces overall energy yield per installed kW and lowers the on-peak coincidence.

Effective Capacity. The source for these numbers is the same as above (NYSERDA study, 1997-1999). The vertical south, east and west values were extrapolated from the NYSERDA numbers based on the results of previous NREL-supported analyses focusing on vertical surfaces. Note that the summer vertical PV's effective capacity is considerably smaller than for tilted or horizontal PV. The BIPV capacity-coincidence factors are included in Table 4.7.12.

Table 4.7.12 BIPV Capacity Coincidence Factors

	Summer Generation Capacity % of Max Output	Non-Summer Generation Capacity % of Max Output
STATE	14%	12%
A	13%	12%
F	16%	11%
G	20%	18%
J	20%	8%
K	16%	12%

2003-2022 Potential. This type of PV application is likely to pertain mainly to new constructions, where the envelope cost tradeoff can be claimed. So two limiting factors are in play for a realistic assessment of PV deployment: (1) as above, the projected size of the PV industry and New York State's share of its output, and (2) the space available on new buildings. The numbers in Table 4.7.13 are the smaller of the two.

Table 4.7.13 Building Integrated PV Technical Potential (25% Annual Average Industry Growth)

	Installed Capacity (kW) 2003	annual kWh2003	Installed Capacity (kW) 2007	annual kWh2007	Installed Capacity (kW) 2012	annual kWh2012	Installed Capacity (kW) 2022	annual kWh202
STATE	407	393,000	2,932	2,832,000	13,121	12,675,000	139,000	134,000,000
A	47	42,000	337	300,000	1,507	1,343,000	16,000	14,000,000
F	33	32,000	236	231,000	1,056	1,033,000	11,000	11,000,000
G	36	35,000	258	256,000	1,155	1,144,000	12,000	12,000,000
J	95	96,000	687	690,000	3,076	3,088,000	33,000	33,000,000
K	80	80,000	578	580,000	2,585	2,595,000	27,000	28,000,000

As above, full potential could be achieved by 2002 with a more aggressive PV industry growth. However, because this full potential would be smaller — limited by new building deployment — a PV industry capacity growth rate of only 40% would be sufficient. This scenario is reflected in Table 4.7.14. This aggressive growth assumption was used in estimating the technical potential values in this assessment.

Table 4.7.14 Building Integrated PV Technical Potential (45% Annual Average Industry Growth)

	Installed Capacity (kW) 2003	annual kWh2003	Installed Capacity (kW) 2007	annual kWh2007	Installed Capacity (kW) 2012	annual kWh2012	Installed Capacity (kW) 2022	annual kWh202
STATE	407	393,000	4,046	3,909,000	27,995	27,043,000	796,000	769,000,000
A	47	42,000	465	414,000	3,215	2,865,000	91,000	81,000,000
F	33	32,000	326	319,000	2,253	2,204,000	64,000	63,000,000
G	36	35,000	356	353,000	2,464	2,442,000	70,000	69,000,000
J	95	96,000	948	952,000	6,562	6,588,000	187,000	187,000,000
K	80	80,000	797	800,000	5,515	5,537,000	157,000	157,000,000

ECONOMIC POTENTIAL

Throughout the time horizon of this analysis, PV technologies do not become cost-effective in terms of comparison to the projected avoided utility costs for energy and capacity that have been used in this study. Therefore, the economic component of the technical potential in both the high and low avoided cost analyses is zero for each of the PV technologies. It is non-zero if one considers delivered energy costs as opposed to utility avoided costs. The cost declines that are projected lead to PV power with levelized total cost per kWh of <$0.15 in 2022. This is a significant accomplishment that will lead to favorable consumer economics in many applications. There also is a growing recognition that, due to its low environmental impacts, distributed nature, and reliable performance, PV provides users and the utility system with benefits that are not fully captured by avoided-cost-based analyses.

ACHIEVABLE POTENTIAL

<u>Base Case Scenario</u>

Currently, in New York State and other markets, the development of most PV applications is the direct result of incentive programs and policy supports that reduce customer costs. The base case scenario

assumes that all incentives and programs supports for PV and other renewable technologies end in 2002. Under these conditions the study forecasts an initial very low level of PV activity (starting with additional installed capacity of ~ 25 kW in 2003) that increases gradually over time as the economics of PV improves due to cost reductions driven by the global market. The growth in the base case is particularly pronounced after 2012, when the study forecasts the installed capacity in the State of New York (in the absence of any further program initiatives or support for photovoltaics) to be approximately 8 MW. By 2022 in the base case the study forecasts total installed capacity of ~ 329 MW as represented by Table 4.7.15.

Table 4.7.15 Photovoltaics Installed Capacity — Base Case

	Installed Capacity (kW) 2007	Installed Capacity (kW) 2012	Installed Capacity (kW) 2022
PV Residential	440	3,540	150,800
PV C&I with solar load control	250	2,010	102,750
PV C&I no load control	250	2,010	68,500
PV BIPV	40	280	7,960

Achievements Under Currently Planned Initiatives

Currently, in New York State and other markets, the development of most PV applications is the direct result of incentive programs and policy supports that reduce customer costs and assist broader market development through activities such as training, consumer education, and demonstration projects including "solar on school" initiatives.

NYSERDA, Long Island Power Authority (LIPA), and New York Power Authority (NYPA) all support PV through a mix of such program activities as detailed in Table 4.7.17. Assigning a 25% portion of the combined funds available for NYSERDA's peak load reduction and strategic energy-reliability programs, the study estimates roughly $31 million of program expenditures for support of PV under currently planned initiatives. Based on this, the study estimates roughly 9 MW of installed PV capacity statewide by 2007, increasing to more than 394 MW by 2022. The impact of the currently planned initiatives in comparison to the base case is greater during the early portion of the study horizon, but due to activities, such as training and certification, solar on schools, and general market infrastructure development, positive incremental impacts are projected through 2022 as shown in Table 4.7.16. The incremental impact of currently planned initiatives over the base case is anticipated to result in more than 100 GWh annually of statewide PV generation by 2022. Including expected deployment under the base case, the total forecast PV generation by 2022 will be more than 627 GWh.

Table 4.7.16 Photovoltaic Installed Capacity — Currently Planned Initiatives

	Installed Capacity (kW) 2007	**Installed Capacity (kW) 2012**	**Installed Capacity (kW) 2022**
PV Residential	4,400	10,620	180,960
PV C&I with solar load control	2,500	6,030	123,300
PV C&I no load control	2,500	6,030	82,200
PV BIPV	405	840	9,552

Table 4.7.17 Photovoltaic Currently Planned Initiatives

		Level & Duration	**Notes**	**References**
Incentives, technical support, infrastructure development support, schools program	Building Integrated PV	NYSERDA Program spending of $3 million for BIPV	NYSERDA estimate of 679 kW. 150 kW already installed	PON 449
	PV on Buildings	NYSERDA Program spending of $5 million for PV on buildings	$5/Watt estimated maximum incentive. Marketing infrastructure development through coordination w new construction efficiency programs.	PON 691
		Peak Load Reduction Program $36 million total	Focus on capacity constrained (downstate) areas	EnergySMart Revised Operations Plan, p. 19.
	PV <10 kW	LIPA Solar Pioneer program Approx. $3 million for 2003 and first half of 2004	$5/Watt for 500kW, then $4/Watt. Systems up to 10kW eligible.	www.lipower.org/solar
	PV on Schools	NYSERDA $1.8 million for PV on schools	$189,000external funding expected, NYSERDA estimates 100kW to be installed.	RFP 622
	Small and High Value PV	Additional $7.2 million of NYSERDA incentives to be shared with wind.	Estimated PV incentives of $3 to $5 per watt.	PON 716
			Strategic Energy Reliability Program	PON 524

Contribution to Greenhouse-Gas Reduction Targets

As discussed above, under the economic potential results, PV does not pass economic screening, based on the avoided costs used in this study. Therefore, driven by the selection of least-cost options from the available range of energy efficiency and renewable technology measures, PV is not included in the least-cost portfolio for attaining GHG-reduction targets.

STRATEGIES FOR ACCELERATING MARKET DEVELOPMENT

The primary approach for accelerating sustainable market development for PV in New York State is to continue to build upon and refine the initiatives already in place. The State of New York is far ahead of most states in its support of providing for PV development. As recognized in national studies of PV market potential,[47] New York — due to a moderate solar resource, utility load match, relatively high retail energy prices, and program supports — has the potential to emerge as one of the leading PV markets in the country. In order to achieve this potential, the State will need to rely on the resources presented by the existing infrastructure of stakeholders and expand this base. Strategic recommendations for maintaining and enhancing the progress of current initiatives include:

- Continue to develop and strengthen ties to national activities that will help New York leverage resources and generate strong consistent approaches to the reduction of market barriers. Affiliation with the North American Board of Certified Energy Practitioners and the Clean Energy States Alliance are two examples of this type of activity. Work in a coordinated fashion with all stakeholders to develop, strengthen, and disseminate the message that New York State can emerge (or has emerged) as a leading market for PV, and that due to activity in neighboring states, the region is a significant "center of gravity" for industry development.
- Extend incentive buy-downs and tax incentives to reduce initial system costs paid by consumers. Incentive programs should be structured to ramp down incentive levels to encourage a transition to sustainable markets without the need for incentive dollars. A long-term commitment (five years), with transparent and well-understood processes for gradually reducing incentive levels over time, is important to spur system purchases and to encourage industry investment in marketing and infrastructure development.
- Work to refine and expand the marketing and educational messages and the delivery channels through which the public learns about PV. Market baseline studies currently in progress for LIPA indicate that consumer awareness and education remain significant barriers. Broad and sustained attention to case studies, solar on schools program curriculums, sophisticated target marketing, and continuing assessment and tracking of market indicators are essential components to reducing this fundamental barrier.
- Eliminate or reduce all remaining barriers to streamlined permitting, inspection, and interconnection procedures. It is particularly important to develop and implement strategies to eliminate significant differences at the sub-regional level. Identifying and facilitating a consistent set of best-practice requirements and procedures will reduce uncertainty and eliminate what can still be, in some cases, deal-breaking impediments to individual project installations.

---

47 Herig, C.; Thomas, H.; Perez, R.; Wenger, H. (2000). Customer Sited PV — U.S. Markets Developed from State Policies (Preprint). NREL Report No. CP-520-28426.

Section 8:
SOLAR THERMAL

SUMMARY RESULTS

Four solar thermal technologies that directly offset electric consumption are included in this study. These are customer-sited systems that use solar thermal energy to provide customer thermal loads that are otherwise served by electricity. Thus, for example, the potential for residential solar hot-water systems is defined by a combination of solar resource and existing electric domestic hot-water consumption. Electric-generating systems based on solar thermal technologies (such as sterling engine systems, or solar concentrating power towers) are not analyzed. The four solar thermal technologies included in the study have the technical potential to offset more than 6,000 GWh per year of electric generation in New York State by 2022. However, by definition, technical potential estimates do not account for cost and other market barriers. Thus, for policy, program, and market planning the projected levels of development under the base case, economic potential, greenhouse-gas reduction and currently planned initiative (CPI) scenarios have more direct bearing.

The projected electric generation under these scenarios is illustrated in Figure 4.8.1. This figure illustrates that solar thermal is expected to grow very modestly in the base case. Under the currently planned initiatives scenario, there is significant growth in the deployment of solar thermal technologies primarily due to increased installation of state-owned and state-operated facilities.

Figure 4.8.1 New York State Solar Thermal Potential Summary

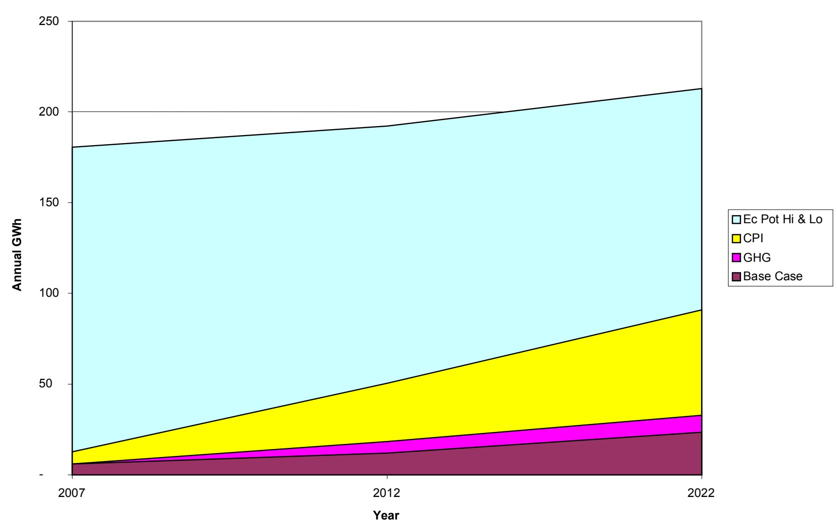
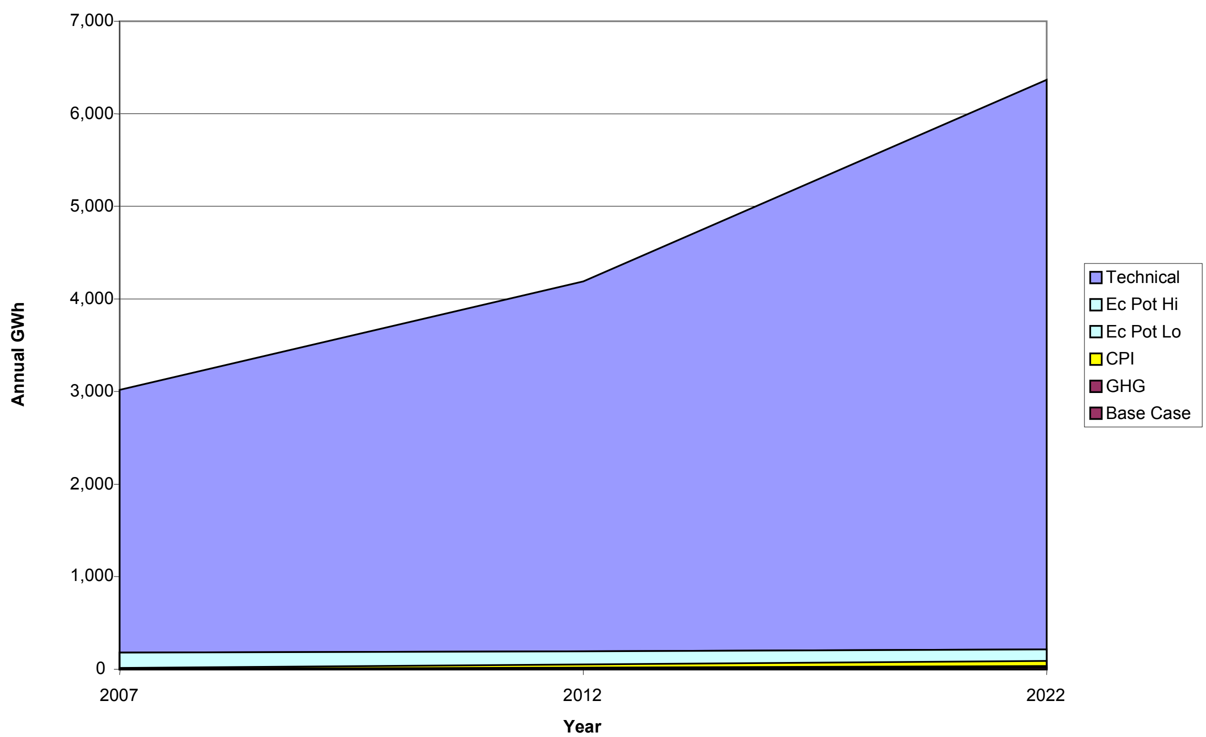


Figure 4.8.1 also illustrates that by 2022, solar thermal technologies in the CPI scenario are expected to offset more than 90 GWh of electric consumption annually, which is 63 GWh more than is expected from

the base case. Another significant finding is that solar ventilation air pre-heating is projected to be capable of providing close to 190 GWh of socially cost-effective electric offsets by 2022. This suggests there may be potential for further programmatic support to encourage a higher, cost-effective level of deployment.

The solar thermal results are similar to those for photovoltaics and fuel cells, since all three have very large technical potential compared to the anticipated achievable potentials. The technical potential for solar thermal technologies is more than 6,000 GWh per year by 2022. This exceeds the expected deployment under the CPI and base case scenarios by a factor of more than 65 times, as illustrated in Figure 4.8.2. Solar absorption cooling systems are the largest contributor to the projected technical potential, accounting for roughly 60% of the total solar thermal technical potential in 2022. Residential and commercial industrial hot-water applications account for another 37% of the technical potential.

Figure 4.8.2   New York State Solar Thermal Technical Potential Summary



TECHNOLOGY DESCRIPTION

Solar Hot Water

Solar hot water systems described here are those that serve the domestic hot water (DHW) loads of residential buildings, service the hot water loads of commercial and school buildings, and service and/or

process hot water for industrial buildings.[48] Solar heat displaces electricity used for water heating at the end use. This is not a wholesale electricity market technology.

Systems typically consist of a liquid-based collector array, a pumping and control system, an anti-freeze system, and a solar-heated storage tank system. Systems also include interface piping and valves to connect to the backup water-heating system.

Collector Arrays. For the relatively low temperatures required for DHW and most service hot water, flat-plate collectors are most commonly used and provide the most energy per unit cost. These collectors are most commonly single glazed, with selective surface[49] copper absorbers, extruded aluminum frames and foam insulation. On single-family homes, the collectors are often screwed down to the south-facing roof of the house, with fastening directly to the structure of the roof. For larger installations — flat roofs in particular — a rack system is needed to install the collectors at the appropriate angle and to provide the necessary structural support and connection to the building. For processed hot water requiring higher temperatures, evacuated tube collectors provide high-temperature water a greater portion of the year.

Pumps and Controls. Pumps can be powered by electricity from the building's AC power supply or from DC electricity produced by a small photovoltaic (PV) panel on the roof. PV-driven pumping is increasingly common for residential systems, as it eliminates the need for other controls for the pump; in the simplest systems, when the sun shines, the pump runs. AC pumps typically use a differential controller that operates the pump whenever the collectors are hot enough to provide additional heat to the storage tank. Electronic controls include tank and collector sensors.

Antifreeze Systems. There are many approaches to eliminating freeze damage to collectors. The most common is to run an antifreeze mixture through the collectors, with a heat exchanger to transfer energy to the storage tank. Antifreeze technology has improved in the past decade, with reliable, long life mixtures available. Another often-used approach is "drain-back," where the fluid in the collectors and exterior piping is drained back to a storage tank within the heated space of the building whenever there is no solar heat to collect. A hybrid incorporates both technologies for additional freeze protection security.

Storage for smaller systems consists of well-insulated, pressurized tanks, often made for solar hot water systems, with heat exchangers for antifreeze incorporated into the tank. Tanks for larger solar hot-water systems may be either pressurized or unpressurized depending on costs and on balance of water-heating system type. Tank sizes are typically 1.5 gallons of storage per square foot of flat-plate collector. Where

48 These systems are not considered here for space heating use, due to low cost effectiveness when these systems are applied to a winter load, when solar resource is low.

solar hot water replaces electric hot water, there may be one or two storage tanks. In the two-tank systems, the cold water supply is fed to the first tank, which is heated by the solar system. Pre-heated water from this tank is fed to the second tank, which is often a conventional electric, tank-type water heater, which will heat the water further if needed. A lower cost system uses a single tank with the electric back-up element in the top and solar heat applied to the bottom of the tank. Performance of the single-tank system is reduced somewhat due to lower effective storage volume, but the cost is lower.

Several vendors have taken steps to simplify system design and lower installation costs by developing pre-packaged systems for single-family residential solar hot water. Larger systems require site- and application-specific designs.

System Scale and Performance. The scale and applications of solar hot-water technologies selected for study in this assessment are summarized in Table 4.8.1.

Table 4.8.1 Solar Hot Water System Scale and Applications

Application	Solar Collector Area, sq. ft.
Residential single family	32 – 128
Residential multi-family	300 – 2000
Commercial	300 – 2000
Schools	300 – 2000
Industrial	300 – 2000

Systems are typically sized to meet one-half to two-thirds of the annual solar hot-water load. Due to higher efficiencies at lower storage temperatures, smaller solar fractions typically result in more usable energy per square foot of collector. Even lower solar fractions will boost efficiency somewhat further, but small systems may represent a loss of opportunity to capture further savings. The summer usage of hot water also plays a role in system sizing, as heat collected must be removed from the system even if there is no hot water load.

Solar Absorption Cooling

Absorption cooling devices use a heat source, such as natural gas or a large solar collector, to evaporate the already-pressurized refrigerant from an absorbent/refrigerant mixture. (Absorption cooling devices do not use an electric compressor to mechanically pressurize the refrigerant.) Condensation of vapors provides the same cooling effect as mechanical cooling systems provide. Although absorption coolers require electricity for pumping the refrigerant, the amount is very small compared to that consumed by a compressor in a

49 Selective surfaces have high solar absorptance rates, typically mid-0.90s, and low emitance rates, typically lower than 0.10, in order to boost performance.

conventional electric air conditioner or refrigerator. When used with solar thermal energy systems, absorption coolers are adapted to operate at the normal working temperatures for solar collectors: 180° to 330°F. The higher temperatures are achieved with evacuated tube solar collectors. Double-effect chillers are now being used to improve system efficiencies. It is also possible to produce ice with a solar-powered absorption device, which can be used for cooling or refrigeration. Back-up cooling is provided by natural gas (or other fossil fuel) for cooling periods when solar gain is not sufficient to carry the load. Systems are typically sized to carry the full air conditioning load during sunny periods, but sizing may also be influenced by the ability to utilize heat produced by the system during non-cooling periods. Solar heat displaces electricity used for cooling at the end use. This is not a wholesale electricity market technology.

System Scale and Performance. A range of 4,000 to 50,000 square feet of collectors is estimated to be the cost-effective size range of these systems. A 4,000-square-foot system will provide approximately 70 tons of cooling, the lower range at which solar cooling is estimated to be cost-effective. A 50,000-square-foot system would provide 850 tons of cooling. The 4,000-square-foot system will provide approximately 0.070 GWh of cooling energy, displacing about 0.015 GWh of electricity; the 50,000-square-foot system will provide approximately .900 GWh of cooling energy, displacing about 0.180 GWh of electricity.[50]

The solar-collector systems used with solar cooling also provide large amounts of solar thermal energy beyond what is needed during peak cooling periods. This can be used for water heating, space heating, and/or process heating, helping to displace additional conventional energy and make these systems more economically advantageous. The 4,000-square-foot system would provide approximately an additional 0.100 GWh of thermal energy; the 50,000-square-foot system would provide about 1.5 GWh of thermal energy.

Evacuated tube collectors produce the high-temperature fluids needed to efficiently operate the double effect (2E) absorption chillers. Producing 330°F water, they operate at approximately 60% efficiency. Some losses are inevitable between collectors and the chillers, resulting in approximately 50% of the solar energy incident of the collectors being delivered to the chiller. The 2E chiller operates at a Coefficient of Performance (COP) of about 1.3, producing 1.3 units of cooling for each 1.0 unit of thermal-energy input, resulting in 65% of the incident solar energy being utilized as cooling. If an electrically driven mechanical chiller provided this cooling energy, it would do so at a COP of approximately 5.0.[51] Therefore, the solar-absorption chiller/solar collector system displaces electricity equivalent to one-fifth of that provided in

---

[50] Performance estimates are based on New York City weather conditions.

[51] Current ASHRAE 90.1-1999, being adopted in New York, lists required efficiencies just above or below a COP of 5.0, depending on chiller size.

cooling energy; i.e., the solar cooling system may be thought of as utilizing solar energy to displace electricity at an overall efficiency of 13%.[52]

Solar Ventilation Air Heating

The unglazed, transpired solar collector is used primarily to heat building ventilation air. Solarwall® (Conservall is currently the only manufacturer) is a solar air-heating system based on a perforated, dark-colored metal cladding that is installed on the south-facing wall of a building and heated by solar radiation. In the winter, ventilation fans located at the top of the wall create a negative pressure in the cavity between the cladding and the building, drawing solar-heated outside air through tiny holes in the Solarwall. The warmed air rises in the cavity to a plenum at the top of the wall, where it is ducted to provide solar-heated ventilation air to the building's ventilation system. Solar heat displaces electricity used for heating ventilation air at the end use. This is not a wholesale electricity market technology.

In the summer, warm air between the Solarwall and the building rises and is ventilated through holes at the top of the cladding. Fresh ventilation air is drawn directly into the building by way of bypass dampers. Solarwall can be used in both new and retrofit applications. In new construction, the system replaces conventional wall cladding, for some cost savings.

System Scale and Performance. This technology is typically applied to buildings that have large daytime- ventilation loads and south-facing walls on which to install the system. (The system can be installed on off-south walls, but performance is degraded.) A range of 10,000 to 50,000 square feet of collector has been selected for analysis, but smaller systems may also be cost-effective, depending on ease of installation in a particular instance.

Solar collection efficiencies are quite high (as high as 75% have been reported) due to convective surface losses that are captured by the surface air film and continuously drawn in through the numerous surface holes. Energy delivered by the Solarwall in the eastern half of New York State is estimated at 150 KBtu/square feet-year. For a 10,000-square-foot installation, this translates into 1,500 MMBtu/year, or 0.004 GWh/year. A 50,000-square-foot installation would deliver 0.020 GWh/year. In the western half of the state, performance estimates are 40% lower.

52 60% collection efficiency * 83% delivery efficiency * 1.3 COP evaporative chiller efficiency / 5.0 COP electric chiller efficiency = 13% solar-to-electric displacement efficiency.

Technologies NOT Selected for Full Analysis in this Study

Solar Trough Systems. Since the late 1980s, 350 megawatts are being generated in California with flawless performance, as are 10 megawatts-equivalent of solar industrial preheat plants. New systems are beginning to enter the market in electric bids ranging from 9 to 18 cents per kilowatt hour for midday electricity generated by solar in the day, and 4 to 6 cents for natural-gas generation at all non-solar time periods.

Solar Dish/Engine Systems: Four companies in the United States offer beta systems, ranging from 1 kW to 25 kW, and potentially 250 kW. Data are just starting to emerge, but these systems appear cost-effective for remote electric applications (electric loads beyond the wire) and electric interconnected systems where electricity costs are above 15 cents per kWh at midday.

Generalized costs for solar trough systems range from 7.5 to 9 cents per kWh (California Energy Commission, 2001) and solar dish engines range from 11 to 15 cents per kWh (U.S. Department of Energy, 2001). While these outputs do not economically displace base load electric generation, they are quite competitive for midday peak electricity. These units also typically use natural gas or landfill gas as back-up and can be turned into full-time capacity generators if needed by the electric grid.

Manufacturing and Service Infrastructure

Domestic shipments of solar thermal collectors in the United States surged 34% in 2001 to 11.2 million square feet. The gain was entirely due to increases in low-temperature collector shipments, which accounted for 98% of total shipments. Total solar thermal collector shipments were valued at $32.4 million in 2001, up 18% from 2000. The average per-square-foot price dropped from $3.28 to $2.90.[53]

Solar thermal systems in the United States are manufactured and assembled on a commercial basis by six companies for low-temperature solar water heating for swimming pools. Ten companies produce and assemble medium-temperature solar systems for water heating or space heating in buildings. Two companies have commercial products for high-temperature water heating or steam for industrial and commercial processes. Within the U.S., three companies manufacture absorption coolers. They are Trane (Wisconsin), York (Pennsylvania) and Industrial Solar Technology (Colorado). Duke Solar (North Carolina) is the only national company that has a successful business combining non-imaging concentrating solar thermal with solar absorption cooling systems in commercial and industrial buildings. Four companies produce solar electric dish/engine systems, with two companies producing solar electric trough

[53] Energy Information Administration, 2002. *Renewable Energy Annual 2001 - With Preliminary Data for 2001*. Table 17. Solar Thermal Collector Shipments by Type, Quantity, Value and Average Price, 2000 and 2001. (see www.eia.doe.gov/cneaf/solar.renewables/page/pubs.html).

systems. Conserval, the company that manufactures Solarwall technology, has moved its manufacturing facilities from Buffalo, NY, to Allentown, PA. All of the above companies have distributors, installers, and related affiliated and strategic partners in New York State.

Nearly three-fourths of solar thermal collectors domestically shipped in 2001 were to Florida and California. Pool heating was the dominant end-use for collectors, accounting for more than 95% of the total market for low-temperature collectors. Total shipments of solar thermal collectors to New York State in 2001 were 67,706 square feet, representing approximately 0.6% of total domestic shipments.[54]

The New York State-affiliated chapter of the Solar Energy Industries Association has 40 company members, of which 30 are involved in some aspect of solar thermal systems with the following breakdown: eight distribution, 20 installation/maintenance, and two assembly.

Regulatory, Permitting, and Siting Issues

Except for historic or historically designated buildings, there are no major siting or regulatory hurdles.

TECHNICAL POTENTIAL

Solar Thermal Category 1: Residential Domestic Water Heating (DHW)

The solar thermal systems considered in this category are designed to displace electricity used for domestic hot water heating.

Overall Resource Potential. Two factors were initially considered to determine overall potential for such solar DHW: (1) The physical roof space availability (same as residential PV) and (2) the size of the electric DHW base to be displaced. The latter is considerably smaller than the former and thus constitutes the resource's potential upper bound. There are approximately 7 million households in New York State, 15% of which use electricity for DHW. The electrical consumption of the average DHW unit is .002 GWh per year.

A typical residential system with two 4' x 8' solar collectors could provide 100% of average DHW consumption for five months of the year, down to 40% to 50% in November, December, and January. Therefore, the results developed for this analysis are based on the assumption that the prevailing types of residential DHW systems would consist of such units. These units would displace .0023 GWh out of the current .0027 GWh electric usage, with an equivalent connected maximum load reduction of 4.5 kW and a

---

[54] Energy Information Administration, 2002. *Renewable Energy Annual 2001 - With Preliminary Data for 2001*. Table 14. Shipments of Solar Thermal Collectors by Destination, 2001.

peak coincident capacity of approximately 1.35 kW. It is further assumed that 50% of the houses using electric DHW could qualify for conversion to solar.

Installed Capacity. Based on the above assumptions, the equivalent installed capacity potential is:

- Statewide: 0.70 GW
- Region A: 0.08 GW
- Region F: 0.06 GW
- Region G: 0.06 GW
- Region J: 0.17 GW
- Region K: 0.14 GW

Energy Potential and Energy Distribution. Energy calculations are based upon a simplified F-Chart approach built upon the Clean Power Estimator engine. This method produces results amounting to conversion efficiencies ranging from 30% in winter to 45% in summer. Overall energy production quantified in displaced electrical energy is:

- Statewide: 1,100 GWh
- Region A: 110 GWh
- Region F: 90 GWh
- Region G: 100 GWh
- Region J: 260 GWh
- Region K: 220 GWh

...with the energy coincidence factors reflected in Table 4.8.2.

Table 4.8.2 Residential Solar DHW Electricity Savings by Period

Summer On-Peak %	Summer Off-Peak %	Summer Shoulder %	Non-summer On-Peak %	Non-summer Off-Peak %	Non-summer Shoulder %
15%	11%	10%	5%	54%	5%
17%	11%	10%	4%	53%	3%
16%	11%	10%	5%	54%	5%
16%	11%	10%	5%	54%	5%
15%	11%	10%	5%	54%	5%
15%	11%	10%	5%	54%	5%

Effective Capacity. Unlike PV that injects electrons into the grid, the effective capacity of solar thermal DHW systems cannot be quantified directly. The approach that the study proposes is based on (1) the

probability that the current electric DHW system would be operating at a time of peak (normalized to the selected solar-system size of 1.35 kW, this probability is (2700/1.35)/8760, or 23%), and (2) the probability that solar could displace this load (i.e., 100% in summer and 45% in winter).

Therefore, the effective capacity of solar DHW systems is 23% in summer and 11% in winter irrespective of the considered region. These numbers are lower than PV. This is understandable because in this case, solar does not displace electrical load directly. Rather, it displaces electrical load that, cumulated over all the considered systems, has a lower probability of occurring at any point in time, including peak time.

2003-2022 Potential. As for PV, a realistic estimate of solar DHW penetration in New York State should be based largely on the ability of the solar DHW industry to provide hardware and the ability of the State to attract sales.

To gauge technical potential, the study has assumed that production capacity for collectors can be increased to meet 100% of the technical potential demand by 2007. This entails aggressive growth rates for the industry, but there are no overriding technical reasons why this manufacturing capability cannot be put in place rapidly.

Solar Thermal Category 1a: Commercial DHW

Projected electricity sales for commercial domestic hot water heating are slightly higher (~3,000 GWh in 2003) than for residential hot water heating.[55] The study has adopted an applicability factor of 50% for the education, grocery, health, lodging, and restaurant market sub-segments to estimate the potential for solar hot water in the commercial sector. These factors have been applied at the statewide level. Zonal differences in solar resources and sales by building type are also incorporated in the analysis.

Solar Thermal Category 2: Commercial/Industrial Ventilation Preheating

The types of systems considered here are assumed to consist largely of vertical, south-facing solar-wall-type collectors. Only those collectors geared to displace electric heat are considered.

Overall Resource Potential. As above, two factors govern the estimation of ultimate deployment potential: (1) available (vertical wall) deployment space, and (2) the size of the load to be displaced. The total commercial electric heating load of 3,800 GWh would require approximately 28 million square meters of collectors to be displaced 100% at all times (including during times of the worst conditions, in December and January). This area is comparable, albeit smaller, than vertical commercial wall space. The estimated

[55] See existing end use sales projections, Appendix 5.2.2, for commercial electric sales by end use.

amount of electric space heating that can be displaced by this technology is based on estimated displaced electric space heat end use for the grocery, education, health and warehouse sub-segments. The study has assigned 25% applicability factors to the grocery, education and health sub-sectors, and 75% to warehouse space-heating end use. Further, assuming that 25% of the electric heat applications in these segments lend themselves to solar wall applications and that the solar systems would, on average, be designed to meet half of the heating load requirements in the highest demand month, the following capacity and energy numbers can be advanced.

Installed Capacity. The equivalent installed capacity potential for commercial/industrial heating is:

- Statewide: 204 MW
- Region A: 47 MW
- Region F: 32 MW
- Region G: 15 MW
- Region J: 35 MW
- Region K: 46 MW

Energy Potential and Energy Distribution. Overall energy production quantified in terms of displaced electrical energy is:

- Statewide: 190 GWh
- Region A: 43 GWh
- Region F: 29 GWh
- Region G: 14 GWh
- Region J: 32 GWh
- Region K: 42 GWh

...with the energy coincidence factors demonstrated in Table 4.8.3.

Table 4.8.3 Commercial Industrial Solar Ventilation Capacity Coincidence Factors

STATE	0%	14%
A	0%	14%
F	0%	13%
G	0%	22%
J	0%	10%
K	0%	14%

Effective Capacity. Effective capacity would be 0% in summer, since the resource would remain idle during this season. For winter, pending more information on the number and average size of electric

heating systems, a safe assumption is to use vertical PV effective capacity numbers (obtained from previous studies by the authors). Table 4.8.4. demonstrates the commercial and industrial solar-ventilation pre-heat savings by period.

Table 4.8.4 Commercial & Industrial Solar Ventilation Pre-Heat Savings by Period

Summer On-Peak %	Summer Off-Peak %	Summer Shoulder %	Non-summer On-Peak %	Non-summer Off-Peak %	Non-summer Shoulder %
0%	0%	0%	10%	80%	10%
0%	0%	0%	9%	82%	8%
0%	0%	0%	10%	80%	10%
0%	0%	0%	10%	80%	10%
0%	0%	0%	10%	80%	10%
0%	0%	0%	10%	80%	10%

2003-2022 Potential. As for DHW, realistic estimates based on the size and growth of the industry capable of producing the considered solar systems will be generated as soon as the industry numbers are assembled and fully analyzed.

The current technical potential estimates are based on the assumption that there are no major impediments to rapid ramp-up of manufacturing capacity for this technology, and that production capacity could meet 100% of technical potential by 2007. This is consistent with the assumptions for flat-plate collectors.

Solar Thermal Category 3: Solar Absorption Cooling

The same two factors are considered to determine the total resource potential: (1) available space, and (2) size of the existing commercial cooling load that could be met by solar absorption cooling. Solar could be used to target 30% of the total estimated 2003 commercial cooling consumption of 10,700 GWh. This percentage is based on 50% applicability factors for the office, education, and health market sub-segments. Assuming that 100% of the available solar cooling energy can be effectively used to displace cooling load, the required collector area would have to be on the order of 7 million square meters.[56] With a collector ground occupation ratio of 50%, this would translate into ~ 14 million square meters of roof and exclusion zone space. This is less than 10% of the total available roof and exclusion zone space; therefore, competition for space with photovoltaics can be ignored in first approximation.

---

56 Area required to meet the needs during the highest cooling load month, assuming 50% solar thermal effective conversion efficiency at the chiller level and a COP of 1.3.

It is interesting to note that, despite a considerably lower solar conversion efficiency, photovoltaics could meet the same load requirements with little or no space premium because this solution would take advantage of the considerably higher COP of conventional cooling systems.

Installed Capacity. Based on the above assumptions, the equivalent installed capacity potential for solar absorption cooling is:

- Statewide: 6.5 GW
- Region A: 0.3 GW
- Region F: 0.2 GW
- Region G: 0.3 GW
- Region J: 4.3 GW
- Region K: 0.9 GW

Energy Potential and Energy Distribution. Assuming that the collectors sized as specified above can effectively displace 80% of their targeted total cooling load, the following energy yields would apply:

- Statewide: 3,700 GWh
- Region A: 170 GWh
- Region F: 110 GWh
- Region G: 170 GWh
- Region J: 2,400 GWh
- Region K: 520 GWh

...with the energy coincidence factors demonstrated in Table 4.8.5.

Table 4.8.5 Solar Absorption Cooling Energy Coincidence Factors

Summer On-Peak %	Summer Off-Peak %	Summer Shoulder %	Non-summer On-Peak %	Non-summer Off-Peak %	Non-summer Shoulder %
29%	21%	19%	0%	31%	0%
30%	21%	19%	0%	31%	0%
29%	21%	19%	0%	31%	0%
29%	21%	19%	0%	31%	0%
29%	21%	18%	0%	31%	0%
29%	21%	18%	0%	31%	0%

Effective Capacity. Again, effective capacity would be 0% in winter. For summer, the effective capacity should be on par with that of PV. As for PV, this effective capacity could be naturally enhanced with

application of solar load control. The associated peak coincidence factor is identified with an asterisk (*) in Table 4.8.6.

Table 4.8.6 Solar Absorption Cooling Capacity Coincidence Factors

Summer Generation Capacity % of Max Output	Non – Summer Generation Capacity % of Max Output
43% —*90%	0%
36% — 90%	0%
33% — 90%	0%
41% — 90%	0%
49% — 90%	0%
47% — 90%	0%

2003-2022 Potential. The technical potential estimates are based on the assumption that production capacity could meet 100% of technical potential by 2022. This is consistent with the assumption related to the growth of manufacturing capacity for photovoltaics.

ECONOMIC POTENTIAL

Throughout the time horizon of this analysis, three of the four solar thermal technologies are not cost-effective in terms of comparison to the projected avoided utility costs for energy and capacity that have been used in this study. The solar ventilation pre-heat technology for commercial industrial applications is cost- effective under both the high and low avoided cost analyses. The economic potential for incremental (over base case) energy production of this technology with high statewide avoided costs is projected to be 174 GWh in 2007, 180 GWh in 2012, and over 189 GWh in 2022. This application is projected to have winter peak capacity savings of 30 MW in 2007, growing to 33 MW in 2022.

ACHIEVABLE POTENTIAL

Base Case Scenario

Solar thermal installations in the State of New York are currently estimated to result in approximately 16,000 square feet of collectors installed for residential applications and 15,000 square feet of collectors for commercial and industrial applications annually. This estimate is based on roughly eight active firms in each market installing an average of 20 systems per year. These figures do not include pool-heating systems, to which the study does not assign a potential electric savings, and which are assumed to make up the balance of collector shipments to New York State. In the base case, the study forecasts no growth or activity in the application of solar absorption cooling technologies but foresees moderate, consistent growth for other solar thermal applications, albeit slightly lower than the growth experienced between 1993 and 2001.

Achievements Under Currently Planned Initiatives

Currently planned initiatives are expected to have impacts in each of the solar thermal technology applications studied. For residential systems, it is assumed that the major impact will be through the strengthening the installation infrastructure as a result of activities such as support for the North American Board of Certified Energy Practitioners (NABCEP) training and certification for both solar thermal and PV practitioners. For commercial- and industrial-scale solar thermal systems, impacts from the implementation of Executive Order 111 and select research and development activities (including support for advanced heating and cooling, next generation technologies), are expected to support significant growth in the installations at facilities owned and operated by the state. The study estimates summer coincident capacity equivalent of roughly 2 MW of installed solar thermal capacity statewide by 2007, increasing to more than 18 MW by 2022. The incremental impact of currently planned initiatives over the base case is anticipated to result in more than 67 GWh annually of statewide electricity savings from solar thermal systems by 2022.

Contribution to Greenhouse-Gas Reduction Targets

As noted, based on the avoided costs used in this study, three of the four solar thermal technologies do not pass economic screening. Therefore, driven by the selection of least-cost options from the available range of energy-efficiency and renewable-technology measures, commercial and industrial ventilation pre-heating is the only solar thermal technology that may be included in the least-cost portfolio for meeting GHG-reduction targets. If fully deployed in the GHG-reduction scenario, this could generate savings equivalent to the economic potential results discussed above.

STRATEGIES FOR ACCELERATING MARKET DEVELOPMENT

Recommended strategies for accelerating market development for solar thermal technologies in New York State include the following:

- Strengthen delivery and installation infrastructure
- Provide support for installations to meet state purchasing targets, such as Executive Order 111
- Increase consumer awareness of the technology
- Reduce first costs through buy-down and tax-incentive program activities

There are many opportunities to harmonize these activities with other renewable and energy-efficiency initiatives that already exist in the State, existing programs to support photovoltaics and to promote energy-efficient new construction in the residential and commercial/industrial sectors.

Section 9:
WIND ENERGY

SUMMARY RESULTS

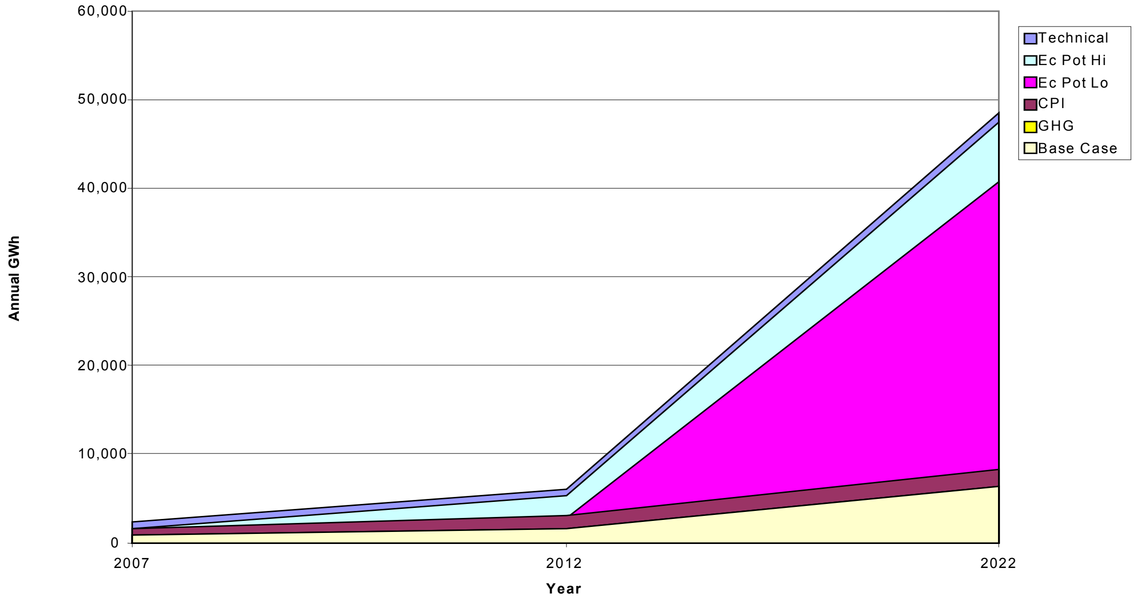
Wind energy has great potential for generating electricity in New York State over the next two decades. This is due to several factors, including the State's significant wind resource, rapidly declining costs associated with wind energy installations, current and future policy strategies designed for wind energy, and the technically mature state of wind turbine development.

In this study, wind energy potential was projected in New York State through 2022 under six cases: technical potential, economic potential (assuming both high and low statewide avoided costs), base case, currently planned initiatives (CPI), and greenhouse-gas reduction (GHG) targets. Technical potential is defined as the upper limit theoretically possible from the resource in New York State without regard to cost, market barriers, or market acceptability. Economic potential is the subset of technical potential that is cost-effective from a societal perspective compared to the cost of electricity the wind power would replace. Economic potential is assessed separately for both high and low statewide avoided costs (provided by NYSERDA). The base case is defined as wind energy capacity and output already on-line, already permitted, or well along in planning as of late 2002. The CPI case is defined as the future impacts expected from currently planned initiatives included in the 2002 New York State Energy Plan. The GHG-reduction case is defined as the least-cost combination of efficiency and renewable resources (above those expected from currently planned initiatives) that can be used to meet greenhouse-gas reduction targets defined by NYSERDA for 2012 and 2022

In each case, wind energy potential was assessed for four sizes and configurations of wind installations: 1) large wind farms comprised of 600 kW to 1.5 MW turbines arranged in groups of 10 to 50 turbines; 2) smaller wind farm "clusters" comprised of 600 kW to 1.5 MW turbines arranged in groups of 2 to 10 turbines; 3) small, stand-alone turbines rated from 1 kW to 300 kW; and 4) offshore wind installations comprised of 1 MW to 3 MW turbines arranged in groups of 1 to 20 turbines per installation.

Across all installation configurations, analysis indicates there are more than 17,000 MW of potential new wind energy capacity in the State of New York. Projected electricity generation ranges from 6,300 to 48,400 GWh/yr, as demonstrated in Figure 4.9.1.

Figure 4.9.1 New York Wind Power Potential Summary



The technical potential for electricity generation from wind increases from 2,300 to 48,400 GWh/yr from 2007 to 2022. This is the result of anticipated increases in average utility-scale machine sizes and a resulting drop in land-use (and water-use) requirements for offshore installations, wind farms, and clusters. Offshore installations offer the greatest technical potential, followed by wind farms, clusters installations, and small wind installations. Under the base case scenario, development is forecast to increase from 0.7 million to 6,300 GWh/yr from 2007 to 2022. Under the currently planned initiatives scenario, wind energy development is forecast to increase from 1,500 to 8,200 GWh/yr from 2007 to 2022. Wind energy does not factor into the integrated (least-cost efficiency and renewable resources) greenhouse gas scenario.

The analysis of the economic potential of wind energy in New York indicates that by 2022 further development of new wind energy installations could result in 41,200 GWh/yr of additional generation over the base case scenario. All of this electricity passes societal economic screening when using high statewide avoided costs. Approximately 84% passes economic screening when using low statewide avoided costs.

The study finds that wind energy has the potential to become a prevailing source of renewable energy in New York State during the next 20 years. While the technical and economic potential exists to expand wind energy development by nearly a factor of eight over the base case, realization of this potential will depend on a number of factors, including: sufficient political and public will; adequate market support strategies; and a solid understanding of the status of the technology, its associated costs, and the potential for its productive use in New York State.

TECHNOLOGY DESCRIPTION

Modern, grid-connected, electricity-generating wind turbine systems have made major technical, reliability, and economic advances since the inception of their recent development in the mid-1970s. In the United States, this development was fueled by the oil embargoes, the subsequent introduction of federal tax incentives and, in California, state tax incentives and favorable power-purchase contracts. During the 1980s, this combination of factors facilitated the attraction and investment of more than $2 billion of private capital. This in turn supported the engineering and operational advances that put modern wind turbine systems on the map as an economically viable, renewable energy generation technology.[57]

Since 1980, more than 4,200 MW of grid-connected wind capacity have been installed in wind farms in the United States.[58] By the end of 2001, worldwide wind energy installed capacity totaled approximately 24,000 MW.[59] Over this period, the installed capital cost decreased from $2,500 per kilowatt (kW) to $1,000 per kW or less for installations of 50 MW or larger. The costs of unscheduled and preventative maintenance have decreased from more than 5 cents per kilowatt-hour (kWh) to less than 1 cent per kWh. The life-cycle cost of energy has decreased from more than 25 cents per kWh to the current range of 4 to 6 cents per kWh, a price competitive with most conventional energy technologies. The millions of operating hours of experience gained with the thousands of wind turbines installed in this country and elsewhere, along with continuing technical improvements, have increased the energy production efficiency. In reasonably energetic regimes, these wind-driven power systems can achieve capacity factors of 30% or more.

During the 1990s, wind was the fastest-growing power source worldwide, with an annual average growth rate of 23%. Since 1994, worldwide growth of wind energy in new capacity has accelerated to a rate of more than 40% annually.[60]

The production of electricity via the wind's energy is an industry composed of mature, productive technologies. Nevertheless, advances continue to be made in the design, manufacture, and siting of wind energy systems. The wind energy section provided in the 1997 report Scoping Study of Renewable Electric

---

57 Scoping Study of Renewable Electric Resources for Rhode Island and Massachusetts submitted by C.T. Donovan Associates Inc., Stowe, VT; wind energy information by Jamie Chapman, OEM Development Corporation, Boston, MA, prepared for the Rhode Island Renewable Energy Collaborative and a consortium of electric utility representatives, regulators, and renewable energy advocates, 1997.

58 From the American Wind Energy Association (AWEA) Web site: http://www.awea.org/faq/instcap.html

59 Global Wind Energy Market Report by AWEA, Washington, D.C., 2002. Installed capacity is defined as the sum of the capacities shown on the nameplates of the wind turbines in a wind energy installation. For example, an installation comprised of 10 wind turbines rated at 50 kW each would constitute 500 kW of installed capacity.

60 The Most Frequently Asked Questions About Wind Energy, AWEA.

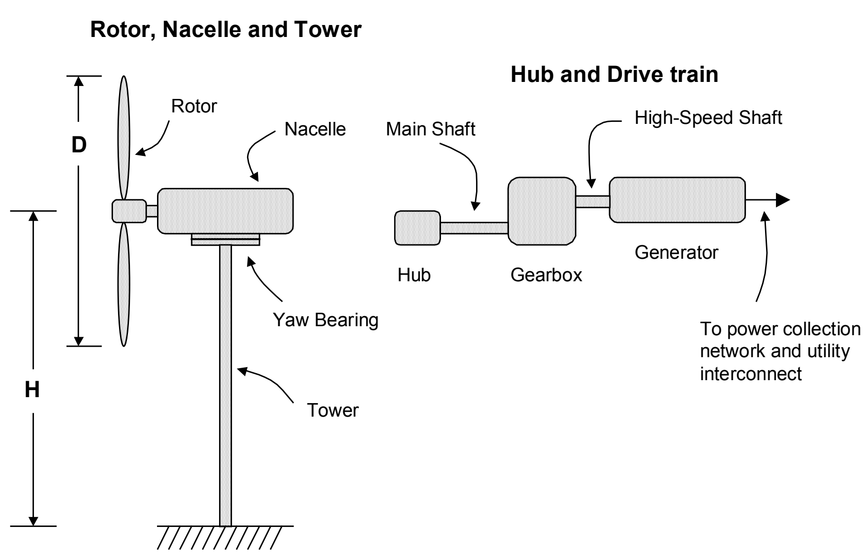
Resources for Rhode Island and Massachusetts provides a thorough description of current wind energy technology. Updates have been made here to account for advances made since 1997.[61]

Wind Turbine Configurations

Wind turbines convert the power in the wind flow field to electric power. This is accomplished through the employment of aerodynamic surfaces configured as propellers. Modern wind turbines typically have two- or three-bladed rotors. As illustrated in Figure 4.9.2, the rotor is comprised of two blades attached to a central hub. The rotor has a diameter (D) and a corresponding swept area ($A = (\pi/4)\ D^2$). The rotor hub is located at a height H above the ground. The wind moving at a velocity (V) impinges on the area swept out by the rotor. A fraction of the power carried by the wind and intercepted by the rotor is converted into drive-train mechanical torque and then into electrical power by the generator.

The principal components depicted in Figure 4.9.2 are the tower, the yaw bearing, the nacelle, and the rotor. The tower may be a cylindrical, tubular, or a truss tower. The yaw bearing allows rotation of the nacelle so as to keep the rotor oriented into the prevailing wind direction. The nacelle houses the mechanical drive train, the electrical generator and, typically, control sensors and electronics.

Figure 4.9.2 Wind Turbine Nomenclature



61 Scoping Study of Renewable Electric Resources for Rhode Island and Massachusetts, 1997.

Rotor Conversion Efficiency

For wind turbines, a fundamental parameter is the power carried by the wind flow field and intercepted by the wind turbine rotor. The study denotes this parameter by the symbol P_W with units in watts. Its magnitude is usually very large relative to the rated power generation capacity of the turbine. The power P_W intercepted by the wind turbine rotor is proportional to the cube of the wind speed V and the square of the rotor diameter D:

$$P_W = \frac{1}{2}\rho V^3 A = \frac{\pi}{8}\rho V^3 D^2 \qquad (Watts)$$

In this equation, the parameter ρ stands for the mass density of the atmosphere at the altitude of the wind turbine. The units of mass density are kg/m^3. This equation describes a very rapid increase of incident wind power as the rotor area and wind speed increase. As the rotor area is doubled, the power incident increases by a factor of four. More important, for a given rotor diameter, the power carried by the wind increases by a factor of eight for each doubling of the wind speed. This rapid increase in the wind power incident upon a wind turbine rotor forms the central design problem for wind turbines: how to control (or modulate) this level of raw power.

For the usual range of operating wind speeds, there is substantial power available in the wind-flow incident on the swept area of the rotor. The study now examines how the rotor converts wind power to shaft power. The details of the theory underlying airfoil operation and response are beyond the scope of this discussion. However, a single number can approximate the effect of aerodynamics. This characterizing number is the rotor power coefficient C_P defined as the ratio of the main shaft mechanical power P_M to the aerodynamic, wind flow power P_W intercepted by the rotor:

$$C_P \equiv \frac{P_M}{P_W} \equiv \frac{P_M}{\frac{1}{2}\rho V^3 A}$$

This definition describes the conversion of the power in the wind incident upon the rotor to the mechanical power P_M in the main shaft.

The rotor aerodynamics are such that the rotor does not exhibit a constant conversion efficiency. The power coefficient C_P is not a constant but rather is a function of the wind speed V and the rotational speed Ω of the rotor. This functional dependence is simplified when expressed in terms of a single variable, the tip speed ratio λ:

$$C_P = C_P(\lambda)$$

where

$$\lambda \equiv \Omega R / V$$

The tip speed ratio λ is the ratio of the linear speed ΩR of the rotor tip over the wind speed V. When expressed in terms of the tip speed ratio, the function C_P has a single maximum value C_{Pmax} at $\lambda = \lambda_{max}$ and then monotonically decreases in value on either side of the maximum. For a well-designed rotor, the maximum value of the power coefficient typically is about 0.48. In wind turbine performance estimates, one should use not the constant value C_{Pmax} but rather the function $C_P(\lambda)$ that describes the variation of the power coefficient on either side of the maximum value.

Simply by rearranging the definition of C_P, the study can go from the wind power incident upon the rotor to the mechanical power P_M transferred to the main shaft:

$$P_M \equiv \frac{1}{2} C_P(\lambda) \rho V^3 A \qquad (Watts)$$

The rotor main shaft also is called the low-speed shaft, since most contemporary designs transfer the main shaft power to the generator through a gearbox. The gearbox is required to match the relatively slow rotor speed to the typical speed of 1,800 rpm required by the generator types most commonly used with 60 Hz grids. In order to match these required generator speeds to the slower speeds required for optimal rotor conversion efficiency [as described by the function $C_P(\lambda)$], the gearbox typically has two or three stages with a total speed change ratio ranging from 25 to 90.

To arrive at an expression for the wind turbine electrical-power output P_E as a function of the incident wind speed V, the study needs to account for the mechanical power losses in going through the gearbox and the electromechanical power losses in going through the generator. The mechanical losses are due primarily to bearing friction and lubricant viscosity. The electromechanical losses arise from bearing friction, windage, resistive heating, and magnetic core losses. Fortunately, these losses are relatively small, resulting in efficiencies for each in the range of 0.93 to 0.98. The gearbox and generator efficiencies are denoted by the symbols ε_{GB} and ε_{GEN}, respectively.

With these approximations, the study comes to the expression that relates the wind turbine electrical-power output to the incident wind speed:

$$P_E \equiv \frac{1}{2} \varepsilon_{GB} \varepsilon_{GEN} C_P(\lambda) \rho V^3 A \qquad (Watts)$$

This relationship is a simplified mathematical description of the wind turbine power curve. Of importance are the dependencies upon the rotor-swept area (the rotor diameter squared), the wind speed cubed, and the air density. The critical function $C_P(\lambda)$ represents the means by which the power flowing through the drive train is modulated or controlled.

Control of Power Flow Through the Drive Train

Techniques for controlling the rotor conversion efficiency generally fall into three classes. The first method of altering the rotor efficiency is active control of the angle of the blade relative to the oncoming wind stream (i.e., actively controlling the pitch angle of the rotor blades). This is the method of pitch control. The second method is to set the pitch angle of the rotor blades to a fixed pitch angle such that their aerodynamic conversion efficiency inherently decreases above a defined wind speed. This is referred to as fixed-pitch or stall-controlled operation. The third, less widely used method may be considered a variation of pitch control. This involves the active control of aerodynamic surfaces on the rotor blades such as flaps or spoilers. Again, there is not general agreement in the wind turbine design community as to which method is superior; each has advantages and drawbacks. The operational success and efficacy of a given power control method depends strongly on the details of the implementation.

Constant-Speed and Variable-Speed Operation

The majority of the wind turbines currently installed employ an induction generator and operate in a constant-speed mode. The very small number of wind turbines employing a synchronous generator may also operate in a constant-speed mode. Operation in constant-speed mode reflects the fact that the wind turbine generator is directly coupled electrically to the load and therefore must operate at or near the 1,800 rpm synchronous speed. Therefore, the rotor, coupled to the generator through a constant-ratio gearbox, must also turn at a constant speed. Thus, for the majority of wind turbines currently installed, the rotor power coefficient is a function only of the reciprocal of the wind speed V:

$$C_P = C_P(\lambda) = C_P(\Omega R / V) \qquad where\ \Omega R = \text{constant}$$

For constant speed operation, the wind turbine designer attempts to locate the maximum value of C_P so as to optimize the annual energy production. This is done through judicious consideration of the gearbox ratio, the V^3 term, and the wind speed frequency distribution. Strictly speaking, the achievement of maximum power in the constant-speed mode of operation can be accomplished only at a single wind speed. In practice, the region of maximal C_P values spans a usefully wide range of wind speeds.

In the widely used variable-speed mode of wind turbine operation, the rotor speed Ω is allowed to be proportional to the wind speed V over a wide range of wind speeds. This means that the tip speed ratio λ can be held constant over this range of wind speeds. Compared with the constant-speed mode of operation, variable-speed operation allows the rotor conversion efficiency to remain at or near its optimum value C_{Pmax} over a much larger range of wind speeds. In general, this results in enhanced energy production and the potential for improved control of drive-train torques. The degree of energy-production enhancement

depends on the details of the wind frequency distribution but may be in the range 5% to 10%. However, variable-speed operation also requires a means for decoupling the aerodynamic rotor and the electric generator from the load (the grid). In all commercial wind turbine designs, this is effected by power electronics between the generator and the grid. While conferring the advantages cited, the added power electronic subsystem represents added cost.

Energy Production

In evaluating the applicability of a wind system for generating electricity, critical parameters are the installation and operating costs together with estimates of the annual energy production. Projection of the annual energy production requires a description of the relationship between the power output of a wind turbine as a function of wind speed (the power curve) and the expected occurrence of various wind speeds throughout the year (the wind speed frequency distribution). Together, these functions describe the matching of the wind turbine power generation characteristics to those of the wind regime in which the wind turbine is situated. These functions can be used to predict or estimate the wind turbine energy production.

After accounting for losses in the electric-power collection system, interactions between wind turbines in a wind farm (array losses) and other losses, the individual wind turbine outputs can be summed to form an estimate of the wind farm energy production. These estimates or projections are most often cast in terms of a calendar year and are referred to as the annual energy production of the wind turbine or wind farm.

Capacity Factor

During the year, there are times when the wind either does not blow or blows at speeds below the cut-in wind speed of a turbine. Wind systems do not produce energy each of the 8,760 hours in a year. Even when a wind system *does* produce energy, it is not always at its fully rated power. A widely used measure of the energy productivity of a wind system is the capacity factor (CF). The capacity factor is defined as the ratio of the energy produced (actual or estimated) to the energy production that would result from operation at full-rated power every hour of the year:

$$CF_{Yr} \equiv \frac{EnergyProduction/Year}{(Power\ Rating\ x\ 8760\ Hours/Year)}$$

The range of capacity factor values is from 0 to 1, or from 0% to 100%. Better performing wind farms have achieved capacity factor values in the range of 24% to 33%, with 28% considered good. Capacity factors for offshore installations have approached 38%. As an example, if a 50 MW wind system generated and delivered 122 million kWh during a given year, the corresponding capacity factor would be 28%:

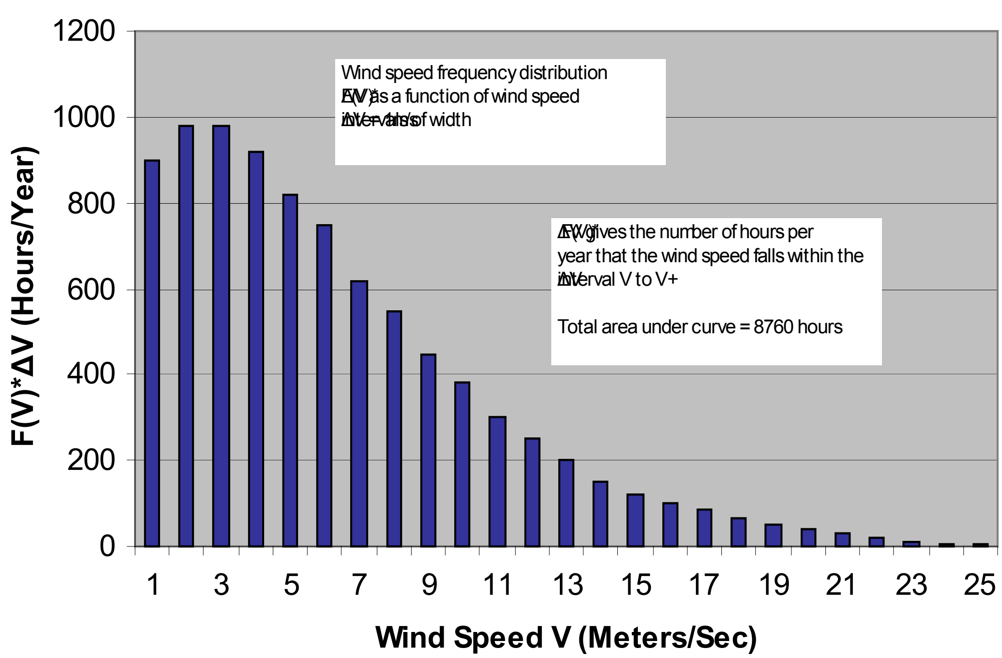
$$CF_{Yr} \equiv \frac{122\, million\ kWh}{(50MW\ \ x\ 8760\ Hours)} = 0.28$$

As a further example, this definition can be used to calculate the annual energy production of a hypothetical 500 kW wind turbine operating at a capacity factor of 0.28. The result is 1.226 million kWh/yr. However, as a simple ratio of energies, the capacity factor says nothing about the physical processes associated with the conversion of the power carried by the wind into electric power. These processes are described by the wind turbine power curve and the wind speed frequency distribution.

Wind Speed Frequency Distribution

The strength of the wind resource is described quantitatively by the wind speed distribution. Graphed in Figure 4.9.3 is the discrete version of a hypothetical wind speed distribution at a wind turbine site. The wind speed distribution function F(V)*ΔV gives the number of hours per year that the wind speed lies within the small wind speed interval or bin of width ΔV located between the wind speed values V and V + ΔV. The value used for the constant bin width ΔV in Figure 2 is ΔV = 1 meters per second (m/s) (2.24 mph). The integer index k identifies the wind speed bins. For example, the bin k = 2 corresponds to the wind speed bin encompassing the range 1 to 2 m/s. The height of the bar for k = 2 indicates that the wind speed lies within this interval for about 980 hours/year. As noted on the graph, the sum of all the bars is 8,760 hours, the number of hours in a year.

Figure 4.9.2 Annual Wind Speed Frequency Distribution



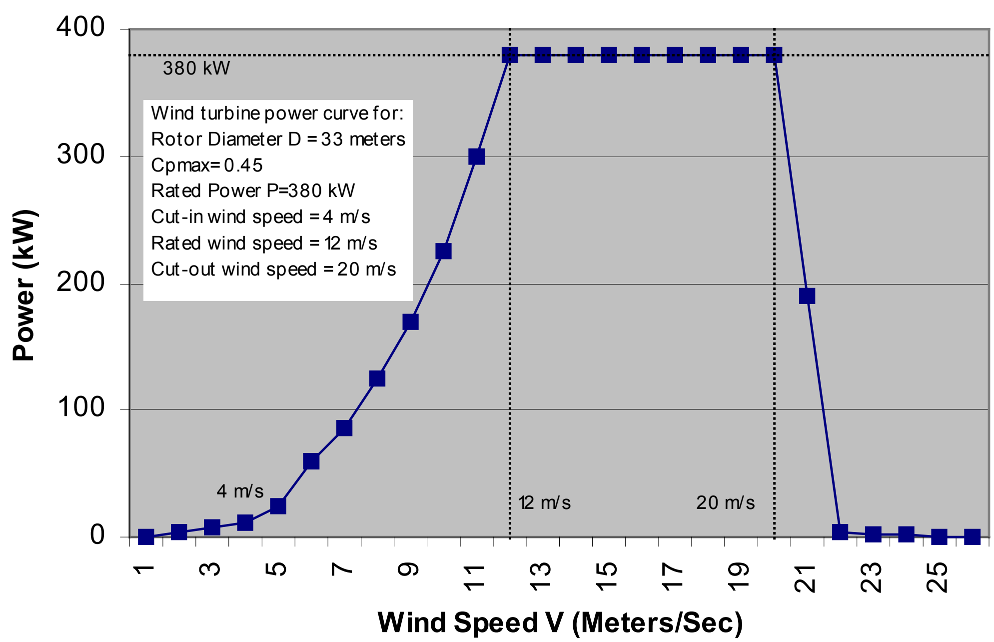
Wind Turbine Power Curve

The graph of wind turbine electrical-power output as a function of wind speed is the power curve. The expression developed above portrays the principal dependencies in simplified form. In practice, a more descriptive theoretical power curve is developed using computer codes that model the lift, drag, and other aerodynamic-performance characteristics of the airfoils employed. These codes may also incorporate realistic wind effects, such as the turbulence structure and the vertical shear, which is the increase of wind speed with height across the rotor span.

Such theoretically derived power curves must then be validated through measurements of the actual power output as a function of wind speed. While conceptually simple, such a determination in practice can be quite complex. Complicating influences on power-curve measurements include the necessary spatial separation of the wind sensor and the wind turbine, the influence of the local terrain on the wind flow, and the possible interaction of the wind gust structure with the wind turbine control system.

Shown in Figure 4.9.4 is an illustrative power curve for a generic 33-meter, 380 kW wind turbine. The wind turbine begins generating power at the cut-in wind speed of 4 m/s. As the wind speed increases further, the power delivered increases proportionate to the V^3 dependence (as modified by the C_P function). This increase continues until the rated wind speed (12 m/s for this example) is reached. This is the wind speed at which the turbine first reaches its rated power of 380 kW.

Figure 4.9.4 Wind Turbine Power Curve



At and beyond the rated wind speed, the properties of the rotor blades are actively controlled so as to be less efficient or are designed to be inherently less efficient as the wind speed increases. The blade efficiency characteristics are such that the delivered power is maintained at approximately a constant value from the rated wind speed (12 m/s) to the cut-out wind speed (20 m/s). Above the cut-out wind speed, the wind turbine is shut down. Generally the wind blows for so few hours per year above the chosen cut-out speed that the incremental energy production does not pay for the increased capital cost incurred by strengthening the structure to accommodate the associated mechanical loads. In conjunction with the wind speed frequency distribution, the power curve describes the power and energy-production performance of a single wind turbine without the complicating effects of complex terrain or of other nearby wind turbines. In a wind farm array, this simplified description of wind turbine response ignores the effects of the turbulence produced by upstream turbines and experienced by those located downstream. These array effects diminish the energy produced by an array relative to the energy produced by a single, isolated wind turbine.

Annual Energy Production

The annual energy production of a wind turbine depends on 1) the shape and strength of the wind resource, 2) the wind turbine power curve, and 3) the degree to which they overlap. The annual energy production of a wind farm is the sum of the energy production from the component wind turbines reduced to account for various losses.

The shape and strength of the wind resource are described quantitatively by the wind speed distribution. The wind speed distribution gives the number of hours per year that the wind speed lies within small, adjacent wind speed intervals. The wind turbine power curve specifies the wind turbine's electric power output as a function of wind speed. Together, the wind speed distribution and the wind turbine power curve, when multiplied together and summed over all wind speeds (all values of the index k), provide an estimate of the wind turbine annual energy production:

$$\begin{aligned} E_{Yr} &= (Hours/Yr) * \Delta V * \sum (F_K * P_K) \\ &= (8760\ Hrs/Yr) * (1\ m/s) * \sum (F_K * P_K) \qquad (Watt - Hours/Yr) \end{aligned}$$

The annual energy production for a wind farm is always less than the summed production from the component wind turbines. There are a number of contributing loss factors. These include the array losses associated with distortion of the wind flow downstream of operating wind turbines, losses associated with the electric-power collection network, and departures from ideal performance of the wind turbine blades. Given a measured or an assumed wind speed frequency distribution and a wind turbine power curve, the relationship of this equation can be used to estimate the annual energy production to be expected from a

wind turbine operating in the wind regime described by the wind speed distribution without consideration of unavoidable loss factors.

COMMON USE AND SCALE

Historically, there have been two categories of wind turbine applications in this country: wind farms and small, stand-alone wind turbines. A third, intermediate category is emerging. This third category — clusters of small numbers of wind turbines — is an ideal model for wind installation configurations in New York State over the next two decades.

The first category includes relatively large numbers of large wind turbines intended for use in interconnected arrays of wind farms. The wind farm arrays are designed to be connected to a grid system. The second category is comprised of one or a few much smaller machines intended for use with light industrial applications, on farms, in villages, and at remote sites. Depending on the details of the technology employed, they may or may not be connected to a grid system of much larger capacity. An emerging, intermediate mode of use is clusters of wind turbines. Typically, a cluster consists of two to 10 utility-scale wind turbines, though the unit power rating may also include smaller wind turbines.

Wind Turbines Designed for Grid-Connected, Wind Farm Use

Because of the large numbers of wind turbines, their relatively large power ratings, and the associated large capital flows, most of the emphasis over the last 20 years has been on utility-scale wind turbines interconnected electrically and delivering their power to the balance of the grid system. The wind turbines used in such wind farm applications have steadily increased in size. In the early eighties, the predominant turbine size ranged from 50 kW to 100 kW. Since then, advances in design, the accumulated operating experience, and other factors have resulted in current commercial utility-scale wind turbines rated between 600 kW and 1.5 MW. Typically, the larger end of these ranges is represented by wind turbines from European companies. Companies in the U.S. have focused on the smaller ends of these ranges, although this is beginning to change as wind energy development occurs in land-constrained areas and the economic benefits of large-scale installations become increasingly important.

Wind farms characteristically are comprised of large numbers of wind turbines. For example, a 50 MW wind farm utilizing 1 MW machines would consist of 50 wind turbines. The power from each wind turbine typically would be fed to a pad-mount transformer at 480 V or 600 V, then stepped up to 21 kV for transmission to a substation. The substation would transform the voltage from 21 kV to the utility system's transmission voltage. A typical transmission voltage is 230 kV.

The wind farm power-collection network and all of the other electrical subsystems (except for the wind turbine itself) are comprised of standard electrical components widely used by utilities in their transmission

and distribution systems. Typically the wind turbine electrical generator is a standard electric motor operated as a generator. Hence, the electrical-power portion of a wind farm utilizes standard utility components and usually interconnects with the utility system at transmission voltage levels.

If an induction generator is used, as is the case with many wind turbines operating today, connection of the generator to the utility grid draws magnetizing current (reactive power) and a frequency reference. For these and other reasons, it is currently thought that the wind capacity on-line at any given time can be no more than about 15% of the total system capacity on-line. Thus, wind cannot provide all of the generating capacity of a utility system without additional power conditioning and control equipment.

Increasingly, wind turbine systems include additional power conditioning and control systems. These machines utilize power electronics between the generator and the grid. The power electronic control system then supplies the needed reactive power and frequency reference to the wind turbine. This effective decoupling of the electric generator from its load (the utility grid) permits operation of the wind turbine in the so-called variable-speed mode. This operating mode allows better control of the mechanical torques and loads in the wind turbine drive train and improved reactive power control. However, an additional subsystem — the power electronic conditioning and control system — is required. While the incorporation of a power electronics system does provide a number of operational and power quality advantages, there is not yet general agreement among wind turbine designers as to which approach is superior.

In either case, there remains the inherent time-variability of the electric power from wind turbines. While the power is smoothed due to the large geographic area occupied by a wind farm, there remain variations in the delivered electrical current that reflect the variability of the wind flow. This generally is not a problem for utility system operators because wind is a small fraction of the total system capacity supplying the load. The variations of the wind farm power can be viewed as a negative load and can be less than or comparable in magnitude to variations in the utility load. As one method of enabling wind farms to eliminate the time variations and supply firm power, consideration is being given to the integration of wind with gas-fired combustion turbines. Such augmentation need not be located at the wind farm site; it can be located at any convenient point in the utility or system service territory.

Because of their large scale, installed costs of wind farms are the lowest of any configuration type and occur in the range of $900/kW to $1200/kW, depending on farm size and site factors. Still, wind farm development is an extremely capital-intensive undertaking and typically requires partnerships that may include state and federal agencies, utilities, and outside investment firms.

Through the Utility Wind Turbine Performance Verification Program (TVP), the U.S. Department of Energy (DOE) and the Electric Power Research Institute (EPRI) have been working with the wind industry

since 1992 to rapidly develop innovative, low-cost wind technologies to compete in global energy markets. This joint effort between DOE, EPRI, wind energy developers, and several utilities is intended to evaluate early production models of advanced wind turbines and to verify their performance, reliability, maintainability, and cost of new wind turbine designs and system components in a commercial utility environment.[62] The first turbines developed under this program are on the market, and new generations of turbines are currently becoming available. In 1994, DOE initiated a $40 million program to develop the next generation of utility-scale wind turbines. For turbines developed in this program, several design innovations have been realized, including more efficient airfoils with low-solidity, flexible blades with individual pitch control. Taller, low-stiffness towers are also being developed, as are advanced control strategies to optimize energy capture and reduce loads.[63]

NYSERDA is conducting a wind energy prospecting program, the objectives of which are to: 1) determine the economic benefits associated with increased wind energy development in the state; and 2) meet an increased state demand for clean energy sources. Program participants are using industry-accepted wind-prospecting techniques to identify areas in New York State where wind energy development would be most economically and environmentally beneficial. Other aspects of the program pertain to public education regarding wind energy, securing land rights for wind-measurement equipment, predicting energy output from potential wind installations, and forecasting the cost of energy associated with project candidates. The program resulted in the detailed and interactive New York State Wind Resource Map developed by True Wind Solutions LLC, located in Albany.[64] The prospecting program as a whole may result in state wind energy capacity development of 10 MW or more.[65]

There are two major wind farm installations in the State of New York: the Madison Wind Power Plant and the Fenner Wind Power Plant. Together, these installations represent about 41.5 MW of capacity. Another 366 MW of the State's wind farm capacity is currently in the planning stages. The study's analysis indicates that, given State wind resources and land-usage patterns, there will be the technical potential for 4,225 MW of wind farm capacity in the State of New York by 2022. A growing public and political interest in indigenous energy sources suggests that market demand may meet this technical potential. However, there appears to be an increasingly vocal opposition to the siting of wind farms, with concerns particularly pertaining to the visual impact of these large installations. Achievement of this technical potential value will depend heavily on measures that address these concerns.

---

62 *Power Performance Testing Progress in The DOE-EPRI Turbine Verification Program* by Brian Smith, National Renewable Energy Laboratory (NREL), Golden, Colorado, and Gordon Randall, Tim McCoy, and John VandenBosche, Global Energy Concepts, LLC, Kirkland, Washington, presented paper at the AWEA Windpower 2001 conference.

63 From DOE Web site: http://www.eren.doe.gov/wind.

64 The New York State Wind Resource Map is available at http://www.abacuswave.com/truewind/.

65 From NYSERDA Web site: http://www.nyserda.org/energyresources/wind.html.

Wind Turbines Designed for Stand-Alone and Village Power Use

A second category of wind turbines has been used in large numbers for many decades. This class includes machines with much smaller power ratings, typically 1 kW to 300 kW. They have been used in this country on ranches, farms, villages, industrial settings, and individual homes. They most often are used singly, in remote locations, and may or may not be grid-connected. In other countries, one or more have been applied as village power systems working with a diesel-electric generator and perhaps battery energy-storage systems. In this configuration, such power systems are called hybrid power systems (described in more detail below).

Because of their small size and individual nature, installed costs for small wind turbines are typically higher than those of wind farms, occurring in the range of $2000/kW to $3000/kW depending on wind turbine size and site factors. However, these machines, whether interconnected with the grid or not, have a high degree of siting flexibility and extensive off-the-shelf availability. They could have a useful role in New York State's total energy picture.

According to the study Market Assessment for Small Wind Systems in New York State, most small wind systems installed in New York over the last several years have been used for off-grid applications, such as remote cabins and trailers.[66] Typically these systems are rated at 1 kW or less and are installed by the system owner. In recent years, grid-connected systems rated at 900 W to 3 kW have been installed in the State with increasing frequency. Often a desire for energy independence or environmental ethics, rather than the need to achieve short-term electric cost savings, motivates the owners of these systems.

Utilities, too, have experimented with small wind systems, primarily as demonstration projects. On Long Island, the Long Island Power Authority (LIPA) has twice attempted to install one or more 50 kW wind turbines over the last few years — one on Shelter Island and one at Camp Hero in Montauk. In both instances, land-use or public support issues thwarted these projects. For 2003, LIPA is planning installation of five 50 kW machines on Long Island's north and south forks.

Research and development of small wind systems is taking place in the U.S under the DOE/National Renewable Energy Laboratory (NREL) Field Verification Program. The intent of the program is to enable the U.S. wind energy industry to "complete the research, testing, and field verification needed to fully develop advanced small wind energy technologies with particular focus on turbine cost-effectiveness and reliability. The Field Verification Program includes cost-shared research with industry partners and support

for projects that verify performance of wind turbine technologies in actual operational applications. The program is aimed at turbines rated from 300 W to 100 kW and includes five recipient organizations (including AWS Scientific Inc. of Albany, New York) managing 13 sites. Turbine manufacturers include Atlantic Orient Corporation and the Bergey Windpower Corporation.[67]

Research and development of small wind systems is also occurring in the State of New York under the NYSERDA-sponsored project Sustainable Market Development for Wind Energy in the Municipal, Agricultural, and Commercial Sectors. The objective of this cost-sharing project is to establish a market development and demonstration program for small-scale wind energy systems in the State. The program targets three key sectors: municipalities, agricultural, and small business, and emphasizes small-scale grid-connected applications, though off-grid applications are also eligible. Depending on the sector served, state cost-sharing levels will reach 70%. At least five 10 kW wind turbines will be installed by the summer of 2003. Performance monitoring and machine maintenance will also be conducted under the program.[68]

Wind turbine systems rated at 1 kW to 50 kW are commercially available from a number of manufacturers in the U.S. and Europe. It is anticipated that machines rated up through 300 kW will become more widely available within the next five years.

Over the next two decades, markets for small wind systems are expected to grow, particularly as the public's environmental awareness increases and state incentives for small renewable energy systems are implemented.

Distributed Systems

Both in numbers of aggregated wind turbines and unit power ratings, wind farms and village power systems span the extreme ends of the application spectrum for wind turbines. Wind farms integrate large numbers of relatively large wind turbines that are connected to the balance of a typically larger grid system. At the other end of the spectrum are the much smaller wind turbines typically operated in a stand-alone fashion.

In addition to these two modes, an intermediate mode is emerging in the United States: distributed, cluster installations. A cluster can consist of two to 10 wind turbines connected to the grid. In contrast with wind

---

66 *Market Assessment for Small Wind Systems in New York State* by Bruce H. Bailey, Susan M. Perry and Denis Nadas, AWS Scientific Inc., Albany, New York, prepared for the New York State Energy Research and Development Authority, Albany, New York, 2002.

67 From NREL Web site: http://www.nrel.gov/wind/fvp/index.html.

68 *Cost-Sharing Opportunity for Wind Energy Systems* by AWS Scientific Inc., Albany, New York for New York State Energy and Research Authority, 2001, and personal communication with Jim Adams of AWS Scientific Inc., December 9, 2002.

farm applications, the distinguishing feature is the small number of grid-connected wind turbines. Depending on the nature of the application and the load, the unit wind turbine size can range from 600 kW to 1.5 MW or more.

The wind turbine component of cluster installations may be similar or identical in configuration to their wind farm counterparts. However, the machines for a distributed or cluster installation probably will cost more than those for a wind farm configuration. This reflects the absence of volume-purchase discounts and a necessarily different mode of maintenance. One of the economic advantages of wind turbines in a wind farm configuration is that a dedicated, on-site maintenance team is built into the wind farm operation and thus into the cost of energy. For a single cluster installation, such an arrangement is not economically feasible, and other maintenance-support arrangements must be made. If there are a number of cluster installations within a geographic region, a dedicated service organization may be viable.

The installed capital cost of clusters falls in the range of $1200/kW to $1500/kW — considerably higher than for wind farm installations. However, the interconnect costs for distributed wind systems can be less costly than those for wind farms. The reason is that the interconnect can take place at distribution-level voltages (e.g., 69 kV or less) in contrast to the two-step voltage transformation required for wind farms of substantial capacity. Because of the reduced electrical currents, a much more costly, high-voltage (e.g., 230 kV) substation typically is not required. In addition, since the interconnection can occur at distribution voltages, there are many more nearby geographic opportunities for such interconnect. This minimizes the costs of additional transmission lines that may be required for wind farms.

The cluster or distributed mode of wind turbine installation is how the Danish wind industry got started. As one travels throughout the Danish countryside, one sees groups of small numbers of wind turbines. In the U.S. and particularly in the Northeast, this may be the predominant installation mode over the next several years, at least until the current restructuring of the electric industry is sorted out.

The recent study, Distributed Wind Power Assessment (2001), compares conditions in Europe and the U.S. with regard to cluster development and recommends several criteria necessary to realizing success with distributed systems in the U.S., including:[69]

- information and technical assistance to utilities, landowners, and the financial community;
- viable ownership models for landowners;
- standard power purchase agreements;
- standard permitting and zoning requirements;

---

[69] *Distributed Wind Power Assessment* by Joseph M. Cohen, Princeton Energy Resources International and Thomas A. Wind, Wind Utility Consulting, prepared for the National Wind Coordinating Committee Distributed Wind Working Group, Washington, D.C., February 2001.

- design and interconnection standards;
- simplified technical evaluation procedures (not one single or required approach) for determining interconnection requirements and impacts;
- affordable and accurate wind resource assessment;
- favorable regulatory and market atmospheres;
- available financing at affordable terms; and
- lower project operation and maintenance (O&M) costs

New York State has in place one cluster installation: the 6.6 MW Wethersfield Wind Power Plant, consisting of 10 Vestas 660 kW turbines. Assuming the State continues to pursue and establish the necessary policies and programs that support cluster development, the study's analysis indicates that, given State wind resources and land-usage patterns, there is the technical potential for 2,535 MW of cluster capacity by 2022. Cluster installations by definition require less geographic area than wind farms — an important advantage for regions in the State of New York that have large wind resources but limited suitable land area (e.g., ridge locations). These installations are also well-suited to small, separately owned land parcels that may be difficult to aggregate into tracts large enough to support large wind farms. The State has several other characteristics that suggest a conduciveness to cluster development, including its significant wind resources and strong farming and industrial bases. Given these conditions and an appropriate climate of public and political support, clusters could become the predominant mode of utility-scale wind energy in New York State over the next 20 years.

Offshore Wind Installations

Offshore wind installations, now emerging in the U.S., are becoming an increasingly attractive option for wind energy production. This is due to the fact that the majority of the U.S. population lives in coastal, land-restricted areas.

Offshore installations are similar to wind farm configurations in that they generally consist of one to 20 utility-scale machines of 1 to 3 MW. These machines are connected to the grid but are situated some distance from land (generally from 1 to 10 km) depending on water depths, shipping lanes, and aesthetic restrictions.

Offshore installations have a number of advantages over land-based installations:

- offshore installations produce proportionately more energy than onshore installations due to higher average wind speeds and reduced turbulence;
- decreased wind shear may allow shorter towers in offshore installations;
- offshore installations typically may encounter fewer land-use, land ownership, and siting restrictions;

- offshore installations encounter fewer environmental restrictions (e.g., noise and aesthetic impacts) when located farther from shore;
- offshore installations possess greater configuration flexibility due to decreased topographic sensitivity; and
- offshore installations may realize longer lifetimes and reduced maintenance requirements due to decreased offshore turbulence

However, there are several drawbacks to offshore installations:

- offshore installation costs can be up to 20% to 50% greater than land-based installed costs due to the need for specialized foundations and greater interconnection costs;
- offshore installations operate in a highly corrosive (i.e., maritime) atmosphere, necessitating upgraded materials and finishes, further raising costs;
- access to offshore wind turbines may be restricted during severe weather;
- offshore wind turbines may require specialized marine foundations to withstand wave and/or ice loading;
- aesthetic impacts of offshore installations may cause public resistance;
- offshore installations may conflict with other coastal activities (e.g., shipping, military, fishing, tourism);
- permitting of offshore installations may require any combination of international, federal, state, and local reviews; and
- offshore installations may necessitate an increase in the capacity of weak costal transmission grids

Europe has taken the lead in offshore wind energy development. Large-scale offshore installations are now being planned and installed in Denmark, the U.K., Sweden, Germany, and the Netherlands. According to one 1998 report, "Offshore Wind Energy — Building a New Industry for Britain," there is sufficient wind energy potential off the shores of European Union countries (in water depths where it is feasible to place turbines) to supply all current electrical requirements for the coastal nations of the European Union.[70] Denmark is planning to install 4,000 MW of offshore capacity over the next 30 years. During the same period, the Netherlands is planning to install nearly 3,000 MW of offshore capacity.

Offshore development is beginning in the United States as well. Cape Wind Associates, LLC, a wind development interest located in Massachusetts, is planning a 420 MW installation to be located five miles off the shores of Cape Cod. The facility is scheduled to be on-line by 2005. According to the recent study, The Potential For Offshore Wind Energy Development in the United States (2001), the U.S. offshore potential annual energy production is 737 terawatt-hours (TWh) — an amount sufficient to meet 23% of

[70] *Offshore Wind Energy — Building a New Industry for Britain,* by Border Wind Limited, Northumberland, United Kingdom, prepared for Greenpeace, 1998.

1999 U.S. electrical consumption.[71] Of this value 72%, or 533 TWh, is located in Lake Erie and off the U.S. mid-Atlantic coast.

Power customers likely to purchase offshore wind energy are those utilities and populations with close proximity to offshore wind resources. In the State of New York, these include LIPA and utilities that serve the communities of western New York State near Lake Erie and Lake Ontario. The highly capital-intensive nature of offshore wind energy development generally precludes cooperative ownership arrangements, such as those found in cluster development.

Long Island, with its higher-than-average energy costs and generous wind resources off its southern shores, represents a prime location for offshore wind energy development within the next two decades. A recent study indicates there are 5,200 MW of installed capacity technical potential off Long Island's shores.[72] Accounting for anticipated wind turbine size increases over the coming decades, the study's analysis indicates there is technical potential for 6,600 MW of offshore capacity in Long Island by 2022. Market dynamics, permitting issues, aesthetics, and transmission issues will affect how much of this technical potential is actually developed.

The Great Lakes region may pose fewer permitting and interconnection issues by virtue of being an area focused less on recreation than Long Island. As well, the industrial history of the region has granted it a robust electrical transmission system. The study's analysis indicates that, considering wind resources and water depth restrictions, there is the technical potential for 2,700 MW of installed capacity off of New York State's Great Lakes shores, primarily on Lake Erie. Considering anticipated wind turbine size increases, the study estimates that there will be the technical potential for 3,500 MW of offshore capacity in the Great Lakes by 2022. Market dynamics, permitting issues, aesthetics, transmission issues, and ice-loading issues will affect how much is actually developed.

Offshore wind turbine systems are currently rated at 1 MW to 3 MW and are commercially available from a number of manufacturers in the U.S., Europe, and Japan. The average offshore machine size is expected to increase from 2 MW to 5 MW in the next 20 years. Wind turbines greater than 3 MW are expected to become commercially available within the next two to five years.

---

[71] *The Potential for Offshore Wind Energy Development in the United States* by Kevin J. Smith, Global Energy Concepts, LLC, Kirkland, Washington and George Hagerman, Virginia Polytechnic Institute and State University, Alexandria, Virginia, presented paper at the AWEA Windpower 2001 conference.

[72] *Long Island's Offshore Wind Energy Development Potential: A Preliminary Assessment* by Dr. Bruce Bailey, Jason Kreiselman, and Jeremy Snyder, AWS Scientific Inc., Albany, New York, for Long Island Power Authority and New York State Energy Research and Development Authority, 2002.

Hybrid Systems

Wind hybrid systems are those that combine one or more different power sources with wind energy. Hybrid systems are in common use around the world. Wind hybrid systems combine wind turbine systems with one or more of the following energy generation sources: photovoltaic systems, micro-hydroelectric systems, fuel cells, or fossil fuel-based sources (e.g., diesel generators). Typically used in off-grid, remote applications, hybrids are particularly appropriate when the redundancy of multiple power sources is necessary to provide a steady power stream.

In a hybrid system, a wind turbine system provides the primary power source, depending on the wind resource. The wind turbine is likely a small, stand-alone system, rated from 1 kW to 50 kW, though it may be a utility-scale wind turbine of 600 kW or greater. In periods of low wind, when the wind turbine is not generating power, the secondary (and, in some cases, tertiary) power source assumes the task of power generation. This can serve to provide a consistent power stream, whereas a wind turbine alone would provide an energy profile that matches wind resource variations. Hybrid control systems can be designed such that secondary power sources produce power concurrently with the wind turbine when additional power is required.

Secondary systems used in hybrid systems include diesel generators, propane or natural gas generators, photovoltaic (PV) systems, and fuel cell generators. Wind/PV hybrid systems are particularly well-suited to steady energy generation because their resource variations are often complementary: wind resources are generally lowest in the summer months when the solar radiation is at its peak, while wind resources are highest in winter when solar radiation is lowest. In many locations, the energy-generating components of wind/PV hybrid systems are well-suited to their respective diurnal resource variations as well.

In locations where maintenance of the power stream is an absolute necessity and fossil fuels are available (though possibly expensive), wind turbines are often paired with fossil-fuel generators as a way to reduce fossil-fuel consumption. Hydro-Quebec's wind/diesel hybrid program reduces the cost of electricity production in 14 villages of northern Quebec and five communities along the north shore of the St. Lawrence River. Historically, these communities have been supplied with electricity produced solely by diesel generators. The peak demand for each community ranges from about 180 kW to 6000 kW, with a total demand of 22 MW. The wind/diesel system controller gives energy production priority to the wind turbines and allows the diesel generators to be shut down when the winds are strong enough to supply the energy required by the network, thus saving considerable fuel expense. This hybrid arrangement is

particularly well-suited in areas where wind energy can be used to displace fuel costs for such purposes as space heating in Quebec's remote communities.[73]

Because hybrid systems are typically off-grid applications, they are generally connected to an energy-storage source such as a battery bank. Currently in development are wind/fuel cell hybrid systems, in which electricity generated by the wind turbine powers the electrolysis process in which hydrogen is produced from water. In this configuration, hydrogen acts as an energy-storage medium and is used to generate electricity via a fuel cell in periods of low wind. Alternatively, produced hydrogen may be stored in a compressed form and transported for use in other applications.

Wind hybrid systems generally have a high degree of siting flexibility and, when grid-connected, possess the added capability of providing voltage support and reactive power to utility systems. This is the case particularly near the termination points of long power distribution networks.

Drawbacks include the fact that hybrid systems are necessarily more complex than non-hybrid wind turbines and, as a result, are generally more costly to install, operate, and maintain than stand-alone wind turbines. Increased system complexity may also increase the likelihood of sub-system failures. Depending on system configuration, installed costs and maintenance costs of hybrid systems can exceed two times that of non-hybrid wind turbines.

Wind/diesel and wind/PV hybrid systems have been in use for a number of years and are commercially available in the U.S. and abroad. Other hybrid combinations are still in development and are anticipated to become commercially available within the next five to 10 years.

Wind hybrid systems are best suited to niche markets — users in need of remote, redundant, non-grid-connected power. For systems less than 10 kW, this could include residences, remote camps, research stations, and telecommunications systems. For systems larger than 10 kW, potential customers include remote villages or collections of buildings, and (in the case of grid-connected systems) power providers needing to provide voltage support and reactive power to utility systems. Other applications and industries that may benefit from hybrid systems include the oil and gas industries, tower obstruction lighting, uninterruptible power supplies for pipelines, and military and scientific applications.[74]

---

[73] *Wind/Hybrid Power System Test Facilities in The United States And Canada* by H. James Green, NREL, Golden Colorado, R. Nolan Clark, USDA Conservation and Production Research Laboratory, Carl Brothers, Atlantic Wind Test Site, and Bernard Saulnier, Institut de Recherche d'Hydro-Quebec, presented paper at the AWEA Windpower 1994 conference.

[74] From Northern Power Systems Web site: http://www.northernpower.com/.

In New York State, this represents a relatively limited market. However, in one respect, any customer considering installation of an off-grid wind turbine may do well to consider a hybrid system, as the added energy source redundancy can ensure enhanced power delivery reliability. However, the added expense of hybrid systems may make them beyond the reach of many customers.

Dedicated Applications

Dedicated wind turbine installations produce energy for purposes other than strict electricity production and consumption. In one sense, dedicated applications represent a return to the origins of wind energy, as the earliest wind energy applications were for grinding grain (thus, windmill) and pumping water. While mechanical windmills are still used for water pumping in many parts of the world, newer dedicated applications use the electric energy produced from modern wind turbines to power processes or machinery that might otherwise be too remote or expensive to operate. These applications include wind electric water pumping, water purification, water desalination, and hydrogen production.

Wind energy is highly adaptable to many remote applications and often represents the most cost-effective energy-production option. Wind electric pumping systems, for example, combine high reliability, low-maintenance small wind turbines, and "off-the-shelf" alternating current electric-centrifugal pumps to provide a simple and robust remote water-delivery system. Since wind is an intermittent resource, reliable water delivery requires storage and, sometimes, a back-up generator to power the pump during extended period of low wind.[75] In this instance, a hybrid-dedicated wind system might be considered.

Seawater desalination using wind energy is a recent technological development, with several installations around the globe. Early experience indicates that wind is a particularly cost-effective energy source for the desalination process, particularly where fresh water is in large demand and the site is isolated. Under Federal Executive Order 12902, which mandates that federal agencies implement renewable-energy programs where practical, the Naval Auxiliary Landing Field on San Clemente Island, California, has installed three 225 kW Micon wind turbines that now produce about 17% of the electricity at the facility. In addition, the facility is implementing an island desalination project using two additional wind turbines. Currently, 14.5 million gallons of fresh water per year are barged from San Diego to the island. Potential annual savings produced by the desalination project could be almost $478,000 per year, and the number of trips made by diesel-powered tugs would be reduced.[76]

---

75 *Wind-Electric Pumping Systems for Communities*, by Michael L.S. Bergey, Bergey Windpower Co., Norman, OK, presented at the First International Symposium on Safe Drinking Water in Small Systems, Washington, D.C., 1998.

76 From U.S. Navy Environmental Leadership Program Web site: http://nelp.navy.mil/nelp_guide_4/conserv/wind.htm.

Hydrogen production using wind energy, described earlier, utilizes the electricity produced by wind turbine systems to power the electrolysis process and produce hydrogen for use in fuel cells. Research into this field is ongoing. In June 2001, the U.S. Energy Secretary Spencer Abraham announced nearly $86 million in research awards to private organizations and universities for research and development of clean energy technologies, many of which are focused on wind energy, hydrogen production, and fuel cell research.[77] Research into remote village desalination and water purification using wind is also continuing. Researchers with the NREL have successfully powered electrodialysis desalination systems and ultraviolet water-disinfection units with small-scale wind power systems.[78]

Dedicated wind energy applications represent technologies that may mature in the next 10 to 20 years. While early research and experience indicate that they hold promise for niche applications, the technologies are relatively untested, and the associated costs are largely unknown.

Because dedicated systems are generally off-grid, they have a high degree of siting flexibility. On the other hand, the location of a dedicated system is likely to be restricted by its purposes (e.g., a wind turbine powering a water-desalination plant will likely be located in a coastal area).

As with hybrid systems, increased system complexity makes dedicated systems more costly to operate and maintain. Increased system complexity may also raise the likelihood of subsystem failures, making these systems less reliable than traditional machines. Depending on the system configuration, installed costs and maintenance costs of dedicated systems can exceed twice that of traditional wind turbines.

Dedicated wind systems are best suited to niche markets — that is, users with specific requirements such as hydrogen production or water purification. Moreover, to be cost effective, dedicated wind systems are best utilized in applications where grid power cannot be provided. Potential customers include remote villages, research stations, telecommunications systems, and military and scientific applications. In New York State, this represents a relatively limited market. However, continuing research — particularly in the field of fuel cells and wind-based hydrogen production – holds promise for broad-based application of dedicated wind systems.

<u>Siting and Operational Characteristics Affecting Scale and Use</u>

Wind farm installations in the U.S. have installed capacities denominated in the thousands of megawatts. To some extent, the size of existing installations reflects the availability of large land areas under single

---

77 From U.S Mission to European Union Web site: http://www.useu.be/Categories/Evironment/EnvWindPower09July01.html.

78 *Desalination and Water Purification for Villages* by David Corbus, NREL/National Wind Technology Center, Golden, Colorado, 1999.

ownership. In Europe, and perhaps for many future installations in the northeastern U.S., ownership and land-use patterns are different. Areas under single ownership are smaller, and other, pre-existing uses make large land areas difficult to consolidate. Thus, in the State of New York, wind installations could be distributed geographically in clusters, each embodying two to 10 wind turbines. Rather than installing 100 MW in a single wind farm location, there might be 20 separate clusters each comprised of 5 MW of capacity. If 500 kW wind turbines are used, a 5 MW cluster would include 10 wind turbines. Current plans for New York State wind farms include installations rated from 40.5 MW to 240 MW. As wind farms of this size are installed, large tracts of aggregated land may become less available, precipitating a trend toward smaller, cluster-sized installations.

The power provided by wind systems is intermittent but able to be predicted statistically on a seasonal basis and, in some cases, for shorter periods of time. In both Europe and the U.S., research is under way aimed at predicting 36 hours in advance the power to be supplied from a wind installation. The energy delivered during the winter and summer peak-demand periods depends on the characteristics of the wind regime. Variations in the wind flow due to topography and other details make it difficult to project energy production during daily peak-demand periods; however, if the wind is blowing during these periods, wind systems can deliver power up to their rated capacity.

Depending on the technical characteristics of utility electrical network and the point of interconnection, the intermittency of wind has the potential to cause small, brief (fraction of a second to seconds) variations in line voltage. Usually this potential for flicker has not been a practical problem due to the relatively small amount of wind capacity compared to that of the conventional capacity supplying the load. A typical rule of thumb in the utility industry is that the wind capacity should not exceed about 15% of the total system capacity. With this upper bound observed, temporal variations in the wind system electric power greater than a few seconds are comparable to the variations in the load and are routinely accommodated.

Even with the total installed capacity at 15% or greater, voltage variations induced by temporal variations of wind can be mitigated by interconnecting wind systems with the utility transmission-distribution system. While most large wind farms are interconnected at the transmission level, where voltages may be 230 kV or higher, the nature of the terrain and land-ownership patterns in the Northeast may result in clusters comprised of three to 10 wind turbines. This is the pattern for many installations in Europe. Such distributed wind systems typically are interconnected at the utility-distribution voltage level. The geographically distributed nature of the wind capacity with the correspondingly reduced electrical currents at any given interconnect point results in reduced potential for induced voltage variations. In some end-of-line situations, voltage support can be provided.

Operational Control and the Firming of Power from Wind Turbines and Wind Farms

As energy-storage systems evolve in capacity and inherent economics, their coupling with wind systems can compensate for wind power variations so that the combined system delivers a constant level of firm power. However, with rare exceptions, battery- and other energy-storage systems currently are not economically attractive enough to justify their incorporation with new wind installations. On the other hand, the integrated control of existing storage systems (particularly hydroelectric power) with wind systems offers the potential for firming the power from wind farms. Similarly, it may be attractive to implement integrated control of gas-fired combustion turbines and wind farms. It is important to note that energy-storage or firming power systems need not be co-located with wind systems. In general, modern wind turbines and wind farms have the capability for centralized control from a remote location (such as a utility's operations facility). Thus, assuming the wind is present, and in the absence of energy storage or firming sources, the delivered wind farm power level still may be levelized or adjusted downward to an intermediate value through the control of individual wind turbines or entire wind farms.

Manufacturing and Distribution Infrastructure

As noted, the technology of wind electricity-generating systems in the U.S. has evolved dramatically since the early 1980s. This increase has been driven by capacity and energy-production incentives designed to attract the large amounts of capital required for such capital-intensive generation systems. However, as the technology has matured, the lack of a stable U.S. market, combined with the lack of predictable and available incentives, has resulted in an industry that has evolved in a turbulent, uneven fashion. The result has been the bankruptcies of some U.S. manufacturers of wind equipment and the struggle for survival of others. Despite the difficult and unpredictable market environment, several strong wind turbine manufacturing and wind energy development companies have emerged. Examples include SeaWest Corp. headquartered in San Diego, California, and Nordex U.S., located in Grand Prairie, Texas. The Enron Wind Corporation, another U.S.-based manufacturer of utility-scale wind turbines, was recently acquired by General Electric Power Systems during the bankruptcy and subsequent restructuring of the Enron Corporation.

The market for wind energy in the U.S. is growing. Wind capacity added worldwide during 2001 was nearly 6,500 MW. Of this, 1,700 MW (or 26%) were added in the U.S. — a 32-fold increase over U.S. wind energy capacity added in 2000. This indicates a trend reversal in which the U.S. annual installed capacity has lagged European annual installed capacity. Still, at the end of 2001, the U.S accounted for 17% of worldwide installed capacity, and European installed capacity accounted for 72% of the worldwide total.[79]

Table 4.9.1 offers a partial listing of U.S.-based manufacturers of utility-scale wind turbines and wind energy developers, presented without any assessment or endorsement of their capabilities, market position, or product offerings.

European wind turbine manufacturers include Vestas, Nordex Energy, Bonus Energy and NEG Micon from Denmark; Enercon from Germany; Lagerwey from the Netherlands; Ecotecnia from Spain; and Turbowinds from Belgium.

Table 4.9.1 U.S.-Based Wind Turbine Manufacturers and Wind Energy Developers[80]

Company	Location	Role
Atlantic Renewable Energy Corporation	Richmond, Virginia	Wind energy developer, operator, and builder
CHI Energy	Stamford, Connecticut	Wind energy developer, operator, and builder
GE Wind Energy	Tehachapi, California	Manufacturer of 900 kW to 3.6 MW wind turbines
Mitsubishi Power Systems, Incorporated	Newport Beach, California	Manufacturer of 300 kW to 1 MW wind turbines
NEG Micon USA, Incorporated	Rolling Meadows, Illinois	Manufacturer and installer of 600 kW to 1.5 MW wind turbines
Nordex USA, Incorporated	Grand Prairie, Texas	Manufacturer of 600 kW 2.5 MW wind turbines
PG&E National Energy Group	Bethesda, Maryland	Wind energy developer
SeaWest Systems	San Diego, California	Wind energy developer and operator of wind farms
Tomen Power Corporation	San Diego, California	Wind farm builder and developer
Vestas-American Wind Technology, Incorporated	North Palm Springs, California	Manufacturer of 660 kW and 1.65 MW wind turbines

Table 4.9.2 presents a partial listing of U.S.-based small wind systems manufacturers.[81]

[79] Global Wind Energy Market Report by AWEA, 2002.

[80] Shown are U.S.-based manufacturers and developers of utility-scale wind turbines with significant experience in the wind energy industry and, in most cases, worldwide distribution channels.

[81] From the AWEA Web site: http://www.awea.org/faq/smsyslst.html.

Table 4.9.2 U.S.-Based Small Wind System Manufacturers[82]

Company	Location	Role
AEROMAX Corporation	Prescott Valley, Arizona	Manufacturer and distributor of a 1 kW wind turbine
Atlantic Orient Corporation	Norwich, Vermont	Manufacturer of 10 kW and 50 kW wind turbines
Bergey Windpower Corporation	Norman, Oklahoma	Manufacturer of 1 kW and 10 kW wind turbines
Northern Power Systems	Waitsfield, Vermont	Manufacturer of 3 kW and 100 kW wind turbines
Southwest Windpower	Flagstaff, Arizona	Manufacturer of 400 W to 3 kW wind turbines
WindTech International, L.L.C.	Katonah, New York	Manufacturer of small water-pumping wind systems
Wind Turbine Industries Corporation	Prior Lake, Minnesota	Manufacturer of 10kW to 20 kW wind turbines

The companies listed in Tables 4.9.1 and 4.9.2 represent U.S.-based manufacturers and developers with significant experience in the wind energy industry and, in most cases, worldwide distribution channels. Due to the increasingly attractive economics of wind energy and rising environmental concerns, the U.S. wind energy industry is in the midst of a substantial increase in market demand. A rapid increase in demand for new wind energy systems in the U.S. is resulting in substantial increases in wind energy manufacturing and service sectors nationwide. Potential increases in demand for wind energy systems in the State of New York should likely be able to be met by the ever-expanding national infrastructure.

The northeastern United States hosts several companies that support the wind energy industry through peripheral equipment, monitoring services, siting assistance, and consulting and analysis. In New York State, AWS Scientific Inc. provides engineering, monitoring, meteorological, and general contracting support to the wind energy industry. As a partner with TrueWind Solutions, LLC, AWS has assisted in the development of the New York State Wind Resource Map — a database and interactive map showing the State's wind resources. In Vermont, NRG Systems Inc. designs and manufactures wind energy resource-assessment systems used in wind energy applications worldwide.

Sales, Service, and Installation Infrastructure

Sales, service, and installation of utility-scale wind installations are typically conducted by a broad network of companies contracted by the primary developer and equipment manufacturer. Because wind manufacturers and developers typically expect to serve national (and even global) markets, most companies

[82] Shown are U.S.-based small wind system manufacturers with significant experience in the wind energy industry and, in most cases, worldwide distribution channels.

located outside of the northeastern U.S. are able to provide equipment, installation, training, and/or service in New York. If regional demand increases, these companies would likely hire local individuals and companies to provide equipment sales, service, and installation. As demand increases, major wind energy manufacturers often conduct local training programs specific to their installation, operations, and maintenance procedures.

The report Market Assessment for Small Wind Systems in New York State (2002) finds that there are roughly 15 to 20 dealers of small wind systems in New York and that most dealers sell several brands of wind turbines. [83] The majority of these businesses have been in the trade for 10 or fewer years, and dealers typically also serve as installers and equipment service people (or are able to subcontract this work for the customer). More than half of the identified businesses have experience with systems smaller than 10 kW. The report also notes that "should orders for small wind systems increase substantially in New York, dealers, installers, and service companies are likely to add staff and facilities to meet the demand. Because of the small, flexible nature of small wind systems and their infrastructures, businesses in this market are generally able to adapt quickly to fluctuations in demand. Also, due to relatively low start-up costs and equipment availability, new dealer businesses are likely to fill supply voids when demand cannot be met by established businesses."

Regulatory Permitting and Siting Issues

Potential Environmental Impacts. Wind electricity-generation systems have positive and potentially negative environmental impacts. Both are well-characterized; however, some are subjective and difficult to quantify. Potential negative impacts include the aesthetics of siting and the visual appearance of wind installations, noise, and bird interactions. While the visual aesthetics of a wind installation are subjective, there are differences in the type of tower, the number of blades, and paint color used. The principal types of towers include freestanding tubular and truss towers. A third type is a guyed, single-pole tower.

While wind farms occupy relatively large areas, the area actually required for the wind turbines and supporting infrastructure is 5% or less of the total land area on which the turbines are situated. Typically, the land can continue to be used for its original purposes. Land use for cluster or distributed generation wind systems is less critical due to the smaller parcels required. Land use for small, stand-alone wind systems is negligible.

Noise sources in early wind turbines included tones from the drive train machinery and nicks and other imperfections in the wind turbine blades. In recent designs, these noise sources have been reduced to insignificant levels. The principal remaining noise sources are associated with the intrinsic aerodynamic

[83] Market Assessment for Small Wind Systems in New York State, AWS Scientific Inc, 2002.

operation (vortex shedding) of the wind turbine blades and in some cases, with passage of the blade downwind of the tower. Generally, noise levels from modern wind turbine designs are consistent with local noise regulations and codes.

Collisions of birds with wind turbine blades have been widely studied since attention was given to this problem several years ago in large wind farm installations in northern California. The issue has been extensively addressed at the Searsburg Wind Power Facility, a 6 MW, 12-turbine project located in southern Vermont. The degree of avian interactions for wind installations in the northeastern U.S. depends on a number of factors that are site- and species-specific. These include the location and topography of the proposed wind turbine sites, the number of wind turbines, the types of birds, and the seasonal (as in flyway) or daily usage of the area by birds. NREL is working with environmental groups, utilities, government agencies, university researchers, consumer advocates, utility regulators, government officials, and the wind industry to address this issue.[84]

Along with some other renewable technologies, wind produces no particulates or greenhouse gases as a byproduct of electricity generation. Emissions offset by the use of renewable energy sources can be determined based on the mix of fossil fuel-based energy sources that would otherwise be utilized for electricity production. For example, according to an analysis conducted by Pacific Gas and Electric, in an average year, the total energy output for the 11.55 MW Madison Wind Power Plant offsets emissions of 12,078 tons of CO_2, 65 tons of SO_2, and 19 tons of NO_x — amounts based on average emissions from New York State power plants.[85]

Siting and Permitting. The most important factor when securing permits and other regulatory approvals is early public involvement and knowledge. Typical issues of concern include visual impacts, other land uses, noise impacts, and wildlife impacts. Dealing with these and other issues may involve many months (or years) and considerable cost. The degree of difficulty in siting and permitting depends on a number of objective and subjective factors. A major factor is the degree to which local citizens and advocacy groups are attuned to environmental concerns. A second factor is the degree to which local citizens are able to participate financially, either as an investment or through participation in a green-energy program.

To date the experience of receiving regulatory approvals and permits for wind energy installations in New York State has been mixed, though the State seems to host an increasingly favorable atmosphere for wind development. Approvals typically differ across technology lines. That is, state and local regulatory hurdles

---

84 From the NREL Web site: http://www.nrel.gov/wind/avian.html.

85 *Credit Trading and Wind Power: Issues and Opportunities* submitted by Kevin Rackstraw and John Palmisano, Econergy International Corporation, prepared for the National Wind Coordinating Committee, Washington, D.C., May 2002.

are different (though not necessarily higher or lower) for small wind installations, wind farms and clusters, and offshore installations. There is also considerable overlap in regulatory considerations between these technologies.

An important siting consideration for grid-connected wind installations is their proximity to existing transmission lines. Because installing new high-voltage transmission lines can cost thousands of dollars per mile, wind installation costs increase in proportion to the distance of an installation to an existing transmission line. For this reason, it is important to locate wind installations as close to existing transmission lines as possible. As noted above, there may be more numerous opportunities for cluster installations to interconnect with the grid because of their ability to interconnect at distribution-level voltages (e.g., 69 kV or less), rather than the higher transmission voltages (e.g., 230 kV) typically required by wind farms. In either case, access to adequate transmission capacity is critical to containing the cost of installing utility-scale wind facilities.

Permitting for Wind Farms and Clusters. Difficulties in the permitting process for land-based wind farm and cluster installations arise primarily from the unfamiliarity of regulatory bodies and the general public with wind energy and its impacts. Developing and Permitting the Madison Wind Power Project illustrates this fact through a comparison of the permitting process for two New York State wind installations: the proposed Ellenville project and the Madison Wind Power Plant.[86]

The Ellenville project represents one example of a casualty of the regulatory process. In 1985, plans for this proposed 40 MW facility collapsed due to a number of factors, including:

- the project location in the Shawangunk Mountains — a pristine and highly visible mountain ridge popular for it recreational resources;
- local political atmosphere, such as a Ellenville mayoral change and lack of county planning board support;
- a lack of local support, particularly among local recreational and environmental advocacy groups; and
- an economic model unacceptable to the New York State Public Service Commission

Although negotiations for this project were abandoned, it must be remembered that Ellenville represented the first major wind installation of its size in the Eastern U.S. and that the fully regulated electric industry of the mid-1980s did not create a favorable climate for independent projects of this type. Considering these facts – plus the high local concern for aesthetics, the site's unique ecosystem and prominent ridge top

[86] *Developing and Permitting the Madison Wind Power Project* by John P. Martin, Ph.D., New York State Energy Research and Development Authority, Albany, New York, presented paper at the AWEA Windpower 2001 conference.

location, a lack of state and local support, and a lack of a single agency able to assume a leadership role — in hindsight Ellenville appears to have been a project doomed from its inception.

Today, the regulatory climate of New York State is considerably more disposed toward wind development, with a movement toward restructured retail and wholesale electric markets. The State's environmental review is still in the form of the State Environmental Quality Review Act of 1978 (The State Environmental Quality Review Act [SEQRA]). SEQRA requires the environmental review of virtually all discretionary acts taken by state agencies and local governments in the State of New York. Thus, almost every unit of government in New York State must conduct a SEQRA review in conjunction with permits or approvals they are empowered to issue.

The relatively rapid approval of the Madison Wind Power Plant, an 11.55 MW installation located in Madison County, NY, stands in contrast to the difficulties encountered by the Ellenville project. Located near the town of Hamilton, the Madison Wind Power Plant project consists of seven 1.65 MW turbines located in an actively farmed field at the edge of the Allegany Plateau in central New York State. The project was developed by Pacific Gas and Electric's (PG&E) National Energy Group and co-funded by NYSERDA.

From the project's inception, NYSERDA assumed the lead role in ushering the installation through the regulatory process. Before the permitting process commenced, independent consulting firms and local advocacy groups conducted a series of environmental and cultural reviews in an attempt to anticipate siting issues. These reviews addressed concerns such as avian impact, noise, visual impact, and site-specific environmental concerns. Concurrently, meetings designed to manage stakeholder concerns were held between local Madison groups, PG&E, Atlantic Renewable Energy Corporation, and NYSERDA. During the summer of 1999, the permitting process and SEQRA review began. In December of 1999 NYSERDA issued a negative declaration under SEQRA (indicating a determination that the Madison project would not have any significant adverse environmental effects), thus averting the need for a lengthy environmental impact statement and ending the environmental review process. By January of 2000, the Federal Aviation Administration issued a lighting permit. In April of 2000, PG&E broke ground for the project, and the installation was on-line by September of 2000.

Two additional land-based installations followed closely behind the Madison project: a 6.6 MW project in Wethersfield, NY, went on-line in October 2000, and a 30 MW project in Fenner, NY, went on-line in December 2001. All three installations received funding support from New York's System Benefits Charge program established by the New York State Public Service Commission (PSC) in 1996 to fund public-policy initiatives not expected to be adequately addressed by competitive electric markets. This rapid succession of three successful wind energy projects reflects New York State's changing electric

market structure, a growing familiarity with the regulatory process on the part of developers and state agencies, an increasing willingness on the part of the public to consider living with these projects, and an informed and anticipatory project planning practices by all involved parties.

Federal authorities with potential jurisdiction over land-based wind installations include the U.S. Army Corps of Engineers and the Federal Aviation Administration. New York State approval or granting authorities include the Department of State, the Department of Environmental Conservation, the Public Service Commission, the Department of Agriculture, the Department of Transportation, and the Office of General Services. Land-based wind installations are also subject to local zoning review.

The New York Independent System Operator (NYISO), which operates and oversees the State's major transmission system and administers the wholesale market for electricity generation in New York State, currently imposes penalties on intermittent renewable generation sources that cumulatively represent more than 500 MW of capacity. As intermittent resources exceed 500 MW, these penalties may serve as a market barrier to utility-scale wind generation participating in NYISO's competitive markets. However, short-term forecasting of wind resources may serve to increase the predictability of wind power generation by aiding power-purchase planning and grid operations, and thereby create a rationale for reducing or removing these generation penalties. Because of the grid control and purchasing benefits associated with wind forecasting, some states, including California, are considering requiring wind installations above a certain size to conduct forecasting.

Permitting for Offshore Installations. "Long Island's Offshore Wind Energy Development Potential: A Preliminary Assessment" (2002) provides an excellent summary of regulatory and permitting issues relevant to New York State's offshore wind energy development.[87] The material is a condensation of a separate report entitled Offshore Development of Wind Energy Facilities: Jurisdictional and Regulatory Analysis (2001).[88] In summary, because no offshore wind farms have been built in the U.S., no clearly defined approval procedures exist as models for the permitting process. There are, however, several federal, state, and local bodies and reviews with potential jurisdiction over offshore facilities. Federal authorities with approval power may include the U.S. Army Corps of Engineers, the U.S. Coast Guard, and the Federal Aviation Administration. Other national reviews that may affect offshore facilities include:

- The National Environmental Policy Act of 1969
- The Coastal Zone Management Act of 1972
- The Clean Water Act of 1977

---

[87] Long Island's Offshore Wind Energy Development: A Preliminary Assessment, AWS Scientific Inc., 2002.

[88] *Offshore Development of Wind Energy Facilities: Jurisdictional and Regulatory Analysis* by Jeffrey M. Freedman, Atmospheric Information Services, Albany, New York, prepared for AWS Scientific Inc., Albany, New York, 2001.

- The Archaeological and Historic Preservation Act of 1974
- Fish and Wildlife Coordination Act of 1958
- Endangered Species Act of 1973
- The Estuary Protection Act

New York State approval or granting authorities include the Department of State, the Department of Environmental Conservation, the Public Service Commission, and the Office of General Services. Other relevant state authorities, regulations, permits, and approvals include:

- The Waterfront Revitalization of Coastal Areas and Inland Waterways Act
- The Tidal Wetlands Act
- The Protection of Waters Program
- The Coastal Erosion Hazard Areas
- Grants of Lands Underwater
- The New York State Public Authorities Control Board
- Environmental Compatibility and Public Need for Major Electric Generating Facilities
- Environmental Compatibility and Public Need for Electric and Gas Transmission Facilities
- The State Environmental Quality Review Act (SEQRA)

Long Island's Offshore Wind Energy Development Potential. "Long Island's Offshore Wind Energy Development Potential: A Preliminary Assessment" (2002) also indicates that wind installations located within borders of New York municipalities are subject to local zoning ordinances. In Long Island, this may include offshore installations, as town and county boundaries often extend to the State border. Governing bodies with jurisdiction over such installations are classified as "involved agencies" under SEQRA. Any local agency or member of the public, regardless of approval powers, may be permitted to participate in SEQRA approval processes.

Permitting for Small Wind Installations. "Market Assessment for Small Wind Systems in New York State" (2002) outlines permitting considerations for small wind systems in the State.[89] The report states that small wind systems require compliance with local zoning laws before installation. However, zoning ordinances in most State municipalities do not include wind systems as a permitted use, and relatively few precedents for wind systems exist as zoning models. As a result, owners of these systems must often obtain zoning variances before these systems are installed. Complicating matters, review boards and the general public are generally unfamiliar with wind systems, requiring careful attention to each objection raised during the permit review process.

Concerns often raised during review processes include height restrictions, aesthetic impact, noise, influence on surrounding property values, safety (e.g., falling towers, lighting strikes, ice shedding), avian collisions, and interference with television reception and cell-phone communication. Regardless of the validity of each of these concerns, system owners should carefully address each of these concerns unless there are preexisting zoning laws allowing wind systems. Even if existing zoning regulations allow wind systems, approval of individual systems is not necessarily assured. For example, there has been some difficulty obtaining approval for wind systems in specific Long Island townships where wind systems exist as a permitted use.

To increase the likelihood of zoning approval, this study recommends that system owners preemptively address common zoning hurdles. Suggested steps include:

- Site the wind turbine at a distance from adjacent property lines equal to or greater than the height of the turbine (i.e., tower height plus blade length);
- Locate the wind turbine no closer than 300 feet from adjacent residences so as to minimize noise impact;
- Select a wind turbine with low noise emission;
- Install climbing barriers on turbine towers; and
- Establish open relationships with surrounding property owners and assess the concerns of neighbors before initiating the zoning approval process

TECHNICAL POTENTIAL

This assessment considers the technical potential of wind energy in New York State and near its shores. The study considers four different wind energy technologies and configurations: wind farm installations, cluster installations, small wind installations, and offshore installations. For purposes of the assessment, technical potential is defined as the upper limit for renewable electricity capacity and output theoretically possible from the wind resource base within New York State, without regard to cost, market barriers, or market acceptability. Grid-penetration limitations are also not considered in the technical potential calculations.

Also considered in this study are the energy coincidence factors and capacity coincidence factors associated with wind energy in New York State. For the purposes of this assessment,energy coincidence factors are defined as the percentage of annual energy output by wind energy sources during six identified time periods. Capacity coincidence factors are defined as the average percentage of installed capacity output expected to be available during two identified time periods.

[89] Market Assessment for Small Wind Systems in New York State, AWS Scientific Inc, 2002.

New York State's wind resource base is comprised of all the wind that occurs within the State's borders and near its ocean and Great Lakes shores. For utility-scale wind turbines, wind speeds measured at 65m above ground level are the best indicator of wind electric potential. This is true for wind farms, clusters, and offshore applications. For small wind applications, wind speeds measured at 30m above ground level are the best indicator of wind electric potential.

Wind is an intermittent but predictable resource. Good wind resource data is critical to determining the feasibility of any wind installation. The nature of the wind resource is such that there are seasonal and diurnal variations in mean wind speed, resulting in variations in energy produced from the wind. In New York State, where winds are generally associated with storm fronts, highest mean wind speeds typically occur in the winter months (November to April), and the lowest occur during the summer (June to July). In many locations in the State, maximum wind speeds occur during early afternoon hours, and minimum wind speeds occur in evening and morning hours, although this behavior varies extensively by location. Mean wind speed (and seasonal and diurnal variations in wind speed) imposes a practical upper limit on the amount of energy that may be produced from the wind.

Several physical, technical, environmental, and sociological factors serve to constrain the full exploitation of the wind's energy. Listed below are the major constraints considered in this study's development of technical potential values:

- Land-use constraints and land-use patterns
- Surface topography
- Offshore conditions
- Infrastructure constraints
- Environmental constraints
- Wind turbine capacity factor
- Wind turbine availability
- Grid availability

Land-use constraints and land-use patterns indicate land that is otherwise utilized and unavailable (or unsuitable) for wind energy development. Constrained land can include state parks or other protected areas, densely developed areas, or agricultural applications not suited to wind energy development.

Surface topography indicates natural land geography that renders land unsuitable for wind energy development. For example, waterways, ravines, leeward hillsides, and other natural features are areas where wind energy development is unlikely to be appropriate for both performance-related and economic reasons.

Offshore conditions indicate constraints that apply to offshore wind energy development. These include water depth and ice-loading conditions. Current construction technology for offshore wind systems is economically limited to water depths of 50 feet or less. Within the next five to 10 years, seabed-construction technologies are expected to achieve successful foundations in water depths of up to 100 feet.[90] In fresh water, significant ice loading can require specialized wind turbine footings and lessen the economic attractiveness of offshore installation economics. Significant wave loading can pose a similar constraint.

For the purposes of developing installed capacity potential values, infrastructure constraints indicate limitations in electric power transmission capacity or accessibility. Other infrastructure considerations that may influence the future of wind energy development are transportation, manufacturing, and service infrastructures.

Environmental constraints indicate the environmental impacts of wind energy development. These include land-use impacts, aesthetics, potential for aviary collisions, noise, and communication interference.

Wind turbine capacity factor, as described earlier, is a measure of wind turbine productivity. This ratio compares a wind turbine's actual energy production over a given period of time with the amount of energy the wind turbine would have produced if it had run at its full rated power capacity for the same amount of time. Capacity factor is expressed as a percentage or fraction. Most modern utility-scale wind turbines operate with a capacity factor of 25% to 40%, depending on the wind resource.[91]

Wind turbine availability is a measure of the reliability of a wind turbine. It refers to the percentage of time that a machine is ready to generate (that is, not out of service for maintenance or repairs). Modern wind turbines have an availability of 96% to 98%, depending on the installation configuration. For example, large wind farms will likely have a well-developed on-site operations and maintenance structure, which can help reduce mean repair times and increase machine availability.

Grid availability is a measure of the availability of the electrical transmission grid. The transmission grid must be operational in order for grid-connected wind turbines to operate and deliver energy. On an annual basis, most transmission grids have an availability of 99% or greater.

---

[90] Long Island's Offshore Wind Energy Development: A Preliminary Assessment, AWS Scientific Inc., 2002.
[91] The Most Frequently Asked Questions About Wind Energy, AWEA.

Previous estimates of New York State's wind electric potential range from 5,000 MW to 55,000 MW.[92] These estimates are based on a statewide resource database developed by collecting and analyzing information for a two-year period within selected attractive areas identified by an earlier Geographic Information System study. The purpose of this study was to screen the state in an attempt to identify areas possessing the necessary qualities for wind energy development. Any limitations in technical potential are not due to the state of the technology; wind turbines have reached a state of technological maturity and are nearly economically competitive with fossil-fueled generation sources, including gas-fired combustion turbines.[93] The present study refines these estimates based on the constraints described above.

Wind Farm Installations Technical Potential

For purposes of this study, wind farms are defined as installations utilizing wind turbines rated at 600 kW to 1.5 MW output per machine configured in arrays of 10 to 50 machines. Hub heights for these utility-scale machines range from 30m to 75m.

Table 4.9.3 shows the installed capacity technical potential for wind farms located in New York State on a statewide and load zone basis. The methodology for determining the values in the table is described below.

Table 4.9.3 Wind Farm Capacity Technical Potential in New York State[94]

	Wind Farm Installed Capacity Technical Potential (kW)			
Load Zone	**2003**	**2007**	**2012**	**2022**
Statewide	114,000	523,000	1,050,000	4,225,000
Zone A: West	49,020	224,890	451,500	1,816,750
Zone F: Capitol	570	2,615	5,250	21,125
Zone G: Hudson Valley	0	0	0	0
Zone J: NYC	0	0	0	0
Zone K: Long Island	8,778	40,271	80,850	325,325

Table 4.9.4 shows the annual energy generation technical potential for wind farms located in New York State on a statewide and load zone basis. The methodology for determining the values in the table is described below.

---

92 Wind Power Potential in New York State by Bruce H. Bailey and Michael J. Markus, AWS Scientific Inc., Albany, New York for the Empire State Electric Research Corporation, 1996.

93 Comparative Cost of Wind and Other Energy Sources, AWEA, Washington, D.C., 2001.

94 Installed capacity technical potential values are based on land available for wind farm development and anticipated increases in utility-scale wind turbine sizes over the coming decades. Technical potential for wind resources reported in the Volume 4 includes wind development expected in the base case scenario. The incremental development (above base case)of wind resources is reported in Volumes 1, 2, and 6.

Table 4.9.4 Wind Farm Generation Technical Potential in New York State[95]

	Wind Farm Annual Energy Generation Technical Potential (GWh/yr)			
Load Zone	**2003**	**2007**	**2012**	**2022**
Statewide	300	1,377	2,766	11,131
Zone A: West	129	592	1,189	4,786
Zone F: Capitol	1.5	6.8	13.8	55.6
Zone G: Hudson Valley	0	0	0	0
Zone J: NYC	0	0	0	0
Zone K: Long Island	23.1	106	213	857

Table 4.9.5 shows the energy coincidence factors for wind farms located in New York State. Wind farm energy coincidence factors are assumed to be approximately equivalent across the State and are therefore presented only on a statewide basis. Energy coincidence periods and the methodology for determining the values in Table 4.9.5 are described below.

Table 4.9.5 Energy Coincidence Factors for Wind Farm Installations in New York State[96]

	Wind Farm Energy Coincidence Factors (% of Annual Energy Output)					
Load Zone	Summer On-Peak	Summer Off-Peak	Summer Shoulder	Winter On-Peak	Winter Off-Peak	Winter Shoulder
Statewide	7	12	9	21	27	24

Table 4.9.6 shows the capacity coincidence factors for wind farms located in the State. Wind farm capacity coincidence factors are assumed to be approximately equivalent across the State and are therefore presented only on a statewide basis. Capacity coincidence periods and the methodology for determining the values in Table 4.9.6 are described below.

95 Annual wind farm energy generation technical potential is calculated from the installed capacity technical potential using a wind turbine capacity factor of 31%, a machine availability factor of 98%, and a grid availability factor of 99%.

96 Statewide energy coincidence factors are estimated using values measured at nine sites around the state and provide an approximate reflection of daily and seasonal variations in wind speed. However, wind speed profiles are extremely site-specific and may vary significantly between locations. It is therefore unadvisable to utilize this data as a tool for forecasting wind energy production.

Table 4.9.6 Capacity Coincidence Factors for Wind Farm Installations in New York State[97]

Load Zone	Wind Farm Capacity Coincidence Factors (% of Maximum Energy Output)	
	Summer Generation Capacity	Winter Generation Capacity
Statewide	19	45

Calculation Methodology for Wind Farm Technical Potential

The conservative estimate for statewide installed onshore utility-scale wind energy capacity provided in Wind Power Potential in New York State is 5,000 MW.[98] This 1996 value is based on a calculated 338,630 acres of land available for utility-scale wind energy development. The conversion from developable acreage to installed capacity is based on the assumption of 66 acres required per MW — a value derived from the use of 300 kW wind turbines and associated machine spacing.

Today, the average-sized machine installed on wind farms in the U.S. is 1 MW. In New York, the predominant machine installed on wind farms is 1.5 MW. In wind installations at-large, individual turbines are typically spaced five rotor diameters apart, and rows of turbines are spaced seven to 10 rotor diameters apart, depending strongly on topography and predominant wind direction. On this basis, wind farm land-usage would be reduced to approximately 40 acres required per MW (or 16 MW per square mile). Based on this value and the stated land availability, there are currently 8,465 MW of potential onshore installed capacity within New York State.

However, the average wind farm machine is increasing in size and power rating, particularly in land-restricted areas such as the northeastern United States. European wind farms are also beginning to utilize machines rated at 2 MW due to limited land availability. Because of the relatively open spaces within the U.S., this country has been slower to utilize these larger machines. However, as development occurs closer to land-constrained population centers, it is expected that by 2012 the average U.S. wind farm machine installed will be 1.5 MW, and by 2022 the average machine will be 2 MW or larger.[99] As the average machine size increases, land-usage per MW decreases accordingly, due to the relationship between the

---

[97] Statewide capacity coincidence factors are calculated using values measured at nine sites around the state and provide an approximate reflection of seasonal variations in wind speed. However, wind speed profiles are extremely site-specific and may vary significantly between locations. It is therefore unadvisable to utilize this data as a tool for forecasting wind energy production.

[98] Wind Power Potential in New York State, AWS Scientific Inc., 1996.

[99] The increase in average utility-scale wind turbine size over time is based on the assumptions that 1) public resistance to larger machines is no greater than for smaller machines, and 2) transportation infrastructures (road, sea, rail, and air) and policies allow for the movement of equipment of this size.

machine's power rating and the rotor diameter.[100] By the year 2022, as wind farm machines approach 2 MW, land-use requirements will approach 20 acres required per MW, depending on installation configuration. Given the 338,630 acres of land available for wind energy development in New York State, this will result in a statewide utility-scale technical potential of 16,900 MW by the year 2022. This value represents an upper limit of onshore installed utility-scale wind turbine capacity, given the predicted machine size and land-use requirements.

Because cluster and wind farm installations are likely to occur in similar geographic locations (i.e., ridge tops, large agricultural tracts, shorelines, etc.), the installed capacity technical potential for clusters and wind farms should be considered as a single value. In other words, as a statewide whole in 2022, land in the State available for utility-scale wind development will be divided between wind farm and cluster developments. As described above, New York State's largely land-constrained nature (i.e., aggregated parcels of developed land, divided agricultural tracts, state parks, etc.) favors greater numbers of cluster installations and fewer large wind farms. The projected ratio of clusters to wind farms is estimated to be three to one – i.e., for every four installed megawatts, three will be in a cluster installation, and one will be in a wind farm installation. The 2022 wind farm installed capacity potential is therefore calculated to be 25% of the statewide utility-scale technical potential (16,900 MW) to yield a wind farm installed capacity potential of 4,225 MW. This is the equivalent of 84 50-MW wind farms installed by 2022.

Additional statewide and specific load zone installed capacity-potential values are calculated as follows:

New York State wind farm installations on-line as of early 2003 are the Madison Wind Power Plant (11.55 MW) and the Fenner Wind Power Plant (30 MW). Construction of a 240 MW Tug Hill/Flat Rock installation is anticipated to begin during the fall of 2003. Without regard to cost, market barriers, or market acceptability, the study estimates there is technical potential for 114 MW in the State by the end of 2003. This technical potential value allows for the time required for permitting, installation, and commissioning of utility-scale facilities. It should be noted that any additional wind energy capacity installed in 2003 and beyond depends heavily on an extension of the federal renewable energy production tax credit, which is set to expire after December 31, 2003.

By the end of 2007, the study estimates there is technical potential for 523 MW of wind farm capacity in New York State, based on wind resources, land availability, and favorable commissioning processes.

---

[100] The power P_W intercepted by the wind turbine rotor is proportional to the cube of the wind speed V and the square of the rotor diameter D, as expressed in the relationship:

$$P_W = \frac{1}{2}\rho V^3 A = \frac{\pi}{8}\rho V^3 D^2 \qquad (Watts)$$

where ρ is the mass density of the atmosphere and A is swept area of the rotor.

Applying an installed-capacity annual growth rate of 15% after 2007 (compared to an annual U.S. installed capacity growth rate of 40% during the 1990s[101]) to this value yields statewide wind farm technical potential installed capacities of 1,050 MW in 2012, and 4,225 MW in 2022.

Wind farm installed capacity values in specific load zones are calculated using land availability data provided by the National Resources Conservation Service (NRCS) of the U.S. Department of Agriculture. For example, Load Zone A: West has 145,031 acres open to wind development (43% of the statewide total of 338,630 acres), Load Zone F: Capitol has 1,890 acres open to development (.5%), and Load Zone K: Long Island has 26,171 acres (7.7%). Load Zone G: Hudson Valley and Load Zone J: New York City offer no suitable land for utility-scale wind development.

In Load Zone K: Long Island, the northern and southern forks of eastern Long Island have an attractive wind resource, especially near the shore. However, land-use and environmental concerns pose potential barriers to development in these areas.[102] Also, transmission constraints may limit the projected 325 MW of installed capacity by 2022, as much of the LIPA transmission system is currently fully utilized and congested.[103] However, given the benefits of advanced planning for infrastructure upgrades, this constraint is likely to be overcome so that the full 325 MW can be installed and utilized, assuming land-use and environmental concerns can be surmounted.

Annual energy-generation technical potential is calculated from the installed capacity technical potential using a wind turbine capacity factor of 31%, a machine availability factor of 98%, and a grid availability factor of 99%.

For all technologies considered in the present study, energy coincidence factors indicate the percentage of annual wind turbine energy output that coincides with defined utility energy demand periods. Energy coincidence periods are defined in Table 4.9.7.

---

[101] From AWEA Web sites: http://www.awea.org/faq/instcap.html and http://www.awea.org/news/news991005st.html.

[102] Wind Power Potential in New York State, AWS Scientific Inc., 1996.

[103] Long Island's Offshore Wind Energy Development: A Preliminary Assessment, AWS Scientific Inc., 2002.

Table 4.9.7 Energy Coincidence Periods[104]

Energy Coincidence Period	Months	Time Period
Summer On-Peak	June – August	Weekdays, 12:00 p.m. – 6:00 p.m.
Summer Off-Peak	June – August	Weekdays, 12:00 a.m. – 8:00 a.m.
		Weekends, 12:00 a.m. – 12:00 a.m.
	May, September, October	All days, 12:00 a.m. – 12:00 a.m.
Summer Shoulder	June – August	Weekdays, 8:00 a.m. – 12:00 p.m.
		Weekdays, 6:00 p.m. – 12:00 a.m.
Winter On-Peak	December – February	Weekdays, 12:00 p.m. – 8:00 p.m.
Winter Off-Peak	December – February	Weekdays, 12:00 a.m. – 8:00 a.m.
		Weekends, 12:00 a.m. – 12:00 a.m.
		Christmas, 12:00 a.m. – 12:00 a.m.
	March, April, November	All days, 12:00 a.m. – 12:00 a.m.
Winter Shoulder	December – February	Weekdays, 8:00 a.m. – 12:00 p.m.
		Weekdays, 12:00 p.m. – 12:00 a.m.

Capacity coincidence factors indicate wind turbine energy output during seasonal peak periods as a percentage of the maximum theoretical energy output during the same period. Seasonal peak periods are defined in Table 4.9.8.

Table 4.9.8 Capacity Coincidence Periods[105]

Capacity Coincidence Period	Months	Time Period
Summer Capacity On-Peak	June – August	Weekdays, 12:00 p.m. – 6:00 p.m.
Winter Capacity On-Peak	December – February	Weekdays, 12:00 p.m. – 8:00 p.m.

Statewide energy coincidence and capacity coincidence factors are calculated using values measured at nine sites around the state. Seven of these sites are representative of four areas of the State where suitable wind resources are expected to be available: ridge tops east of Lake Erie, the higher elevations of the Tug Hill Plateau to the east of Lake Ontario, mountaintops west of the Catskill Park, and extreme eastern Long Island.[106] In mountaintop locations (where wind farms may well be located), the data indicate that an off-peak maximum wind speed is typical. Data from these locations also indicate that the highest mean wind speeds occur in the November to April timeframe. The report indicates that in New York State's low-lying, simple terrain, maximum wind speeds typically occur during on-peak time periods.

---

[104] Energy coincidence periods were provided in accordance with a framework defined by the New York State Energy and Research Development Authority and other organizations.

[105] Capacity coincidence periods were provided in accordance with a framework defined by the New York State Energy and Research Development Authority and other organizations.

[106] Wind Power Potential in New York State, AWS Scientific Inc., 1996.

Cluster Installations Technical Potential

For purposes of this study, clusters are defined as installations utilizing wind turbines rated at 600 kW to 1.5 MW output per machine configured in arrays of two to 10 machines. Hub heights of these utility-scale machines range from 30m to 75m.

Table 4.9.9 shows the installed capacity technical potential for cluster installations located in New York State on a statewide and load zone basis. The methodology for determining the values in this table is described below.

Table 4.9.9 Wind Cluster Capacity Technical Potential in New York State[107]

	kW			
Load Zone	**2003**	**2007**	**2012**	**2022**
Statewide	22,000	60,000	208,000	2,535,000
Zone A: West	9,460	25,800	89,440	1,090,050
Zone F: Capitol	110	300	1,040	12,675
Zone G: Hudson Valley	0	0	0	0
Zone J: NYC	0	0	0	0
Zone K: Long Island	1,694	4,620	16,016	195,195

Table 4.9.10 shows the annual energy generation technical potential for cluster installations located in New York State on a statewide and load zone basis. The methodology for determining the values in Table 4.9.10 is described below.

Table 4.9.10 Wind Cluster Generation Technical Potential in New York State[108]

	GWh/yr			
Load Zone	**2003**	**2007**	**2012**	**2022**
Statewide	57.4	156.5	542.4	6,610.7
Zone A: West	24.7	67.3	233.2	2,842.6
Zone F: Capitol	0.3	0.8	2.7	33.1
Zone G: Hudson Valley	0	0	0	0
Zone J: NYC	0	0	0	0
Zone K: Long Island	4.4	12.0	41.8	509.0

[107] Installed capacity technical potential values are based on land available for cluster development and anticipated increases in utility-scale wind turbine sizes over the coming decades.

[108] Annual energy generation technical potential for cluster installations is calculated from the installed capacity technical potential using a wind turbine capacity factor of 31%, a machine availability factor of 97%, and a grid availability factor of 99%.

Table 4.9.11 shows the energy coincidence factors for cluster installations located in New York State. Cluster energy coincidence factors are assumed to be approximately equivalent across New York and are therefore presented only on a statewide basis. Energy coincidence periods are defined in Table 4.9.7.

Table 4.9.11 Wind Cluster Energy Coincidence Factors in New York State[109]

	% of Annual Energy Output					
Load Zone	**Summer On-Peak**	**Summer Off-Peak**	**Summer Shoulder**	**Winter On-Peak**	**Winter Off-Peak**	**Winter Shoulder**
Statewide	7	12	9	21	27	24

Table 4.9.12 shows the capacity coincidence factors for cluster installations located in New York State. Cluster capacity coincidence factors are assumed to be approximately equivalent across the State and are therefore presented only on a statewide basis. Capacity coincidence periods are defined in Table 4.9.8.

Table 4.9.12 Wind Cluster Capacity Coincidence Factors in New York State[110]

	% of Maximum Energy Output	
Load Zone	**Summer Generation Capacity**	**Winter Generation Capacity**
Statewide	19	45

Calculation Methodology for Cluster Technical Potential

Because machine size and land-use patterns are similar for cluster installations and wind farm installations, the general methodology used for determining the technical potential of cluster installations is similar to that of wind farms. That is, suitable acreage statewide and in each specific load zone is used to calculate a total installed capacity technical potential and predicted increases in average machine size over time.

Clusters are a form of distributed power generation (rather than bulk power generation, as in the case of wind farms) and, by nature of their business and cooperative ownership models, comprise fewer machines per installation than wind farms. As a result, there will be a lower area density of wind turbines on New York State's land available for utility-scale wind energy development should it be populated with clusters

[109] Statewide energy coincidence factors are estimated using values measured at nine sites around the state and provide an approximate reflection of daily and seasonal variations in wind speed. However, wind speed profiles are extremely site-specific and may vary significantly between locations. It is therefore inadvisable to utilize this data as a tool for forecasting wind energy production.

rather than wind farms. This area's density reduction ranges from 60% to 90%. Cluster technical potential values have therefore been calculated by reducing utility-scale technical potential values by 80%. The 2022 cluster installed capacity potential is therefore calculated to be 75% of the statewide utility-scale technical potential of 16,900 MW, and reduced again by 80% to account for the lower area density of cluster installations. These calculations yield a statewide cluster technical potential of 2,535 MW. This is the equivalent of 253 10 MW cluster installations and represents an upper limit of installed cluster capacity by 2022, given the predicted machine size and land-use requirements.

The 6.6 MW Wethersfield Wind Power Plant is the only New York State cluster installation on-line as of early 2003. Without regard to cost, market barriers, or market acceptability, the study estimates there is technical potential for 22 MW of cluster capacity in the State of New York by the end of 2003. This value allows for the time required for permitting, installation, and commissioning of cluster facilities. Applying an installed capacity annual growth rate of 28% (compared to an annual U.S. installed capacity growth rate of 40% during the 1990s[111]) to this value yields statewide cluster technical potential installed capacities of 60 MW in 2007, 208 MW in 2012, and 2,535 MW in 2022.

As with wind farm calculations, cluster installed capacity values in specific load zones are calculated using land availability data provided by the NRCS.

Annual energy generation technical potential for cluster installations is calculated from the installed capacity technical potential using a wind turbine capacity factor of 31%, a machine availability factor of 97%, and a grid availability factor of 99%.

Because clusters use machines similar in size to that of wind farms, and occur in similar geographic locations, statewide energy coincidence and capacity coincidence factors are identical to those of wind farm installations.

Small Wind Installations Technical Potential

For purposes of this study, small wind installations are defined as those utilizing stand-alone wind turbines rated at 1 kW to 300 kW output per machine. Hub heights of these stand-alone machines range from 25m to 30m.

---

[110] Statewide capacity coincidence factors are calculated using values measured at nine sites around the state and provide an approximate reflection of seasonal variations in wind speed. However, wind speed profiles are extremely site-specific and may vary significantly between locations. It is therefore inadvisable to utilize this data as a tool for forecasting wind energy production.

Table 4.9.13 shows the installed capacity technical potential for small wind installations located in New York State on a statewide and load zone basis. The methodology for determining the values in Table 4.9.13 is described below.

Table 4.9.13 Small Wind Installations Technical Potential in New York State — Capacity [112]

	KW			
Load Zone	**2003**	**2007**	**2012**	**2022**
Statewide	3,000	43,000	93,000	225,400
Zone A: West	913	13,084	28,299	68,586
Zone F: Capitol	274	3,924	8,488	20,571
Zone G: Hudson Valley	148	2,126	4,598	11,144
Zone J: NYC	161	2,304	4,983	12,078
Zone K: Long Island	574	8,220	17,779	43,090

Table 4.9.14 shows the annual energy generation technical potential for small wind installations located in New York State on a statewide and load zone basis. The methodology for determining the values in Table 4.9.14 is described below.

Table 4.9.14 Small Wind Installations Technical Potential in New York State — Generation[113]

	GWh/yr			
Load Zone	**2003**	**2007**	**2012**	**2022**
Statewide	3.7	53.1	114.9	278.6
Zone A: West	1.1	16.2	35.0	84.8
Zone F: Capitol	0.3	4.8	10.5	25.4
Zone G: Hudson Valley	0.2	2.6	5.7	13.8
Zone J: NYC	0.2	2.8	6.2	14.9
Zone K: Long Island	0.7	10.2	22.0	53.2

Table 4.9.15 shows the energy coincidence factors for small wind installations located in New York State. Small wind energy coincidence factors are assumed to be approximately equivalent across the State and are therefore presented only on a statewide basis. Energy coincidence periods are defined in Table 4.9.7.

---

[111] From AWEA Web sites: http://www.awea.org/faq/instcap.html and http://www.awea.org/news/news991005st.html.

[112] Installed capacity technical potential values are based on land available for small wind development and a development rate of 10 MW per year after 2003.

Table 4.9.15 Small Wind Installations Energy Coincidence Factors in New York State[114]

	% of Annual Energy Output					
Load Zone	**Summer On-Peak**	**Summer Off-Peak**	**Summer Shoulder**	**Winter On-Peak**	**Winter Off-Peak**	**Winter Shoulder**
Statewide	13	5	11	26	20	25

Table 4.9.16 shows the capacity coincidence factors for small wind installations located in New York State. Small wind capacity coincidence factors are assumed to be approximately equivalent across the State and are therefore presented only on a statewide basis. Capacity coincidence periods are defined in Table 4.9.8.

Table 4.9.16 Small Wind Installations Capacity Coincidence Factors in New York State[115]

	% of Maximum Energy Output	
Load Zone	**Summer Generation Capacity**	**Winter Generation Capacity**
Statewide	10	19

Calculation Methodology for Small Wind Technical Potential

New York State small wind installed-capacity technical potential has recently been estimated at 225.4 MW.[116] This estimate is derived from state land-use patterns provided by the NRCS and a detailed New York State wind resource database.

The primary applications for small wind systems are private residences, farms, and small commercial interests. Given that the electrical load requirements of these applications remains relatively fixed over time, small wind systems are not expected to increase in average size within the next 20 years. As a result, 225 MW represents an upper limit of installed small wind capacity by 2022.

For 2003, a technical potential of 3 MW of small wind is estimated on a statewide basis. This value is based on figures provided by NYSERDA, LIPA, and small wind manufacturers, and includes installations

113 Annual energy generation technical potential for small wind systems is calculated from the installed capacity technical potential using a wind turbine capacity factor of 15% and a machine availability of 95%.

114 Statewide energy coincidence factors are estimated using values measured at nine sites around the state and provide an approximate reflection of daily and seasonal variations in wind speed. However, wind speed profiles are extremely site-specific and may vary significantly between locations. It is therefore inadvisable to utilize this data as a tool for forecasting wind energy production.

115 Statewide capacity coincidence factors are calculated using values measured at nine sites around the state and provide an approximate reflection of seasonal variations in wind speed. However, wind speed profiles are extremely site-specific and may vary significantly between locations. It is therefore inadvisable to utilize this data as a tool for forecasting wind energy production.

planned in NYSERDA's wind energy cost-sharing initiative.[117] For 2007, 2012 and 2022, a statewide development rate of 10 MW per year is assumed.

In the case of individual load zones, land-use patterns are determined from NRCS data and adjusted according to an assumed land availability for small wind development, as shown in Table 4.9.17. The values in Table 4.9.17 were developed in the report Market Assessment for Small Wind Systems in New York State (2002).[118]

Table 4.9.17 Land Available for Small Wind Energy Development in New York State

Land-Use Type	Land Available for Small Wind Development(millions of acres)	Percent Land Available for Small Wind Development(%)
Agricultural	7.9	70
State-owned	3.9	1
Developed	3.3	10
Forest	15.1	1

Wind resource data is determined from the New York State Wind Resource Map database provided by AWS Scientific Inc. According to this database, more than half of the state's land area (excluding the Adirondack and Catskill State Parks) is estimated to have a 5m/s or greater wind resource at 30m above the ground — a minimum resource recommended for small turbine applications.[119] Table 4.9.18 shows the percentage of land with wind resources sufficient for small turbine applications on a statewide and individual load zone basis.

Wind-resource data is combined with land-use data, and an installed capacity potential is calculated according to the assumptions that the average-sized small turbine is rated at 10 kW and that one turbine is installed on every 200 acres (the average farm size) on non-developed land. For developed land, it is assumed that one turbine is installed on every 10 acres.[120] Table 4.9.18 also shows the installed capacity potential in megawatts and the potential number of installed turbines on a statewide and individual load zone basis.

---

116 Market Assessment for Small Wind Systems in New York State, AWS Scientific Inc, 2002.
117 Cost-Sharing Opportunity for Wind Energy Systems by AWS Scientific Inc., 2001.
118 Market Assessment for Small Wind Systems in New York State, AWS Scientific Inc, 2002.
119 Ibid.
120 Ibid.

Table 4.9.18 Potential Installed Capacity of Small Wind Systems in New York State[121]

Location	Land with mean wind speed ≥ 5m/s at 30m above ground level (%)	Installed Capacity Potential (MW)	Number of turbines
Statewide	50	225.4	22,540
Load Zone A: West	77	68.6	6,860
Load Zone F: Capitol	29	20.6	2,060
Load Zone G: Hudson Valley	23	11.1	1,010
Load Zone J: NYC	68	12.1	1,210
Load Zone K: Long Island	92	43.1	4,310

The analysis of AWS Scientific Inc. reveals that more than 22,000 small wind turbines could theoretically be installed on 9.7% of New York State's land area — 61% on agricultural land and 37% on developed land.[122] Because small wind turbines typically occupy geographic locations and wind regimes different from that of utility-scale machines, the figure of 225 MW can be considered to be in addition to the installed capacity technical potential for wind farms, clusters, and offshore installations.

Capacity factors for small wind systems fall in the range of 8% to 25%, depending on wind conditions.[123] Annual energy-generation technical potential for small wind systems is calculated from the installed capacity technical potential using a wind turbine capacity factor of 15%. Most small wind turbines are relatively reliable but are not likely have a dedicated O&M structure. For this reason, machine availability is assumed to be 95%.

Small wind systems are divided between on-grid and off-grid applications. Transmission grid availability is therefore considered a factor in determining small wind energy generation technical potential, and is estimated to be 99%.

Statewide energy coincidence and capacity coincidence factors are calculated using values measured at various sites around the State in low-lying, open areas and shoreline locations. Data from these sites indicate that maximum wind speeds occur during early afternoon hours and the highest mean wind speeds occur in the November to April timeframe.[124]

---

121 Shown is the percentage of land with wind resources sufficient for small turbine applications and installed capacity potential on a statewide and individual load zone basis. Wind resource data is determined from the New York State Wind Resource Map database provided by AWS Scientific Inc.

122 Market Assessment for Small Wind Systems in New York State, AWS Scientific Inc, 2002.

123 Ibid.

124 Wind Power Potential in New York State, AWS Scientific Inc., 1996.

Offshore Installations Technical Potential

For purposes of this study, offshore wind is defined as installations utilizing wind turbines rated at 1 MW to 3 MW output per machine configured in arrays of one to 20 machines. Hub heights of these utility-scale machines range from 40m to 85m.

Table 4.9.19 shows the installed capacity technical potential for offshore installations located in New York State on a statewide and load zone basis. The methodology for determining the values in Table 4.9.19 is described below.

Table 4.9.19 Offshore Installations Installed Capacity Technical Potential in New York State[125]

	KW			
Load Zone	**2003**	**2007**	**2012**	**2002**
Statewide	100,000	264,000	890,000	10,100,000
Zone A: West	35,000	92,400	311,500	3,500,000
Zone F: Capitol	0	0	0	0
Zone G: Hudson Valley	0	0	0	0
Zone J: NYC	0	0	0	0
Zone K: Long Island	65,000	171,600	578,500	6,600,000

Table 4.9.20 shows the annual energy generation technical potential for offshore installations located in New York State on a statewide and load zone basis. The methodology for determining the values in Table 4.9.20 is described below.

Table 4.9.20 Offshore Installations Generation Technical Potential in New York State[126]

	Offshore Installation Annual Energy Generation Technical Potential (GWh/yr)			
Load Zone	**2003**	**2007**	**2012**	**2022**
Statewide	277.6	732.9	2,470.7	28,038.0
Zone A: West	97.2	256.5	864.7	9,716.1
Zone F: Capitol	0	0	0	0
Zone G: Hudson Valley	0	0	0	0
Zone J: NYC	0	0	0	0
Zone K: Long Island	180.4	476.4	1,605.9	18,321.9

[125] Installed capacity technical potential values are based on water depth, wind resources, installation distance from shore, shipping exclusions, installation density, and anticipated increases in utility-scale wind turbine sizes over the coming decades.

[126] Annual energy generation technical potential for offshore installations is calculated from the installed capacity technical potential using a wind turbine capacity factor of 33%, a machine availability factor of 97%, and a grid availability factor of 99%.

Table 4.9.21 shows the energy coincidence factors for offshore installations located in New York State. Offshore energy coincidence factors are considered to be approximately equivalent across the State and are therefore presented only on a statewide basis. Energy coincidence periods are defined in Table 4.9.7.

Table 4.9.21 Offshore Installations Energy Coincidence Factors in New York State[127]

	% of Annual Energy Output					
Load Zone	**Summer On-Peak**	**Summer** Off-Peak	**Summer Shoulder**	**Winter On-Peak**	**Winter Off-Peak**	**Winter Shoulder**
Statewide	15	7	13	24	18	23

Table 4.9.22 shows the capacity coincidence factors for offshore installations statewide. Offshore capacity coincidence factors are assumed to be approximately equivalent across the State and are therefore presented on a statewide basis. Capacity coincidence periods are defined in Table 4.9.8.

Table 4.9.22 Offshore Installations Capacity Coincidence Factors in New York State[128]

	% of Maximum Energy Output	
Load Zone	**Summer Generation Capacity**	**Winter Generation Capacity**
Statewide	19	45

<u>**Calculation Methodology for Offshore Technical Potential**</u>

A recent assessment by TrueWind Solutions estimates Long Island's offshore wind energy installed capacity potential to be 5,200 MW.[129] Calculation of this estimate is based on the following criteria:

- an average wind speed of 18 mph;
- installations located a minimum of 3 miles from shore in water depths of 50-100 feet;
- shipping lane exclusions;
- a minimum project size of 100 MW comprised of 3 MW wind turbines; and
- a water area installation density of 6 mi^2 for a 100 MW installation (or 16.7 MW/mi^2).

---

127 Statewide energy coincidence factors are estimated using values measured at select shoreline sites and provide an approximate reflection of daily and seasonal variations in wind speed. However, wind speed profiles are extremely site-specific and may vary significantly between locations. It is therefore inadvisable to utilize this data as a tool for forecasting wind energy production.

128 Statewide capacity coincidence factors are estimated using values measured at select shoreline sites and provide an approximate reflection of seasonal variations in wind speed. However, wind speed profiles are extremely site-specific and may vary significantly between locations. It is therefore inadvisable to utilize this data as a tool for forecasting wind energy production.

129 Long Island's Offshore Wind Energy Development: A Preliminary Assessment, AWS Scientific Inc., 2002.

Wind resource data for this estimate is derived from a high-resolution map of Long Island's on-shore and offshore wind resources. 5,200 MW for New York's Long Island shores represents an upper limit of installed offshore wind capacity in Load Zone K, given Long Island's current technology. However, as with wind farm machines, the average offshore machine size is expected to increase in the next two decades — from 2 MW to 4 MW in the next 10 years, and to 5 MW in the next 20. As this occurs, power-to-water area densities will increase from 16.7 MW/mi^2 in 2007 to 18.7 MW/mi^2 in 2012 to 21.3 MW/mi^2 in 2022. Offshore technical potential values will rise accordingly. In Load Zone K: Long Island, for example, 5,200 MW of offshore technical potential based on the use of 3 MW wind turbines will become 5,900 MW in 2012 and 6,600 MW in 2022.

A review of the National Oceanic and Atmospheric Administration (NOAA) nautical charts indicates there are 54 miles of New York State shoreline on Lake Erie and Lake Ontario that meet the above-described criteria. Assuming installations are located between three to six miles from shore, this provides 162 square miles of suitable offshore water area, 90% of which is in Lake Erie. Using the conventional turbine-spacing assumptions used in the above-cited study, a 100 MW project requires approximately six square miles of water area. This results in an installed capacity technical potential of 2,700 MW for New York's Great Lakes shores and represents an upper limit of installed offshore wind capacity in Load Zone A: West given current technology. As machine sizes increase, this number will rise to 3,000 MW in 2012 and 3,500 MW in 2022. Due to ready access to transmission capacity on New York's Great Lakes shoreline, transmission constraints do not present a significant impediment to offshore wind development in this area.

Given the lead times associated with offshore development and the fact that no offshore installations yet exist in U.S. waters, the earliest an offshore installation might be operational in New York State is 2006. However, to define a starting point, and without regard to cost, market barriers, or market acceptability, this study assumes 100 MW of offshore capacity installation will be on-line by the end of 2003 and a 28% annual growth rate (compared to an annual U.S. land-based installed capacity growth rate of 40% during the 1990s[130]) will drive offshore installations over the next two decades. These values yield statewide offshore technical potential installed capacities of 264 MW in 2007, 890 MW in 2012, and 10,100 MW in 2022.

Because the Great Lakes are cold, freshwater bodies, sheet ice frequently forms across portions of the lakes during winter months. Ice loading may challenge the economics of Great Lakes wind energy development,

130 From the AWEA Web sites: http://www.awea.org/faq/instcap.html and http://www.awea.org/news/news991005st.html.

though is not expected to present an insurmountable obstacle. In European offshore development, ice loading issues have been overcome through specialized foundation designs, albeit at increased expense.[131]

Since there are no other New York State offshore locations that meet the above siting criteria, the statewide offshore installed capacity technical potential for 2022 is the combination of those in Load Zone A: West and Load Zone K: Long Island, or 10,100 MW. This number represents a statewide upper limit of installed offshore capacity by 2022.

Annual energy generation technical potential for offshore installations is calculated from the installed capacity technical potential using a wind turbine capacity factor of 33%, a machine availability factor of 97%, and a grid availability factor of 99%.

Statewide energy coincidence and capacity coincidence factors are calculated using values measured for two years at the extreme eastern end of Long Island. Data from this site indicate that maximum wind speeds occur during early afternoon hours and the highest mean wind speeds occur in the November to April timeframe.[132]

ECONOMIC POTENTIAL

Economic potential is defined in this study as the subset of technical potential that is cost-effective compared to the electricity supply the wind power would replace. Economic potential is determined by removing from technical potential the portion of wind power that is not cost-effective under long-run estimates of avoided electricity costs. NYSERDA provided projections of avoided electricity generation and capacity costs for each load zone, which vary by year and within each year according to season and time of day. Wind power technologies were "screened" (as were all efficiency and renewable energy technologies assessed in this study) to determine the portion that are projected to be economic from a societal cost perspective.

The analysis of the economic potential of wind energy in New York State indicates that by 2022 further development of new wind energy installations could result in 41,200 GWh/yr of additional generation over the base case scenario. All of this electricity passes societal economic screening when using high statewide avoided costs. Approximately 84% passes economic screening when using low statewide avoided costs.

---

[131] The Potential for Offshore Wind Energy Development in the United States, presented paper at the AWEA Windpower 2001 conference.

[132] Wind Power Potential in New York State, AWS Scientific Inc., 1996.

ACHIEVABLE POTENTIAL

Base Case

For purposes of this assessment, the base case achievable potential is defined as the market penetration of wind energy technologies resulting from market forces, absent in any further market intervention beyond 2002, but recognizing future market effects of past market interventions. The base case scenario reflects the impact of wind energy projects already on-line, already permitted, or well along in planning as of 2002. Grid-penetration limitations are not considered in base case scenario calculations.

Presented in Table 4.9.23 is a 20-year statewide summary of the base case achievable potential for the four scales and configurations of wind technologies evaluated in this study. Load zone-specific base case achievable potential data is provided in Technical Appendix Table 6.3.8.

Table 4.9.23 Wind Energy Achievable Potential — Base Case [133]

	Base Case Scenario Achievable Wind Energy Potential (kW)			
Scale/Application	**2003**	**2007**	**2012**	**2022**
Wind Farm: 600 kW – 1.5 MW turbines x 10 – 50 turbines per installation	41,500	405,700	588,000	1,535,000
Cluster: 600 kW – 1.5 MW turbines x 2 – 10 turbines per installation	6,600	11,500	23,200	93,900
Small Wind: 1 kW – 300 kW stand-alone turbines per installation	596	972	1,790	6,078
Offshore: 1 MW – 3 MW turbines x 1 – 20 turbines per installation	0	100,000	184,000	625,000

Wind farm installations on-line as of 2003 are the Madison Wind Power Plant (11.55 MW) and Fenner Wind Power Plant (30 MW). Construction of a 240 MW Tug Hill/Flat Rock installation is anticipated to begin during the fall of 2003.

Cluster installations on-line as of 2003 include the 6.6 MW Wethersfield Wind Power Plant. Wind farm and cluster installed capacity projections for 2007, 2012 and 2022 are based on the anticipated impact of existing state and federal development incentive programs, including the New York System Benefits Charge Research and Development programs, public benefits funds administered through LIPA and NYPA, and the efforts of research and outreach organizations such as NYSERDA, LIPA, and NYPA.

Estimates of small wind installations on-line as of 2003 include approximately 346 kW of statewide capacity from machines produced by major manufacturers, such as Bergey Windpower Corporation and Southwest Windpower.[134] This includes nine small wind turbines installed as part of NYSERDA's wind energy cost-sharing initiative. Additionally, 250 kW of capacity have been built or are planned on Long Island as part of the LIPA-Long Island Farm Bureau's Wind Turbine Generation Project. Small wind capacity projections for 2007, 2012, and 2022 are based on the anticipated impact of existing state-development incentive programs, such as the New York Energy Smart Loan program and the wind energy systems property-tax exemption.

No offshore installations are expected to be on-line as of 2003. LIPA is anticipating development of an approximately 100 MW installation off of Long Island's southern shore, which is projected by LIPA to be operational within the next three to five years.[135] Offshore capacity projections for 2012 and 2022 are based on the anticipated success of the LIPA installation and the future impact of existing state and federal development incentive programs.

Currently Planned Initiatives Scenario

For purposes of this assessment, the scenario referred to as the "currently planned initiatives (CPI) achievable potential" is defined as the market penetration of wind energy technologies resulting from future impacts expected from currently planned initiatives included in the State Energy Plan. The CPI scenario initiatives include NYSERDA's System Benefits Charge programs, NYPA incentive programs, LIPA Clean Energy Initiative programs, and New York's Executive Order 111. A complete listing of initiatives considered in the CPI scenario analysis is provided in Technical Appendix Table 6.4.2. Grid-penetration limitations are not considered in CPI scenario calculations.

Presented in Table 4.9.24 is a 20-year statewide summary of the CPI achievable potential for the four scales and configurations of wind technologies evaluated in this study. Load zone-specific CPI achievable potential data is provided in Technical Appendix Table 6.3.8.

---

[133] The base case scenario reflects the impact of wind energy projects already on-line, already permitted, or well along in planning as of 2002.

[134] Personal communication with Susan Perry of AWS Scientific Inc., March 25, 2002.

[135] Request for Information to Support Issuance of a Request for Proposals to Purchase Power from an Offshore Wind Power Plant, Long Island Power Authority, August, 2002.

Table 4.9.24 Wind Energy Achievable Potential — Currently Planned Initiatives [136]

	Currently Planned Initiatives Scenario Achievable Wind Energy Potential (kW)			
Scale/Application	**2003**	**2007**	**2012**	**2022**
Wind Farm: 600 kW – 1.5 MW turbines x 10 – 50 turbines per installation	41,500	698,000	1,047,200	1,995,50 0
Cluster: 600 kW – 1.5 MW turbines x 2 – 10 turbines per installation	6,600	18,300	65,300	150,240
Small Wind: 1 kW – 300 kW stand-alone turbines per installation	596	1,235	3,075	7,901
Offshore: 1 MW – 3 MW turbines x 1 – 20 turbines per installation	0	100,000	259,400	812,500

Consistent with the New York State Energy Plan and direction provided by NYSERDA, the CPI scenario assumes programmatic funding for currently planned initiatives through June 2004 for LIPA and NYPA initiatives and through June 2006 for NYSERDA renewable initiatives (with the exception of New York State Executive Order 111, whose funding is assumed to continue through 2020).[137]

The CPI scenario analysis reflects incremental impacts in the years 2007, 2012, and 2022 (above those expected in the base case scenario) resulting from currently planned initiatives, assuming the initiatives do not continue beyond their current authorizations (as described above). The analysis also accounts for any program impacts expected after authorization for the initiatives ends. Program funding levels, funding duration and estimated returns on program costs are used to estimate achievable wind energy capacities shown in Table 4.9.24. Wind farm, cluster, small wind, and offshore capacity projections are based on the anticipated impact of these and other currently planned initiatives up to and beyond the funding durations described above.

Currently planned initiatives expected to most significantly impact wind farm and offshore development include green-power marketing, large wind project development incentives, Executive Order 111, federal renewable energy production tax credits, and tax-exempt bond financing. Under currently planned initiatives, NYSERDA will provide approximately $17 million to support the development of 316.5 MW of wind farm capacity in upstate New York, including a 100 MW installation in Lewis county and a 75 MW

---

[136] The Currently Planned Initiatives scenario is defined as the market penetration of wind energy technologies resulting from future impacts expected from currently planned initiatives included in the State Energy Plan. The CPI scenario analysis reflects incremental impacts in the years 2007, 2012, and 2022 (above those expected in the base case scenario) resulting from currently planned initiatives, assuming the initiatives do not continue beyond their current authorizations.

installation in Steuben and Yates counties.[138] Additionally, NYPA is seeking to develop 50 MW of wind energy by 2005.[139] Because initiatives planned under the CPI scenario are expected to have a negligible impact on the amount of installed capacity during 2003, achievable wind energy potential values under the CPI scenario in 2003 are the same as those for the base case scenario.

Currently planned initiatives expected to most significantly impact cluster development include green power marketing, Executive Order 111, federal production tax credits, tax-exempt bond financing, and research and development support programs.

Currently planned initiatives expected to most significantly impact small wind development include NYSERDA and LIPA incentives and technical support of small wind projects, standard interconnection requirements, grant and loan programs associated with the 2002 Farm Bill, NO_x emission credit set-asides, tax-exempt bond financing, and research and development support programs.

Contributions to Greenhouse-Gas Reduction Targets

The greenhouse gas (GHG) reduction target scenario is defined as the market penetration of wind energy technologies resulting from the least-cost combination of efficiency and renewable resources (above those expected from currently planned initiatives) that can be used to meet greenhouse-gas reduction targets defined by NYSERDA for 2012 and 2022. The GHG scenario initiatives include NYSERDA's Systems Benefit Charge programs, NYPA programs, LIPA Clean Energy Initiative programs, New York's Executive Order 111, net metering for small wind installations, and a state personal income tax credit for small wind systems. A complete listing of initiatives considered in the GHG scenario analysis and their anticipated authorization periods is provided in Volume 6, Tables 6.4.2 and 6.4.3. In general, the initiatives considered in the GHG scenario assume a continuation and/or expansion of currently planned initiatives beyond their current authorization periods. Grid-penetration limitations are not considered in GHG scenario calculations.

Presented in Table 4.9.25 is a 20-year statewide summary of the GHG achievable potential for the four scales and configurations of wind technologies evaluated in this study. Load zone-specific GHG achievable potential data is provided in Technical Appendix Table 6.3.8.

---

137 On June 10, 2001, Governor George E. Pataki signed Executive Order 111 directing state agencies and other entities to be more energy efficient and environmentally aware. Among other directives, the order requires State agencies to purchase or generate 10% of their electric requirements from renewable sources by 2005 and to purchase or generate 20% of their electric requirements from renewable sources by 2010.

138 NYSERDA press release, August, 2002.

139 From New York State Web site: http://www.state.ny.us/governor/press/year02/aug21_4_02.htm.

Table 4.9.25 Wind Energy Achievable Potential – Contributions to GHG-Reduction Targets

	Installed Wind Energy Capacity (kW)			
Scale/Application	**2003**	**2007**	**2012**	**2022**
Wind Farm: 600 kW – 1.5 MW turbines x 10 – 50 turbines per installation	41,500	698,000	1,141,000	3,491,000
Cluster: 600 kW – 1.5 MW turbines x 2 – 10 turbines per installation	6,600	18,300	91,500	1,840,000
Small Wind: 1 kW – 300 kW stand-alone turbines per installation	596	1,235	4,246	50,130
Offshore: 1 MW – 3 MW turbines x 1 – 20 turbines per installation	0	100,000	385,800	5,742,000

In the GHG scenario analysis, program funding levels, funding duration and estimated returns on program costs are used to estimate achievable wind energy capacities shown in Table 4.9.25. Wind farm, cluster, small wind, and offshore capacity projections are based on the anticipated impact of the planned GHG initiatives according to the funding durations described in Tables 6.4.2 and 6.4.3 in Volume 6.

Because initiatives planned under the GHG for the most part are continuations and/or expansions of those anticipated for the CPI scenario, they are expected to have little impact on the amount of installed capacity during 2003 and 2007. For this reason, achievable wind energy potential values under the GHG scenario in 2003 and 2007 are the same as those for the CPI scenario.

The GHG initiatives expected to most significantly impact wind farm and offshore development in 2012 and 2022 are continuations and expansions of green-power marketing, large wind project development incentives, Executive Order 111, federal production tax credits, and tax-exempt bond financing.

The GHG initiatives expected to most significantly impact cluster development in 2012 and 2022 are continuations and expansions of green-power marketing, Executive Order 111, federal production tax credits, tax-exempt bond financing, and research and development support programs.

The GHG initiatives expected to most significantly impact small wind development in 2012 and 2022 include an expanded net metering program, standard interconnection requirements, state personal income tax credit for small wind systems, NO_x emission credit set asides, tax-exempt bond financing, and research and development support programs.

COST AND RELATED INFORMATION

Presented in Table 4.9.26 is a summary of current and projected installed costs under the base case scenario for the four scales and configurations of wind technologies evaluated in this study. All cost information is expressed in 2003 dollars.

Table 4.9.26 Wind Technology Installed Costs — Base Case[140]

Scale/Application	2003 Installed Cost ($/kW)	2007 Installed Cost ($/kW)	2012 Installed Cost ($/kW)	2022 Installed Cost ($/kW)
Wind Farm: 600 kW – 1.5 MW turbines x 10 – 50 turbines per installation	1100	987.5	875	650
Cluster: 600 kW – 1.5 MW turbines x 2 – 10 turbines per installation	1400	1275	1150	900
Small Wind: 1 kW – 300 kW stand-alone turbines per installation	2500	2375	2250	2000
Offshore: 1 MW – 3 MW turbines x 1 – 20 turbines per installation	1650	1520	1390	1000

The term "installed cost" refers to the installed cost of a wind energy system including the cost of all planning, equipment purchase, construction, and installation for a turnkey system, ready to operate. The installed cost includes the wind turbine and tower delivered and installed at the site together with all electrical, maintenance, and other supporting infrastructure. The installed cost also includes the costs of planning, permitting, land-use arrangements, and other pre-construction costs. The most economic arrangement for land use is not to purchase the land outright. Since at most 5% of the land area used is actually needed for the equipment used for a wind farm, the most common (and economic) land-use arrangement is to secure an easement for use of the land and for the remaining 95% of the land to remain in its original use. Rather than being considered part of the installed cost of a wind farm, land-use payments are typically accounted for in annual O&M costs and typically equal 2% or more of the gross energy production revenue. The installed capital cost does not take into account the strength of the wind resource or the matching of the wind turbine power curve to the distribution of wind speeds. Thus, installed cost is not a complete measure of the economic performance of a wind system. The actual cost for a given installation depends largely on the size of the installation, the difficulty of construction, and the sophistication of the equipment and supporting infrastructure. [141]

---

[140] Installed cost forecasts under the base case scenario are made by projecting cost reductions over the past 15 years and accounting for improvements in technology and reductions in manufacturing costs due to increased volume and installation processes.

[141] Scoping Study of Renewable Electric Resources for Rhode Island and Massachusetts, 1997.

Installed cost forecasts under the base case scenario in Table 4.9.26 are made by projecting cost reductions over the past 15 years and accounting for improvements in technology and reductions in manufacturing costs due to increased volume and installation processes. For example, installed costs for wind farms have decreased from more than $2,500/kW in the early 1980s to a current range of $900/kW to $1,200/kW, and they are expected to decrease to $650/kW by 2022.

Installed costs are expected to decline under the CPI, GHG, and technical potential scenarios. Under each of these scenarios, as successively greater numbers of wind turbines are installed, State wind energy facility construction expertise and installation infrastructure reliability is likely to increase. As well, techniques for foundation construction, wind turbine installation, and facility commissioning should improve. Equipment costs should also decline if the growth in the number of New York's wind energy facilities is a reflection of a larger national and international pattern of wind energy growth. The study estimates that for utility-scale installations (wind farms, clusters, and offshore facilities), installation costs will decline from the base case installation costs by 5% under the CPI scenario, 10% under the GHG scenario, and 15% under the technical potential scenario. For small wind applications, where a large-scale installation infrastructure is less of a factor, the study estimates that installation costs will decline by 2% under the CPI scenario, 4% under the GHG scenario, and 6% under the GHG scenario. Specific installation costs under each of these scenarios are provided in Technical Appendix Table 6.3.8.

Table 4.9.27 shows current and projected annual O&M costs under the base case scenario for the four scales and configurations of wind technologies evaluated in this study.

Table 4.9.27 Wind Technology Operation and Maintenance Costs — Base Case.[142]

Annual Wind Technology O&M Costs Under the Base Case Scenario				
Scale/Application	**2003 O&M Cost ($/kW-yr)**	**2007 O&M Cost ($/kW-yr)**	**2012 O&M Cost ($/kW-yr)**	**2022 O&M Cost ($/kW-yr)**
Wind Farm: 600 kW – 1.5 MW turbines x 10 – 50 turbines per installation	26.34	23.71	21.07	15.80
Cluster: 600 kW – 1.5 MW turbines x 2 – 10 turbines per installation	39.10	35.19	31.28	23.45
Small Wind: 1 kW – 300 kW stand-alone turbines per installation	49.97	47.47	44.97	39.98
Offshore: 1 MW – 3 MW turbines x 1 – 20 turbines per installation	41.64	38.85	36.09	27.75

[142] O&M cost forecasts under the base case scenario are made by projecting cost reductions over the past 15 years and accounting for improvements in technology and reductions in servicing costs due to increased volume as well as improved materials, designs, and manufacturing processes.

O&M costs include all normally recurring costs associated with the routine operation of the installed facility, including scheduled major overhauls of the system. The majority of O&M costs are associated with maintenance, which is generally grouped into three categories:

- the cost of unscheduled but statistically predictable, routine maintenance visits to address wind turbine malfunctions;
- the cost of scheduled preventive maintenance for the wind turbines and the power collection system; and
- the cost of scheduled major overhauls and subsystem replacements of the wind turbine

Major overhauls are typically performed at system half-life (approximately 10 years) and are included in the levelized annual O&M cost. O&M costs for modern turbines used in wind farms are currently 1 cent/kWh or less. This value translates to an annual O&M cost of $26.35 per kW of rated capacity, using a wind turbine capacity factor of 31%, a machine availability factor of 98%, and a grid availability factor of 99%. The major component of the total maintenance cost is for unscheduled maintenance, followed by a distant second by preventive maintenance, and a still more distant third by the cost of major overhauls and replacements. Maintenance costs for wind farms, clusters, and offshore systems might be apportioned as follows:

- Unscheduled maintenance visits 70%
- Preventative maintenance visits 20%
- Major overhaul 10%

Market Assessment for Small Wind Systems in New York State (2002) indicates that, while there are no comprehensive studies addressing the maintenance costs of small wind systems, annual O&M costs can be estimated to be 1% to 3% of the system installed cost.[143] Mick Sagrillo of Sagrillo Power and Light, a recognized small wind systems expert, estimates annual O&M costs of small wind systems to be 1% to 2% of the system installed cost.[144] This study uses an annual small wind O&M cost of 2% of the installed system cost.

The above-cited report states that, for systems rated at 10 kW and smaller, annual maintenance typically involves a visual inspection of the blades and other system parts. Systems greater than 10 kW may require annual fluid replacement and lubrication. Depending on the specific turbine model, weather conditions, and wind regime, a major system repair (including blade replacement) is often required three to 10 years after the system is installed.

[143] Market Assessment for Small Wind Systems in New York State, AWS Scientific Inc, 2002.
[144] Personal communication with Mick Sagrillo, December 4, 2002.

Levelized O&M costs include all O&M costs over the projected 20-year lifetime of wind farm, cluster, and small wind systems, including routine and preventive maintenance (both scheduled and unscheduled), periodic overhauls, operation of the systems, insurance, property taxes, and land-use payments. A projected lifetime of 25 years is used for offshore machines in this analysis.

O&M cost forecasts under the base case scenario in Table 4.9.27 are made by projecting cost reductions over the past 15 years and accounting for improvements in technology and reductions in servicing costs due to increased volume as well as improved materials, designs, and manufacturing processes.

O&M costs are expected to decline under the CPI, GHG, and technical potential scenarios. Under each of these scenarios, as successively greater numbers of wind turbines are installed in increasingly close geographic proximity, individual O&M companies will be able to service greater numbers of installations in closer geographic proximity, thereby taking advantage of the economies of scale and realizing increased efficiencies in labor, transportation, management, overhead and servicing infrastructure. The study estimates that for utility-scale installations (wind farms, clusters, and offshore facilities), O&M costs will decline from the base case O&M costs by 5% under the CPI scenario, 10% under the GHG scenario, and 15% under the technical potential scenario. For small wind applications, where a large-scale servicing infrastructure is less of a factor, the study estimates that O&M costs will decline by 2% under the CPI scenario, 4% under the GHG scenario, and 6% under the GHG scenario. Specific O&M costs under each of these scenarios are provided in Technical Appendix Table 6.3.8.

STRATEGIES FOR ACCELERATING MARKET DEVELOPMENT

There are a variety of factors that have constrained market development of wind energy installations for electricity production. These include:

- market uncertainty associated with deregulation of the electricity industry;
- historically low cost of gas used with combustion turbines;
- generally low payments for wind-generated energy, usually associated with avoided costs, coupled with the currently higher cost of wind-generated energy relative to avoided costs;
- absence of societal (political) recognition of the environmental values associated with wind-generated energy or, conversely, full recognition of the downstream costs of fossil-fueled energy, including gas;
- relatively high cost of capital due to incorporation of a risk premium (both technology and political) and absence of access to tax-advantaged capital sources (e.g., municipal bonds);
- long lead times associated with siting, permitting, and dealing with public opposition to siting wind systems; and
- the absence of reliable, regional wind-resource measurements carried out for at least one to two years and their limited availability in the public domain. (Such information is expensive

for an individual company to obtain and is needed in order to develop reliable estimates of energy production and thus the cost of energy.)[145]

The coordinated efforts of several New York State organizations have led to the establishment of promising policy, advocacy, and research initiatives designed to address many of the barriers listed above. These initiatives represent an increasingly favorable social and political attitude toward wind energy development in the State of New York. This attitude has resulted in the rapid deployment of the State's 48.1 MW of installed utility-scale wind energy (greater than any other Northeastern state), an aggressive development program for the small wind market, and the State's leadership role in establishing offshore wind energy.

To build on these successes and move toward realizing more of the State's considerable wind energy potential, the State of New York is advised to pursue a combination of current and additional initiatives and policies that will serve to create a viable market for electricity produced by wind energy installations. Generally, the goals of such initiatives are to achieve one or more of the following: 1) reduce the cost of capital and thus the cost of energy, 2) increase the price paid for the delivered energy, 3) supplement or buy-down the installed cost, 4) increase the market size, and 5) reduce the cost of delivery to distant load centers.

The policies and combinations of policies that are pursued depend heavily on the specific goals of each. For example, to help realize the goal of ensuring that a significant level of utility-scale wind development (i.e., wind farms, clusters, and offshore installations) occurs, the following will prove to be important policy initiatives:[146]

- Renewable Portfolio Standard, in which a certain percentage of a utility's added generating capacity must be derived from renewable resources;[147]
- Production incentives, in which wind energy installation investors or owners are awarded a direct cash subsidy or price-support payments based upon electricity production.Production tax credits, in which investors or owners of wind energy installations are awarded with an annual tax credit based upon the amount of electricity generated by that qualifying facility;
- Investment incentives, in which investors or owners of wind energy installations are awarded direct cash subsidies;
- Standard contracts, in which standard, long-term power purchase contracts are awarded to all sellers of wind energy that meet certain size, type, and ownership requirements;
- Project aggregation, in which small-scale installations (i.e., clusters) may be combined under one financing and contractual umbrella; and

---

145 Scoping Study of Renewable Electric Resources for Rhode Island and Massachusetts, 1997.

146 *Strategies for Supporting Wind Energy* by Nancy A. Rader and Ryan H. Wiser, National Wind Coordinating Committee, Washington, D.C., 1999.

147 AWEA reported that on January 8, 2003, New York Governor George Pataki announced plans for a statewide renewable portfolio standard, which is expected raise the amount of New York electricity generated from renewable energy sources to 25% by 2012 — mainly from wind and biomass energy development.

- Fuel source disclosure and certification, in which utilities are required to provide customers information concerning generation fuel sources, as well as assurance as to the type and amount of renewable energy advertised to be in a given fuel mix

To assist in the development of the small-turbine market, the following policies will be particularly useful:

- Investment incentives, in which small wind turbine owners are awarded direct cash subsidies (also known as buy-down programs);
- Investment tax credits, in which owners of small wind systems are awarded income-tax credits based on their level of investment;
- Net metering, in which grid-connected, small wind systems are permitted to sell excess generation capacity back to a utility or wholesaler;
- Line-extension policies, in which transmission line extension subsidies are reduced or eliminated so as to render remote wind energy systems a more attractive alternative;
- Sales tax reductions, in which buyers of small wind systems are exempted from the state-assessed equipment sales tax; and
- Property tax reductions, in which owners of small wind systems are awarded property-tax credits based on the value of the investment

To further increase their influence, the policies listed should be coordinated with those of surrounding states and incentives available at the federal level (e.g., the Wind Energy Production Tax Credit). Overall, the decision of which policies are used to stimulate the growth of wind energy in the State of New York will be based on many factors, including cost, effectiveness in reaching stated goals, and political expedience. In any instance, the choice of strategies will need to be made based on a solid understanding of the status of the technology, its cost, and the potential for its productive use in New York State.

APPENDIX:
DISCUSSION OF CLEAN & AVAILABLE LANDFILLED WOOD RESIDUES

Definition of Clean and Available Wood Residues

Available supplies for three categories of *landfilled* wood residues (Woody Yard Trimmings, Pallets and Other Wood Waste, and Construction and Demolition Wood) were estimated using information from the article "How Woody Residuals Are Recycled in the U.S." by David McKeever of the U.S. Forest Service (published in *Wood Recycling: How to Process Materials for Profitable Markets* by BioCycle — Journal of Composting and Recycling, The JG Press Inc., Emmaus, PA, 2000.). For all three of these supplies (and all other supplies considered in this analysis), the term "available" is taken as the *useable and recoverable* quantity of wood residue that is not presently recovered for combustion, composting, mulching, or all other beneficial uses. The "available" supply estimate excludes that part of discarded wood that is not considered to be useable and recoverable due to excess contamination (e.g., treated wood not suitable for combustion, composting, or mulching), excessive commingling with other waste, or not recoverable for other reasons.

Pallets and Other Wood Waste

The category "Pallets and Other Wood Waste" includes landfilled wood items such as furniture and cabinets, pallets and containers, scrap lumber and panels from activities other than construction and demolition activities, and landfilled wood from manufacturers. Repaired or recycled pallets are not included. Of the total amount of pallets and waste wood discarded in landfills, about 46% is estimated as available for recovery and use. All of this was considered in this analysis to be potentially available for new biopower projects (assuming sufficient incentives and changes in existing landfill practices could be implemented to recover all of this material).

Woody Yard Trimmings

Yard trimmings are the second-largest single component of MSW, representing about 12% of total MSW generation. Yard trimmings include tree limbs and stumps, brush, leaves, and grass clippings. According to a recent study (NEOS Corp, 1995, Urban Tree Residues: Results of the First National Inventory, final report prepared for Arboriculture Research Trust, Allegheny Power Service Corp., and National Arborists Foundation, NEOS Corp., Lakewood, CO, Sept., 1994.), about 95% of all yard trimmings are woody materials. About 44% of the total generated woody yard trimmings is already being recovered for composting or recycling, about 15% is being combusted, about 14% is considered unrecoverable or unusable, and the remaining 27% is considered available for further recovery. All of this remaining 27% of woody yard trimmings was considered in this analysis to be potentially available for new biopower projects.

Construction and Demolition Residues

Although construction and demolition (C&D) wood residues are considered as a single biomass resource category in this analysis, the two types of waste are very different in several ways:

- The manner in which they are generated
- Their characteristics
- The ease with which they can be separated, recovered, and recycled.

Wood residues from construction activities tend to be fairly clean and easily separable at the job site. Of the total amount of wood used in construction activities, about 16% is estimated to end up as waste. About 76% of the total construction wood waste is considered to be recoverable — the remaining 24% is either already being recovered or is not usable. Demolition wood waste often is commingled with aggregate, concrete, paper, insulation, glass, and other building materials, some of which contain contaminants or hazardous materials. Entire loads of demolition waste are typically rejected at recycling facilities if contaminated materials are present. An estimated 34% of total demolition wood waste is considered to be usable, separable from other demolition materials, not presently recycled, and available for recovery.