NYPSC Case 03-E-0188 - Proceeding on Motion of the Commission Regarding a Retail Renewable Portfolio Standard

Comments of the Solar Energy Industries Association

9/26/2003

I. Introduction

The Solar Energy Industries Association (SEIA) is the national trade organization representing photovoltaics and solar thermal manufacturers, component suppliers, and national distributors.

In the interests of avoiding duplication, we intend to limit our comments to those areas where we have new or amplifying information; in all other respects, we are substantially in agreement with the positions advanced by RETEC.

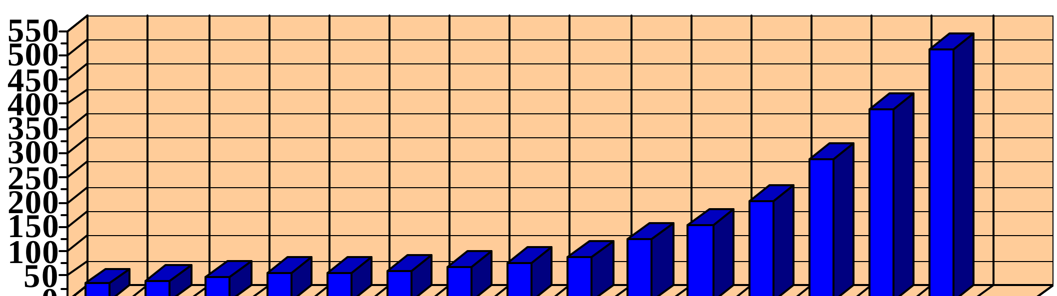
IV.D 2 – Eligibility (Tiers) (Emerging Technology Tier)

We firmly believe that customer-sited photovoltaics (PV) are an ideal resource for New York's unique requirements for regional and technological diversity, peak demand shaving, grid support, and environmental justice, and that these compelling benefits argue for the use of additional incentives to develop a functioning and mature market for these technologies in the state.

Photovoltaic Technology Status and Prospects

The photovoltaics industry is experiencing rapid and sustained growth due to the establishment of full and functioning markets in some US states and overseas. World PV manufacturing grew over 30% last year, to more than 500 MW of peak production, the latest entry in a 15-year growth trend that has seen the industry grow by a factor of nearly 10 in the past 10 years.

Fig.1: World PV Production Survey Data (MWp of sold solar capacity)
PV News, Paul Maycock, Editor: yearly February editions.



	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	
Total	33.6	40.2	46.5	55.4	57.9	60.09	69.44	77.6	88.6	125.8	154.9	201.3	287.7	390.5	512.2	

This growth has driven a substantial reduction in photovoltaic prices; general industry experience has been that for every doubling in installed PV capacity, installed priced drop by ca. 18%. Recent PV growth rates and technological advancements have attracted increased notice on the part of the investment community and of multinational and very large-scale energy companies.

Clearly, there is great potential for the future growth, technological advancement, and price reduction of this technology, provided that it is supported in the near term by adequate incentive policies. State incentive programs offer critical policy tools needed to drive US-based PV markets, creating local jobs, state revenues, improved grid reliability, and improved air quality.

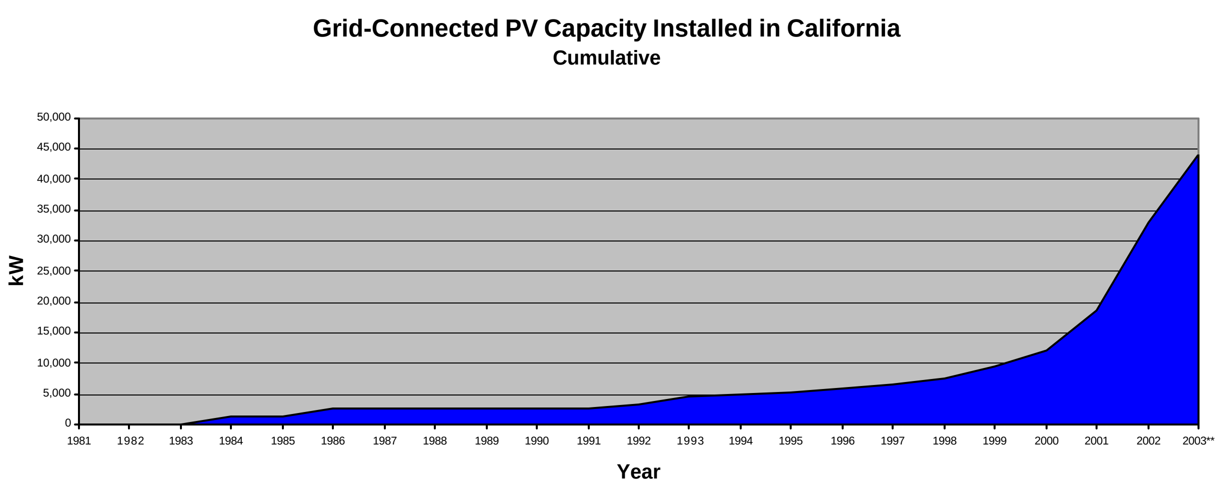
Current Emerging Technologies Proposals Are Well-Designed, But Insufficient

SEIA enthusiastically supports the concept and implementation of an "emerging technologies" incentive, as proposed in the RETEC Straw Proposal. For capital – intensive technologies such as solar, an up-front buydown based on generating capacity is the most effective means of encouraging increased installations. Programs designed on this model have experienced great success in many markets.

However, we note with concern that the staff analysis of such a buydown program contemplates the installation of only ca. 1 MWp of PV generating capacity per year of the RPS, and an overall contribution by all emerging technologies of less than 1% of the RPS increment. Further, the Staff estimate contemplates a requirement to incentivize solar technologies at ca. $4 / Wp for the foreseeable future. SEIA believes that a better use of rate-payer funds would be to gradually reduce the dollar per Watt incentive amount over time. This approach would extend the available customer incentives over a larger pool of participants and lead to a greater number of total installed generating capacity over time.

Simply put, a requirement for 1 MW of solar per year and approximately 7 MWp total installed capacity through 2013 amounts to a demonstration project, rather than a meaningful technology deployment and renewable power procurement strategy. The state of New Jersey is contemplating a contribution of ca. 90 MWp of solar photovoltaics to their state electrical system by 2008; the state of California's comprehensive incentives have resulted in the installation of ca. 45 MWp of capacity to date, with another 40 MWp of PV capacity currently reserved and ready to be installed.

Fig. 2: Cumulative Grid-Connected Photovoltaic Capacity in California
http://www.energy.ca.gov/renewables/documents/2003-07-31_GRID_PV.XLS



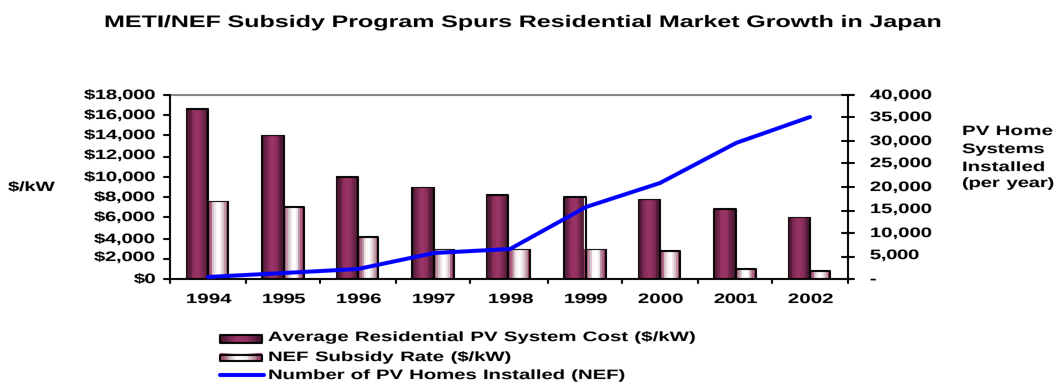
New York has the near-term opportunity to build on the growing momentum created by these existing state markets and attract new local jobs, PV industry investment in New York, and increased tax revenues generated by PV industry driven economic development. However, to achieve these benefits the State must first demonstrate a meaningful policy commitment to attracting PV manufacturer investment in New York.

The proposal set forth in the RETEC comments would establish New York I as a market leader in solar electric installations, and would favor the establishment of a functioning dealer, distributor, and installer network – one which encourages sufficient price transparency and competition to enable a rapid decline in prices even as capacity (and associated benefits) ramped up substantially.

An analogous program can be found in Japan, where a very large initial buydown from the New Energy Foundation has spurred sufficient economies of scale and market operation that incentive levels could be gradually phased out. (Japanese and US electric rates are, of course, not comparable.)

With New York's good solar resources, attractive financing, need for peak demand shaving and comparatively higher retail electric rates, it stands out as one of the United States' natural solar markets. We are confident that a descending incentive level and increasing installed MWp levels like that set forth in the RETEC model, is achievable given a sufficient market spur.

Fig. 3: Japanese Residential Experience -
http://www.nef.or.jp/english/new/present.html



VIII. Cost and Benefit Considerations

Increased Deployment of Photovoltaics to New York Would Bring Major Employment Benefits

Renewable technologies in general are highly employment – intensive per watt when compared with nonrenewables, which rely on large-scale acquisition of fuels and their consumption in highly automated systems with minimal staff. *Displacing conventional resources with renewables increases overall employment in the energy industries.*

It is also worth noting that this employment, dependent on installation, servicing, and in many cases small manufacturing, may be more biased towards in-state jobs, as compared with generation sources that rely on imported fuels.

The attached study, by the Renewable Energy Policy Project (REPP,) **(Appendix A)** demonstrates that photovoltaics generate more jobs per watt than any other renewable technology, with necessarily local systems integration and assembly occupying a large share of this total. Wind projects also demonstrate very high employment numbers, though REPP's analysis is not at this time capable of estimating employment totals from small wind installations (or fuel cells.)

Using an initial analysis based on an emerging renewables incentive like that contemplated in the RETEC straw man, REPP also produced an employment analysis specifically focusing on New York. **(Appendix B)** This simulation finds that 2013 employment assignable to the RPS would increase from ca. 13,980 in the base case to 15,880 with the larger emerging renewables tier – with both estimates *only* including employment from wind, PV, and biomass co-firing.

This is in line with earlier estimates issued by REPP and the Nevada AFL-CIO, estimating more than 27,000 FTE jobs would be generated by that states' solar – intensive RPS. (http://www.repp.org/labor/index.html)

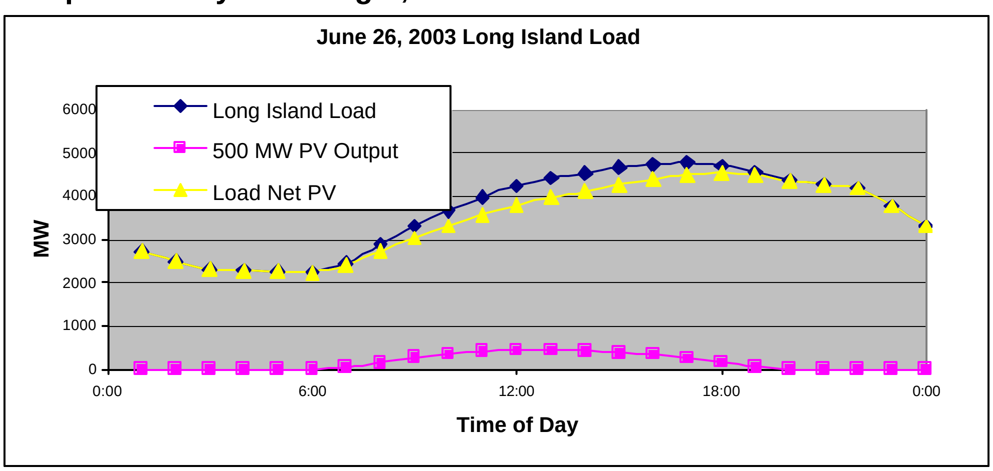
We feel that these benefits are quantified in sufficient detail to be entered into the Commissions' consideration of costs and benefits.

Large Photovoltaic Deployments Would Provide Valuable and Quantifiable Electrical System Benefits

Photovoltaic devices produce the most electricity when the sun is highest in the sky. Fortuitously, this fact coincides well with the pattern of New York consumer electric demand (especially the summer seasonal demand.) The contribution of electricity supplied from photovoltaic generating systems is therefore best evaluated as a premium, peak-power asset, rather than as commodity electricity. The importance of PV's contribution from this system perspective is that peak load reduction reduces the need for utilities to purchase spot-market power during constrained periods at the highest price. Reducing utility costs by reducing peak load can be passed as a direct rate benefit to New York ratepayers.

The following graph uses historical output from a PowerLight PV system on Long Island (as measured by the manufacturer – a Long Island system was chosen for data quality and ease of administration) to scale up the peak-shaving effects that could be demonstrated were 500 MW of PV to be installed on the Island.

Fig. 4: PV Output Coincidence with Peak
(data provided by PowerLight,



Inc.)

Aside from the obvious environmental benefits – infrequently-used "peaker" plants are generally speaking far dirtier and less fuel-efficient than constant-running "baseload" plants, there are more quantifiable economic benefits as well.
The attached "Mid-Atlantic States Cost Curve Analysis," (**Appendix C)** prepared by JBS Energy for the National Association of Energy Service Companies and Pace Law School's Energy Project, examines the value of peak load reduction in the PJM Interconnect *from the ratepayer perspective.* It states, in part, that:

> "The value of load reduction was found to be about 24 cents/kWh on summer weekday afternoons in the year 2000 –compared to a market price of 5 cents/kWh.1 In other summer heavy load hours (6am-10pm except peak hours), load reduction was worth almost 14 cents, with a market price of 4 cents/kWh. Off-peak and in the winter, the value of load reduction was less, but still ranged from 3.5 to 6 cents/kWh, with market prices in the range of 1.5 to 3 cents/kWh." (p.2)

By contributing the majority of their output to the times when the market is most constrained, PV can offer substantial relief to ratepayers who would otherwise have to absorb this anomaly.

We feel that these benefits are quantified in sufficient detail to be entered into the Commissions' consideration of costs and benefits.

Photovoltaics Offer Unique Opportunities in Urban Areas

Attractive or barely visible, low-profile, requiring minimal installation and transportation infrastructure, and seldom suffering from NIMBY attacks, photovoltaic systems can be deployed simply and quickly into suburban and urban areas alike. Photovoltaic installations are operating today at 4 Times Square in Manhattan, atop the Dormitory Authority building in Albany, throughout Long Island, and in major cities from Boston to San Francisco. Much like fuel cells, they can be deployed in urban areas simply and at no additional cost. Urban photovoltaic applications are commonplace nationwide. no mo

The technologies incentivized in the Emerging Renewables component of the RPS are the only electric generating systems devices that are likely to have substantial urban or suburban deployments in the immediate future. They therefore have a unique contribution to make in New York's pursuit of improved air quality (frequently a regional environmental justice issue caused by urban fossil-fuel combustion generators,) and grid reinforcement as transmission and generation requirements experience their most severe legal, community and financial obstacles in urban areas.

In particular, PV has been successfully deployed on contaminated urban industrial sites. In a number of contaminated former industrial sites around the world, PV installations have converted former "dead zones" into economically productive solar electric power plants – often directly near major urban load centers. A BP Solar installation of this type in Paulsboro, NJ recently had to open a visitor's center to accommodate tourist load at this former oil storage facility.

The full range of these capabilities has yet to be explored, but there are compelling reasons for the PSC to ensure that a true market for these emerging renewable technologies is developed in the state, so that applications like these can be fully utilized.

IX. Other Issues

Solar's Speed of Deployment Enables Rapid Institution of the RPS

The full deployment time for even the largest distributed PV projects can be measured in months; smaller residential systems can take mere weeks. Especially if the emerging renewables incentive program operates as a multi-year, declining per-watt incentive program, New York can take advantage of the copious previous experience that has been amassed by other states in quickly deploying MWs of PV generating capacity.

PV systems will be among the simplest early deployment of renewable generating capacity possible in an RPS. Accordingly, they will enable the state to demonstrate real renewable power installations much earlier than would be otherwise the case. The net effect of immediate PV deployment would be to reinforce the demonstrable benefits of the RPS in the eyes of the public, while spreading compliance costs out over a longer horizon.

SEIA supports the RETEC position that the NYRPS should take effect in 2005; our industry has more than sufficient capacity to provide the contemplated levels of PV installation by that time.

Effective Use of Emerging Renewables Will Require Supporting Rulemakings

One of the defining attributes of the "emerging" technologies contemplated herein is that they interact with the grid from behind the customer meter. Unfortunately, in the past, this has served as a competitive barrier, as LSEs, whether competitively hostile to, or technically unfamiliar with customer-generated power, have used interconnection as a procedural or financial barrier to small generator deployment.

An effective RPS will rest on a number of enabling policies; as a part of implementing the RPS, we urge the PSC to ensure that interconnection to the grid is simple, equitable, and inexpensive across the state – including in network environments. We further urge that interconnection and net metering provisions be extended to reflect current national and market trends towards solar, fuel cell, and small wind systems up to the megawatt scale.

Finally, as noted in the RETEC comments, it is eminently possible for small clean energy systems to monitor and verify their output to a high degree of accuracy; if they are to be truly integrated into a renewable energy credit (REC) – based system. The PSC may need to incorporate existing inverters and other output-measurement devices into its procedures for certifying and verifying other load and supply monitors (e.g. customer meters.)

Small and Intermittent Renewables Make Documented Contributions to System Reliability

SEIA would submit that in their reduction of peak load, their movement of load away from stressed primary paths and to customer sites, and in their ability to provide critical supporting power during cascading blackouts, that customer-sited renewables, and solar in particular, can substantially contribute to overall system reliability.

As part of any consideration of the system reliability effects of renewables that may occur, we note for to see the PSC's administrative consideration the extensive empirical data summarized in the relevant chapters and References section of "Small is Profitable" – available in its entirety from http://www.smallisprofitable.org/.

REPP

RESEARCH REPORT

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THE WORK THAT GOES INTO RENEWABLE ENERGY

By Virinder Singh with BBC Research and Consulting and Jeffrey Fehrs[1]

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THE WORK THAT GOES INTO RENEWABLE ENERGY

By Virinder Singh with BBC Research and Consulting and Jeffrey Fehrs

EXECUTIVE SUMMARY

This report examines the labor requirements for renewable energy in the United States, from collecting fuel to manufacturing components to building and running power plants.

A variety of reinforcing trends make it essential to understand the job benefits of renewables. Renewable energy is growing steadily both domestically and worldwide, thanks to policy and technological advances. In the United States, policies such as state energy funds, state mandates for renewables, environmental regulations, improved technology and retail consumer interest have increased the number of installations. Globally, dramatic growth continues in developed nations such as Denmark, Germany and Japan as well as the developing world.

Specifically, this study estimates the total hours required to manufacture, install and service wind power and solar photovoltaics (PV). For biomass co-firing, this study estimates the hours needed to collect, transport and process biomass to fuel a portion of a power plant primarily fueled by coal. The study is based upon extensive surveys of firms with U.S. operations. The co-firing study also includes literature review since commercial operations are still few.

Labor Estimates for Renewables

On an energy capacity basis, PV employs the most workers among the renewables examined in this report, followed by wind and biomass co-firing.

Co-firing has a range of job requirements since different forms of biomass have different labor needs. Energy crops such as switchgrass provide the most jobs. Mill residues and urban wood wastes provide jobs at the low end of the co-firing job range.

Table ES-1. Labor Requirements for Renewable Energy Technologies

Technology	Model Project Scale	Person-Years per MW
Solar PV	2-kW systems	35.5
Wind	37.5 MW	4.8
Biomass Co-Firing	100-750 MW	3.8-21.8

Module assembly (30%), systems integration (17%) and contracting (15%) make up almost two-thirds of jobs in PV. Blade manufacturing (26%), turbine servicing (20%) and installation (11%) lead the activities within the wind power sector in job requirements. Since co-firing represents a range of biomass feedstock and an associated range of job requirements, different activities hold different relative job values depending on the feedstock. Farming is the most important source of work when co-firing with energy crops. Truckers garner the most work for mill residues.

Economies of scale and technological change will affect labor requirements in the future:

- PV manufacturing plants will grow in size and undergo more automation in module manufacturing, with both trends cutting the need for labor. The labor requirements for installation should also drop as local markets grow and standardized PV systems are the norm.

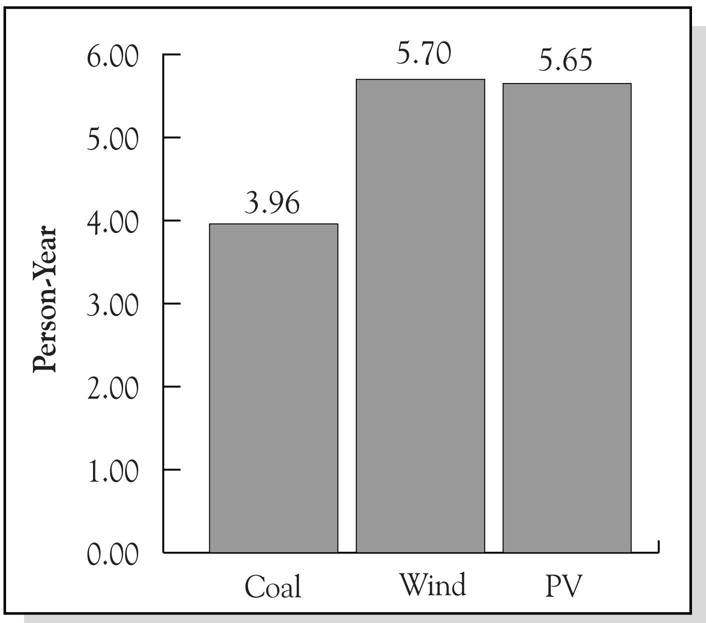
- The wind industry will feature more advanced rotor manufacturing, reductions in custom design of blades and lower operations and maintenance (O&M) needs. These factors will cut the need for labor. Economies of scale may represent over half the overall cost reductions for wind over the next 30 years, with reduced labor one component of lower costs.

- Finally, biomass co-firing may witness greater yields in energy crops that cut labor requirements for cultivation and harvesting. However, because biomass co-firing is in its infancy, it is difficult to predict what labor trends will occur.

Comparison with Coal

Wind and PV offer 40% more jobs per dollar than coal. And while the labor intensity for renewables may drop due to economies of scale and technological change, sharp declines in coal mining should continue, cutting the average labor requirements to fuel and operate coal power plants by 17% from 1998 to 2008 alone.

Figure ES-1. Comparison of Coal, Wind and PV (In Person-Years Per $1 Million in Cost Over 10 Years Including Capital and Construction)

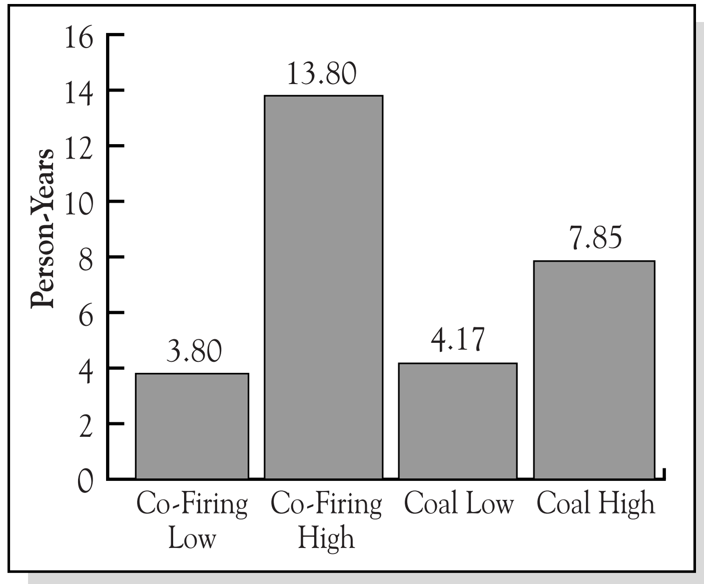


Co-firing may or may not employ more people than coal on a power output basis. However, the range of job requirements for biomass co-firing extends far beyond that for coal power. Co-firing with energy crops will employ more workers than coal, while mill and urban residues offer more ambiguous results. (Since co-firing does not require construction of a new power plant, the comparison with coal is limited to coal mining, transport and plant-site coal preparation.)

Organized Labor and Renewables

The results of this study demonstrate that renewables offer many diverse jobs to American workers. For this reason, those, including organized labor, who wish to advance economic development should look seriously at ex-

Figure ES-2. Biomass Co-Firing Versus Coal Mining, Transport and On-site Preparation (Total Person-Years Per 1,000 Megawatt-Hours)



panding renewable energy markets. Organized labor's involvement in the renewable energy sector represents a symbiotic relationship with the renewables industry. While the industry offers jobs and growth, organized labor can provide two elements essential to the long-term health of the renewables industry:

- First, labor unions offer certified skills to perform duties such as manufacturing, installation and servicing.

- Second, unions offer marketing benefits such as the "union label" and on-the-ground workers who have an incentive to expand renewable energy markets—for example, more sales of PV at the retail level by encouraging curious residential customers to commit to buying a PV system.

Labor unions and the renewable energy industry have good reason to work together. Renewable energy sources such as solar, wind and biomass offer a diverse array of jobs. They also tend to offer more jobs than coal power. Unions' ability to bring skills and recognition to the renewables sector should complement other market, technology and policy trends that point to the continued growth of renewable energy in the United States.

THE WORK THAT GOES INTO RENEWABLE ENERGY

By Virinder Singh with BBC Research and Consulting and Jeffrey Fehrs

PART ONE. INTRODUCTION

The energy industry is the largest in the United States: oil, coal and gas extraction, petroleum and coal products and gas and electricity provision totaled $289 billion in 1998.[1] That amount represents 4.6% of the United States' gross domestic product.

Given the size of the energy industry, it is not surprising that one crucial consideration for future energy investments is their impact on employment. Electric and gas utilities combined employed 616,000 workers in 1998. Coal mining, engine and turbine manufacturing and electric distribution equipment manufacturing added another 258,000 workers.[2]

Renewable energy is a relatively new entrant in the energy industry. As markets for renewables have slowly grown, there has been increasing interest from policymakers, labor unions and renewable energy supporters themselves in the impact of renewables on economic development. In particular, labor unions have asked whether or not renewables mean more jobs, and if they represent a poor alternative to dominant energy technologies such as coal and natural gas power plants.

In response to such questions and related questions on climate change policy, which surely would include a transition to cleaner sources of energy such as renewables, studies up to now have either painted a scenario of economic doom for American workers or asserted the economic development benefits of wind, solar, biomass and geothermal energy, including jobs and local revenue generation.[3] However, beyond the estimates of total jobs gained or lost, none of these studies discuss the types of jobs renewables offer.

The following analysis intends to fill the gaps between the current analyses of renewables' labor impacts. The analysis focuses on four questions:

- What factors, if any, are driving the expansion of renewable energy markets? Answering this question will help readers who are not experts in renewable energy understand the convergence of a number of positive factors affecting renewable energy's present and future.
- What are the types of jobs involved in the manufacture, installation and operation of renewable energy technologies, specifically solar PV, wind and biomass co-firing?
- How does renewable energy compare with coal energy in jobs created? As natural gas price volatility forces utilities to rethink their strategy of relying on natural gas for new power generation, coal will gradually assert a more important role in power generation. A comparison with coal also helps to better understand the labor impacts of biomass co-firing in place of coal-only power plants.
- How can labor union involvement in the development of clean energy influence the expansion of renewable energy markets?

By addressing these questions, this analysis hopes to help labor leaders, policy makers and even renewable energy supporters understand the kinds of jobs and the number of jobs that certain renewable energy technologies represent now and in the future, as well as the potential benefits of labor unions' involvement in the renewable energy sector.

PART TWO. TWO FORMS OF RENEWABLE ENERGY

Overall, renewable energy technologies fall into two categories: central-station and distributed generation. As a result, the labor analysis below includes prominent examples for each of these categories.

I. Central-station Renewables

Because the U.S. electricity sector overwhelmingly relies upon electricity generated by large, central-station power plants connected to customers by long transmission and distribution wires, it is not surprising that the bulk of national renewable energy generation also comes from central-station plants such as wind, geothermal and biomass.

This trend is not likely to change significantly in the near future. Wind energy, and particularly large turbines concentrated in wind "farms", will capture the vast majority of the 2,000 megawatts (MW) of renewables to be built in Texas by 2009. With wind turbines growing in size and productivity (many new turbines in the market are now 1 MW and larger, compared to 600-kW to 750-kW just a couple of years ago), wind power on average is the cheapest source of new renewable energy in the United States today.

While it has not grown as rapidly in recent times as wind power, geothermal power plants still supply the most non-hydroelectric, renewable power in the United States today. In fact, geothermal power supplies 8% of California's electricity needs. (See Box 1 on geothermal's contributions to economic development.) Unlike wind and solar power, which produce power variably when the wind blows or the sun shines, a geothermal power plant can produce power as consistently as "baseload" fossil-fuel plants. With volatile natural gas prices dampening enthusiasm in natural gas power plants, increasing numbers of electricity suppliers are seeking to build more geothermal power plants in the West.

And finally, biomass energy is another popular source of renewable power. Much of this power is produced in the pulp and paper industry in the Northeast, Midwest and Southeast. Biomass co-firing is perhaps the most promising near-term "biopower" technology. Co-firing involves feeding 5% to 15% of a coal plant's fuel intake with biomass ranging from wood to herbaceous plants. Co-firing thus directly replaces coal and has a clear environmental benefit in reduced nitrogen oxide (NOx), sulfur dioxide (SO_2), toxics and carbon dioxide (CO_2) emissions. One study estimates that co-firing biomass as 15% on the heat input for a 100-MW coal plant running at a 85% capacity factor would reduce SO_2 by 15% and CO_2 by 14%, assuming good biomass collection practices that permit carbon sequestration on biomass plantations.[5] Co-firing biomass as 7% of heat input into a coal plant can cut NOx emissions by up to 15%.[6]

Thus, co-firing can play an important role in "decarbonizing" coal-fired power plants throughout the United States. The Electric Power Research Institute (EPRI) and U.S. Department of Energy (DOE) estimate that 12 U.S. coal-fired power plants are either co-firing with biomass, or plan to do so. Utilities include the Tennessee Valley Authority, Niagara Mohawk and Xcel. Other utilities such as Southern Company are examining co-firing options to reduce pollution.[7]

Box 1. Examples of Economic Benefits of the U.S. Geothermal Industry

In 1996, the U.S. geothermal energy industry provided about 12,300 direct domestic jobs, and an additional 27,700 indirect domestic jobs. The electric generation part of the industry employed about 10,000 people to install and operate geothermal power plants in the United States and abroad, including power plant construction and related activities such as exploration and drilling; indirect employment was approximately 20,000.

Taxes received from geothermal operations are a significant source of revenue. For example, in 1993, Nevada's geothermal power plants paid $800,000 in county taxes and $1.7 million in property taxes. In addition, the U.S. Bureau of Land Management collects nearly $20 million each year in rent and royalties from geothermal plants producing power on federal lands in Nevada–half of these revenues are returned to the state. [4]

II. Distributed Renewables

While central-station power plants typically enjoy a long life in the United States, there is a growing movement among environmentalists, consumers and select energy suppliers to move to small-scale, "distributed" energy that supplies power close to the point of use. There are several reasons for this trend. Environmentalists hope for lower emissions compared to central-station power plants. Customers desire more reliable electricity supplies that do not rely upon constrained transmission and distribution grids. And numerous energy suppliers expect a profitable market as the novelty of distributed generation evolves into conventional wisdom.

Currently, 100,000 MW of diesel generators dominate the distributed generation market.[8] However, stringent environmental regulations for distributed generation will emerge in California, and may also emerge in Texas, Wisconsin and other states. Such regulations portend a new fleet of distributed energy technologies that are relatively clean and quiet. Among these technologies are fuel cells, microturbines and PV. Fossil fuels such as natural gas will power the first two technologies for now. PV requires no fuel other than the sun and exhibits the lowest emissions among all commercially available technologies.

PV deserves special attention due to its rapidly declining costs and improving efficiencies. PV scores highest in public preferences for electricity sources, scoring higher than natural gas, hydropower and even wind power.[9] The most established of the cleanest distributed energy technologies, PV has system costs that hover between $5 and $10 per installed Watt. Booming markets in Germany and Japan have induced PV manufacturers to build more and bigger plants. For example, First Solar has built the largest PV plant in the United States at 100 MW of annual production capacity. Fortune 100 firms such as Shell and British Petroleum have invested in new PV divisions, as environmental concerns, favorable economics of remote power, power reliability needs and volatile electricity prices have fueled sales of PV technology.

What these trends mean for labor are more jobs. The following section examines current labor requirements for wind, biomass co-firing and PV, three renewable energy technologies fueled by concerns about the electricity sector.

PART THREE. DRIVERS INFLUENCING THE EXPANSION OF RENEWABLE ENERGY MARKETS

I. Domestic Trends

Since the 1960s, interest in the environmental and consumer impacts of the electricity sector has burgeoned and appears to be here to stay. Many policies and programs translate public support for renewables into on-the-ground projects. First, and most recently, electricity sector restructuring has spurred the creation of **new state clean energy policies**. Restructuring in 13 states has led to the creation of over $3.5 billion in state clean energy funds to advance renewables, energy efficiency and low-income energy supply. (Regulated states can also participate in the trend. As of October 2001, only Wisconsin and Montana have done so among the ranks of regulated states.) Clean energy funds are expected to support a wide array of renewables and other, cleaner alternatives, including solar PV and fuel cells as well as wind, geothermal and biomass.

In addition to developing clean energy funds, several states undergoing restructuring, such as Texas, and a few regulated states, such as Minnesota, have passed mandates for the installation of a certain amount of renewable energy. These mandates, some of which are labeled "renewable portfolio standards" (e.g., in Texas, Massachusetts, Arizona and nine other states), have enabled vibrant regional markets, particularly for wind power. In Texas, wind power will meet the vast majority of the 2,000-MW renewable portfolio standard with a 2009 compliance deadline.

Second, **environmental regulations** covering electricity production appeared in the 1970s and have evolved since then. The Clean Air Act in particular has forced electricity suppliers to incorporate environmental controls into power plants.

In the future, new air regulations may limit emissions of mercury and perhaps carbon dioxide. Air regulations should set more stringent limits on nitrogen oxides. Electricity generators are responsible for large proportions of these pollutants.[10] Policymakers, including those at the U.S. Environmental Protection Agency, have proposed that renewables receive a greater share of pollution "allowances," the currency for emissions trading programs including those for sulfur dioxide and nitrogen oxide. Even without formal inclusion in regulatory programs, renewables' emission profile makes them an attractive source of energy for energy suppliers to avoid more stringent air regulations in the future.

A spirit of environmentalism, as well as a desire to attract non-utility entrants to electricity generation, has also crept into federal energy legislation. The Public Utility Regulation and Policy Act (PURPA) of 1978 and the Energy Policy Act (EPAct) of 1992 facilitated the adoption of renewable energy. PURPA required utilities to buy power from non-utility, renewable energy generators if it cost below the avoided cost of power to be generated by the utility itself. PURPA's enforcement in California in particular was instrumental in the implementing new, non-utility generation. (These "non-utility generators" now control 14% of total generation in the United States.) For renewables, California was central to the arrival of wind, geothermal, biomass and solar power plants. EPAct's production tax credit for wind has provided essential financing for thousands of new wind turbines nationwide.

Third, energy technology and market trends have made renewables such as wind an economic choice for utilities and others concerned about volatile electricity costs. At 4.5 cents per kilowatt-hour, wind power is now competitive with new natural gas and coal plants in areas such as the Northwest, where Bonneville Power Administration and PacifiCorp Power Marketing are installing over 1,000 MW of new wind farms. Beyond a narrow cost comparison, fuel-free renewables offer significant risk reduction value, especially when compared to natural gas power plants subject to wild price fluctuations, and even to hydropower that is dependent on unpredictable rain and snow patterns.[11]

Fourth, consumer choice, particularly from large customers such as industrial facilities, has led many states to deregulate the electric utility industry. Restructuring and the arrival of new entrants in the electricity market hold ambiguous impacts for renewables. Price competition alone among generators and retail suppliers does not bode well for renewables.

However, competition based on values, such as environmental values and low risk of price fluctuations, rather than just price, will translate into larger markets for renewables. In several deregulated markets including Pennsylvania and Ohio, one unmistakable trend has been the entry of new companies, and even a few traditional utilities, to supply renewables-based power as a potentially lucrative retail product for which customers will pay a small premium. These "green power" programs are not unique to deregulated markets, but restructuring has spurred companies in most states to offer green power as a competitive product. In states that are yet to deregulate, utilities are offering green power in anticipation of restructuring.

Overall, voluntary "green power" purchases have supported 450 MW in existing and planned renewables nationwide over approximately four years of activity.[12] Existing wind and geothermal plants have been the workhorse energy sources in supplying green power, with wind and to a lesser extent biomass (particularly landfill gas) serving as the technologies of choice for new installations.

Competition based on better services also could benefit renewables, particularly for those customers who demand greater reliability in electricity supply. These customers typically cannot afford power blackouts and brownouts due to sensitive computer equipment, high-revenue business operations that can come to a halt or the need for essential services such as medical care. "Distributed" renewables such as solar PV and small wind turbines are two parts of the burgeoning distributed energy market. For example, power interruptions in San Diego during Summer 2000 spurred a consumer run on PV, as well as innovative building design such as residential subdivisions consisting of PV-integrated homes. Overall, observers in the California market have witnessed demand that is outstripping available supply, with the potential for over 10 MW in sales in that state alone in 2001.

Due to the confluence of state energy policies, environmental drivers and consumer choice, renewable energy capacity should continue to grow throughout the United States. (See Table 1.)

II. Overseas Trends

Renewable energy holds even greater promise thanks to overseas markets. Nations such as Japan and Germany have swiftly seized the lead in solar photovoltaic markets, both as suppliers and consumers. The same trend has occurred in Denmark, Germany and Spain for wind power. Firms such as Kyocera (Japan) and Siemens (Germany) dominate the PV industry, while NEG Micron (Denmark) and Vestas (Denmark) now lead the global wind industry.

Beyond the developed world, developing nations are buying more renewable energy to meet energy needs. Geothermal energy is an important source of power in Indonesia, the Philippines and Central America. India and China have made significant commitments to new wind energy facilities. And India, in addition to having a nascent solar energy industry, is applying small-scale biom-

Table 1. Renewable Energy Growth in the United States
(In MW)

Technology	Installed Capacity (Latest Year with Data)	Previous Year Installed Capacity	% Growth from Previous Year
Solar including PV	365 (1998)	334	9%
Wind	3,804 (2001)	2,554	49%
Biomass	7,367 (1998)	7,676	-4%
Geothermal	2,917 (1998)	2,853	2%

Source: Wind data from correspondence with Kathy Belyeu, American Wind Energy Association. All other data from U.S. Energy Information Administration (EIA). *Renewable Energy Annual 1999*. Washington, DC, March 2000. DOE/EIA-0603(99). Biomass data includes wood and wood waste, agricultural waste, straw, digester gas, paper pallets, methane, waste alcohol, tires, fish oils, sludge waste and tall oil. It does not include municipal solid waste and landfill gas.

ass energy technologies to supply gas and power to its many villages located far from electricity distribution networks.

Overseas trends listed above have contributed to impressive growth in the renewable energy industry, as Table 2 indicates.

The totals for the United States and overseas show that renewables are growing—in particular, wind in the United States and PV and wind overseas. Biomass and geothermal are also likely to grow due to their ability to run as often as fossil fuel plants and therefore provide "baseload" power. The figures also indicate that renewables are not yet a significant portion of electricity supply in the United States and worldwide. In fact, renewable energy provided just 2.4% of electricity in the United States in 1999, and 1.6% of electricity worldwide in 1998.[13]

But these percentages mask the absolute growth of the industry and what renewable energy's potential means for jobs and economic development. For example:

- The global PV industry earned $1.3 billion worldwide in 1997, with the U.S. PV industry collecting $380 million.[14]

Table 2. Renewable Energy Growth Worldwide
(In MW)

Technology	Total Shipments/ Installed Capacity in Most Recent Year of Data[a]	Shipments/Installed Capacity in Previous Year of Data	Annual Growth (in %)[b]
PV	288 (2000)	201 (1999)	43%
Wind	17,300 (2000)	13,500 (1999)	28%
Biomass	14,000 (1998)	N/A	N/A
Geothermal	7,974 (1999)	6,797 (1995)	3%

a. Annual shipments data pertains to PV, for which reliable data on global installed capacity is unavailable.
b. Annual growth for geothermal is extrapolated from 1995 and 1999 annual data, and assumes constant growth between 1995 and 2000.

Source: PV data from Worldwatch Institute. *Vital Signs 2001*. New York: W.W. Norton & Co., 2001. Geothermal data from Geothermal Energy Association website, www.geotherm.org/wwfacts.htm, viewed December 1, 2000. Wind data from AWEA (see Table 1). Biomass data from U.S. DOE Biopower program website, www.eren.doe.gov/biopower/basics/ba_bmo.htm, viewed December 1, 2000. Geothermal data from John W. Lund. *World Status of Geothermal Energy Use: Overview 1995-2000*. Geothermal Resources Council, October 2000.

- The global wind industry is expected to sell $3.8 billion in equipment in 2001. In the United States, investors will pour $1 billion into projects in 2001.[15]

- In 1995, the U.S. geothermal industry paid out $150 million in payroll.

- According to the U.S. DOE, the U.S. biomass power industry represents $15 billion in cumulative investments.[16]

One conclusion is clear: there is money in the renewable energy industry, which is poised to grow both domestically and through export markets. At the same time, the industry is young enough that its early entrants can win today and in the future. While renewable energy will likely not provide more than 10% of the nation's energy within the next 10 years, market growth is very real. For American labor, that means jobs.

PART FOUR. LABOR REQUIREMENTS FOR RENEWABLE ENERGY

I. Methodology Behind the Labor Estimates for Renewables

Up to now information on the particular skills and associated hours required to build renewable energy facilities has been difficult to find. The following analysis estimates both skills and associated person-hours for two examples of cleaner "central-station" power plant operations—wind and biomass co-firing—and one example of clean, distributed energy—PV.

The studies for wind and PV are based upon surveys of the wind and PV industries. The surveys were conducted by phone and written communication. Whenever possible, more than one firm served as the basis for labor estimates for each industry activity. Only firms with operations in the United States were contacted, and only operations in the United States were surveyed.

The biomass co-firing study is based upon surveys of existing biomass energy projects as well as a literature review. The former includes surveys of co-firing projects. It also includes projects that are not co-firing projects, such as power plants that are dedicated to using biomass resources. The reason for this approach is biomass co-firing's relative infancy in the United States, which precludes wide-ranging surveys of firms within a mature market offering a good indication of labor requirements in the near future. Because co-firing projects are so few, it will take more time to see what kind of operations will fare well and in a sustained manner. The sources of the literature review are cited in the biomass co-firing section.

This study estimates the following jobs for wind and PV:

- Manufacturing of all finished parts to be incorporated in power plant

- Delivery of goods to power plant

- Construction/installation of power plant, including project management

- O&M of power plant for 10 years

For biomass co-firing, this analysis looks at the following over 10 years:

- Cultivation and collection of biomass fuel

- Delivery of biomass to power plant

- Manufacturing of biomass feeder system in power plant

- O&M of power plant for 10 years

Biomass co-firing differs from wind and PV because it is dominated by fuel costs and O&M costs, rather than one-time capital costs.

This study, since it is based on surveys, differs from studies that typically run an input-output (I-O) economic model. I-O models examine economic relationships in state and national economies, and determine the impact of a certain amount of renewable energy development on jobs and revenues. I-O models do not break down renewable energy jobs by specific tasks, as this study does. I-O job estimates include direct jobs, indirect jobs (e.g., metal industry jobs created to supply wind blade manufacturing) and induced jobs resulting from the multiplier effect. The following analysis does <u>not</u> include jobs resulting from the multiplier effect or jobs for manufacturing basic inputs such as steel for wind turbine towers.

This last item, the multiplier, induces the most job creation in I-O models. The multiplier is a factor based on dollars spent by workers employed in direct and indirect jobs. This spending supports additional jobs to provide goods and services. Of course, workers in these additional induced jobs spend their money, thereby creating a new chain of job creation. The size of the multiplier is largely based on the savings rate of all the workers involved in the spending chain. By putting money away for future use, each worker chips away at the dollar that is flowing through the economy, until the dollar is depleted.

Because this study does not include induced jobs not specific to the renewable energy sector, or even just the energy sector, the total job figures reached will be lower than those reached in I-O models.

The companies included in this study provided information under the understanding that their names would not be revealed.

II. Solar Photovoltaics: Bringing in New Skills to the Electricity Sector

A. Description of Technology

Solar PV presents a strategic opportunity to skilled labor as a distributed energy technology. PV's suitability as a rooftop system means that unlike large, central-station power plants, it requires the skills of building trades, such as roofers, electricians and sheetmetal workers who up to now play essentially no role in electricity generation. By engaging workers and skills in a new sector, PV offers a fresh source of local jobs.

The following analysis relates to a PV system installed on a house. The analysis is of a fixed system, in which the PV faces one way all of the time, as opposed to a tracking system, which moves the solar panel to face the sun. The system produces power for the owner, plus it can send some power into the electricity grid, thereby becoming a small power plant feeding into the local electricity system.

The foundation of a PV system is the cell, which converts sunlight to energy. Most cells today are made from silicon, usually discarded from semiconductor manufacturing plants. When assemblers connect cells with one another and with glass and plastics, they produce a module. Since a PV system in the United States produces more electricity when it faces the south, we assume it sits on top of a mounting frame, which connects it to the roof of a building. The module is then connected to wires, which transmit power to an inverter. The inverter, which in this case is a low-voltage inverter most common to the PV market, converts direct current (dc) coming from the module to alternating current (ac) suitable to send to the electricity grid. Wires then send the ac power to the grid. A systems integrator puts the module together with the wires so it is ready for installation. An installer is responsible for setting the module on the roof, connecting it to the inverter, and connecting the inverter to the grid. A servicer then provides routine maintenance and repairs.

B. Results

Table 3 shows the hours and skills required to perform 12 different activities to construct, transport, install and service 1 MW of PV. The data is based upon interviews with 10 firms engaged in one or more of these activities. The survey specifically examined the labor requirements to create a 2-kW residential photovoltaic system, a size that is fairly representative of the systems residential customers choose to adopt and supplies a portion of their total power needs, since few customers choose PV for all power needs due to its cost.

Thus, unlike the labor figures for 1 MW of wind, the PV study reaches figures for 1 MW not by adapting data for a system larger than 1 MW, but by extrapolating based on data for a much smaller system. With this fact alone, Table 5 implicitly assumes no economies of scale between 2-kW and 1 MW. In reality, the data was obtained from PV firms participating in a domestic industry that produced 60.8 MW of PV last year. The data also includes firms serving the most active local markets in the United States, so it is based on the existence of a substantial market with some economies of scale for manufacturing and distribution. Thus, Table 2 does include current economies of scale in its estimates.

Table 3. Labor Requirements Per Megawatt of Photovoltaics[a]
(in hours)

Project Activity	Occupational Category									TOTAL by Project Activity
	Prof, Tech & Manage (0/1)	Clerical & Sales (2)	Service (3)	Agri, Fishery, Forestry (4)	Process-ing (5)	Mach. Trades (6)	Bench-work (7)	Struc-tural Work (8)	Misc. (9)	
Glass	50				50	50			50	200
Plastics	50					250				300
Silicon	1,550	200	200		3,300	200	200			5,650
Cell Manufacturer	800				1,600		600	50	150	3,200
Module Assembler	3,500				1,600		8,250	750	6,850	20,950
Wires	150					1,700				1,850
Inverters	750				1,000	1,000	1,000	1,000		4,750
Mounting Frame	500	500				150	100	150	100	1,500
Systems Integration	8,900	2,850								11,750
Distributor Contractor/	1,500	1,500							1,000	4,000
Installer	2,500							8,000		10,500
Servicing[b]	5,000									5,000
TOTAL by Occupation	25,250	5,050	200	0	7,550	3,350	10,150	9,950	8,150	69,650
TOTAL Person-Years	12.9	2.6	0.1	0	3.9	1.7	5.2	5.1	4.2	35.5[c]

a. Figures derived from a survey to determine labor requirements for a 2-kW residential PV installation.
b. Includes servicing for ten years of operation.
c. Totals for person-years do not add up due to rounding.

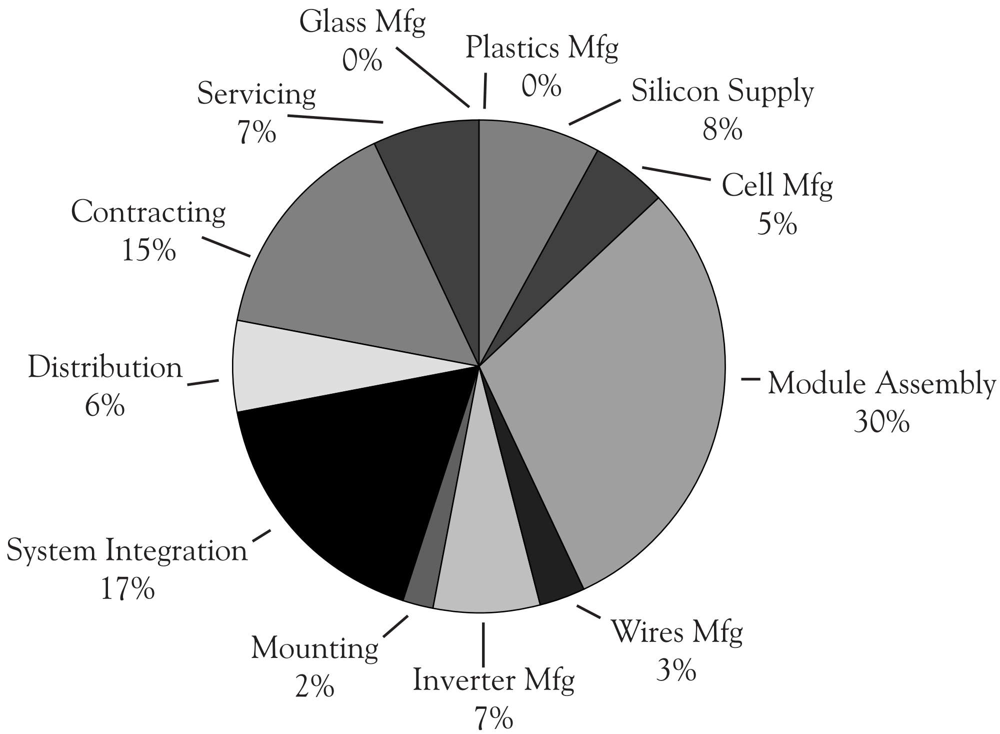
The data shows that 1 MW of PV relies upon 69,650 hours of labor. This translates into approximately 36 person-years, assuming 49 weeks of labor at 40 hours per week and three weeks of vacation and sick leave. The leading activity is module assembly. Systems integration and installation are the second and third leading activities, respectively. Figure 1 shows the relative job impacts of different components in a PV project.

The leading occupations, as classified in one-digit occupational codes published by the U.S. Department of Labor (DOL), are professional, technical and managerial work, benchwork and structural work.

C. Trends Affecting Labor Intensity in the Future

The PV industry is ripe for change in manufacturing, assembly, distribution and servicing, due both to technology development and economies of scale. Technology

Figure 1. Labor Requirements for PV According to Activity



development includes more automated manufacturing systems. For example, thin film PV involves a process of depositing silicon between a glass substrate and electrical contact that makes it easily amenable to automated manufacturing.

Economies of scale feature greater production that induces lower unit production costs. Lower costs occur because of greater labor specialization, marginal increases in output from a facility that don't require significantly more capital investment, additions to a supply chain that do not require much more investment upstream (e.g., adding a new factory without having to investment in new silicon supplies) and many other factors.

Larger regional and local markets can greatly reduce the labor requirements for distribution, installation and servicing. The reduced labor needs result from the proximity of systems and more efficient installation and servicing shifting the industry away from custom projects to more standardized ones with common configurations, procedures and staffing that make what was previously complicated more routine.

One study estimates that for every doubling of PV production, there is a corresponding reduction in the price per installed Watt of 18%. While the study is solely based upon empirical data, there are several industry factors that help explain the trend. First, the efficiency of energy conversion (i.e., sunlight to electricity) by PV cells has improved tremendously and is expected to improve even more in the future. Second, economies of scale have nurtured the construction of larger manufacturing plants with lower production costs. Third, the labor intensity in manufacturing has dropped. For example, according to labor data from U.S. Energy Information Administration (EIA), labor intensity for PV cell and module manufacturing in the United States dropped 48% from 1993 to 1998.[17]

Since the U.S. PV industry—especially those firms that integrate, distribute, install and service PV systems—is fairly immature, economies of scale will play a significant role in reducing PV costs, expanding PV markets and impacting the labor intensity of PV. Several trends should occur in the future:

- Labor intensity in manufacturing should continue to drop due to automation and newer, larger factories, such as the new plant in Perrysburg, Ohio capable of producing 100 MW of PV per year.

- The cost and labor requirements for systems integration should drop with the rise of standardized PV system packages.

- There will be lower servicing needs due to more reliable systems.

III. Wind Power: New Jobs in a Boom Market

A. Description of Technology

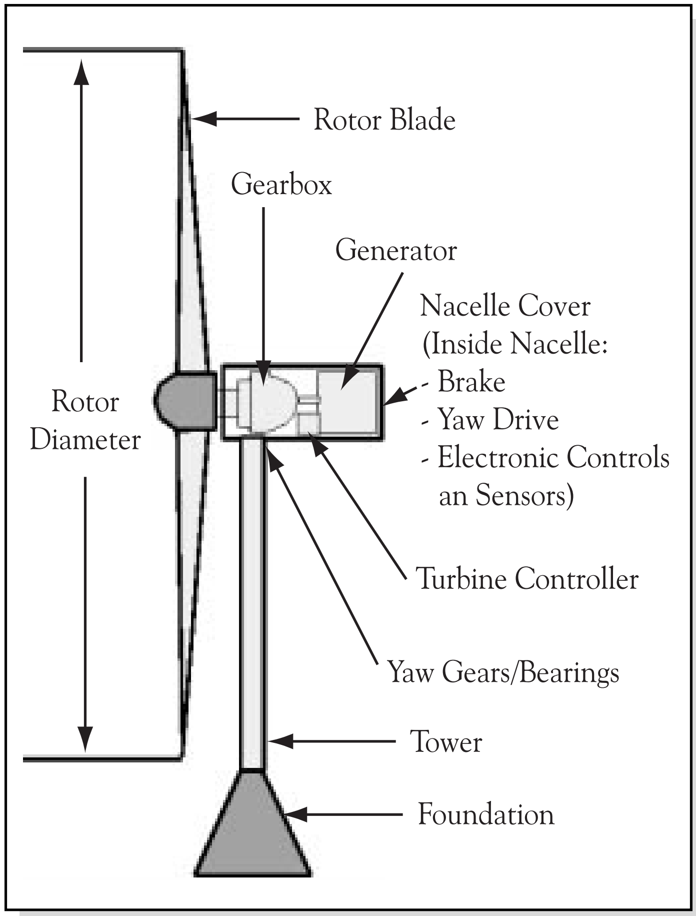
Much of the labor requirements for wind power relate to the manufacturing and assembly of wind turbine components. The components work together in the following manner (See Figure 2.):

The blades of a wind turbine connect to a rotor hub. The rotor hub connects to a drive train consisting of a gearbox, a generator, shaft and couplings, all of which convert the energy of the moving rotor hub into electricity. Electronic controls manage the rotation of the blades in reaction to changing wind directions and speed, thereby regulating power output and, in the case of excessive winds or some other need to shut off power production to stabilize the voltage of the grid, shutting off power production by employing a brake. A nacelle is the pod that covers the entire drive train. A tower props up the blades and nacelle.

B. Results

Table 4 shows the hours of labor required to perform 15 different activities to manufacture, transport, install and service 1 MW of wind power. The data is based upon interviews with 19 firms engaged in one or more of these activities. The survey specifically examined the labor requirements to create a 37.5-MW wind farm, a size that EPRI and U.S. DOE consider to be fairly representative of new farms. As of January 2001, of the 38 new projects for which the American Wind Energy Association stated

Figure 2. Horizontal-Axis Wind Turbine



a capacity, 17 (45%) were between 20 and 60 MW. It is assumed that the facility is near a high-voltage transmission line required to send power to customers. Thus, new transmission line construction is not included. Also not included, due to lack of data, are labor requirements for transformers, hydraulics and safety equipment.

The table indicates that 1 MW of wind power installed and operating for one year supports 9,500 hours of labor. This translates into approximately four person-years, assuming 49 weeks of labor at 40 hours per week and three weeks of vacation and sick leave. The leading activities in job creation are blade manufacture, installation, tower manufacture and gearbox manufacture. The leading occupations, as classified in one-digit occupational codes published by the U.S. DOL, are structural work, machine trades, professional, technical and managerial work and benchwork. Figure 3 depicts the share of jobs according to components in a wind project.

Table 4. Labor Requirements Per Megawatt of Wind[a]
(in hours)

Project Activity	Occupational Category									TOTAL by Project Activity
	Prof, Tech & Manage (0/1)	Clerical & Sales (2)	Service (3)	Agri, Fishery, Forestry (4)	Process-ing (5)	Mach. Trades (6)	Bench-work (7)	Struc-tural Work (8)	Misc. (9)	
Transportation	20	20							120	160
Blades	400					670	670	670		2,410
Couplings	40					160		10		210
Brakes	60					320		10		390
Monitoring/ Controls	70	50	50		30		270			470
Gearboxes	190	10	10			250	60	80		600
Rotor Hubs	10				80	80				170
Generators	40					190	110	40		380
Towers	100					110	30	550		790
Nacelles	70							380	20	470
Turbines	60							310		370
Development	120									120
Installation								530	530	1,060
Servicing[b]	300		1,600							1,900
TOTAL by Occupation	1,480	60	1,660	0	110	1,780	1,140	2,580	670	9,500
TOTAL Person-Years	0.7	0	0.7	0	0.1	0.9	0.6	1.3	0.3	4.8[c]

a. Figures derived from a survey to determine labor requirements for a 37.5-MW wind facility.
b. Includes servicing for ten years of operation.
c. Totals for person-years do not add up due to rounding.

Applying the results to real world scenarios results in the following:

- A 37.5-MW wind farm would create over 356,250 hours of work, or 180 person-years.

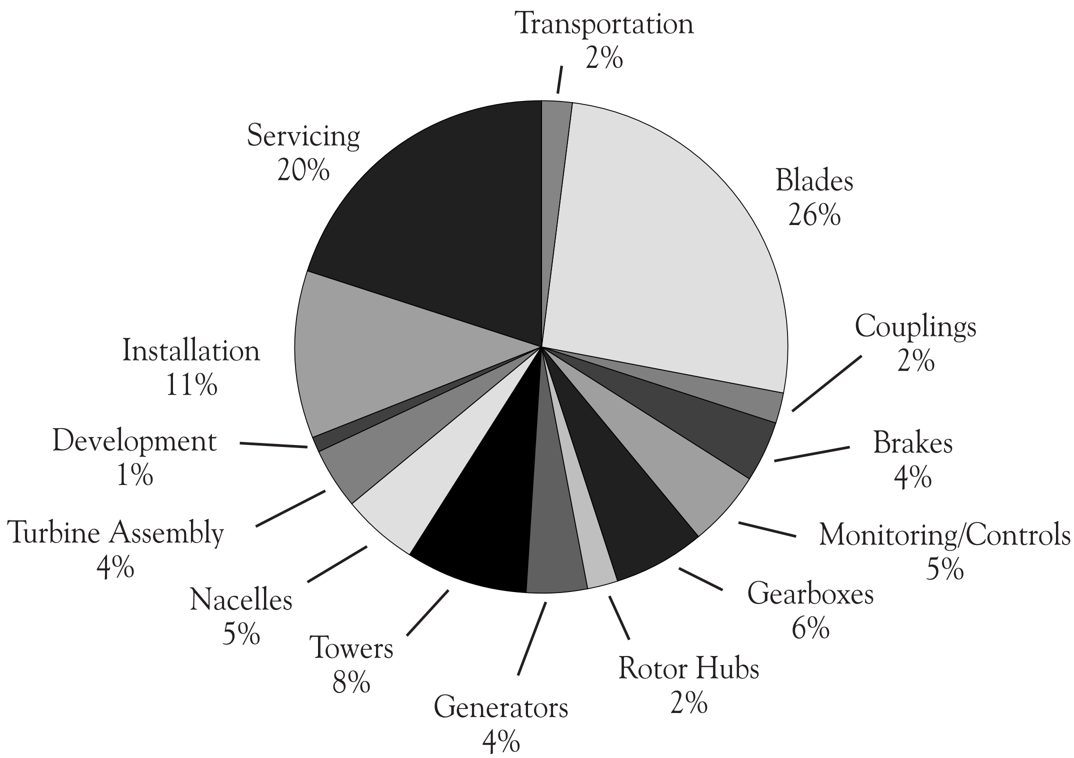
- 2,000 MW of wind power, as is expected in Texas shortly, will create 19 million hours of work, or 9,694 person-years.

To help assess the many economic development aspects of wind farms, Box 3 provides data from two case studies in Iowa and Minnesota.

C. Trends Affecting Labor Intensity of Wind in the Future

Applying the figures in Table 3 to future growth in the wind industry should be done with caution. As industries mature and reduce costs, labor is usually one factor

Figure 3. Labor Requirements for Wind by Activity



of production that is affected by technology trends and economies of scale.

Technology trends. EPRI and the U.S. DOE expect several technology trends that may actually increase labor requirements per unit of wind power. By 2005, they expect higher installed costs due to larger wind turbines, which feature higher towers, larger rotors, higher-performance generators, larger "balance of system" components (including substations, shipping and control and monitoring equipment) and larger blades. (Improved blade

Box 3. Economic Benefits of Two Wind Farms in the Midwest

Iowa wind farms. Not including the labor required to manufacture parts for wind turbines and wind farm support, the 240 MW of wind capacity installed in Iowa in 1998 and 1999 produced: 200 six-month-long construction jobs and 40 permanent maintenance and operations jobs, $2 million per year in tax payments to counties and school districts and $640,000 per year in direct lease payments to landowners.

Lake Benton, Minnesota wind farms. Not including the labor required to manufacture parts for wind turbines and wind farm support, the 143 wind turbines in the 107-MW Lake Benton I project, installed in early 1998, brought $250 million in investment and 10 full-time jobs to Lincoln and Pipestone counties, the poorest in Minnesota. Lake Benton's director of economic development says that each 100 MW of wind development generates about $1 million annually in property tax revenue. [18] Additionally, farmers hosting a wind farm on their property through leasing plans can expect $40 to $55 per acre per year revenue on top of earnings from farming or grazing, with the wind turbines occupying only a small fraction of their land. [19]

manufacturing techniques may offset the heavier labor requirements for larger blades.)

After 2005, EPRI and U.S. DOE expect technology trends to reduce labor requirements due to R&D advancements. Trends include:

- A reduction in custom design needs for blades, thereby cutting blade costs by 10% for every doubling of volume
- Advances in rotor manufacturing
- Reduced O&M needs for wind farms due to improved blade design and associated reliability improvements, as well as larger turbines
- Small improvements in manufacturing and design costs for generators

In 2010, the following components will represent a greater percentage of total initial project capital cost compared to 1996: rotors, towers and generators. Jobs in the manufacture of these components may accordingly rise as a share of total jobs. Power electronics and controls, brakes, nacelles and gearboxes will all drop as a share of total cost. Subsequently, jobs in the manufacture of these components may drop as a share of total jobs.

Economies of scale. Economies of scale can take place in the manufacturing sector as well as at the wind farm itself. For wind, the best example of economies of scale is the addition of wind turbines to an existing wind farm. The new turbines, unlike the original turbines, would not have to follow an extensive siting process including wind assessments and environmental impact analyses, nor would they require the construction of roads, grading, fences and wind farm monitoring equipment, as the original turbines would have required. Thus, the cost of the new installation would be lower in terms of installed capacity, as well as power production. According to EPRI and U.S. DOE, increasing the size of a 50-MW wind farm to 200 MW would cut the cost of installed capacity by 10%.

EPRI and U.S. DOE expect economies of scale will cut the cost of installed wind capacity. Of the cost reductions expected per installed MW of wind power between 1996 and 2030, economies of scale may represent 50% to 75% of the reduction, with research and development (R&D) accounting for the remainder. Economies of scale will reduce costs per installed MW for all wind components, except for towers. Thus, economies of scale may have a downward effect on jobs for the manufacture of all components other than towers.

IV. Biomass Co-Firing: Reducing Air Pollution From Existing Power Plants

A. Description of Technology

Biomass co-firing is a renewable energy option that uses existing fossil fuel power plants. Therefore, co-firing's direct labor benefits will be less than those for wind and PV, since the power plant is already built. Its unique, indirect benefit is in replacing fossil fuel power generation without eliminating the infrastructure that lies behind it. Thus, co-firing can be seen as akin to a pollution control measure for coal power plants—it does not eliminate the plant itself, but when integrated into its operations, it can reduce the environmental impact of the plant.

That said, co-firing relies on a unique infrastructure of biomass collection, transportation and energy conversion. This labor study examines the direct labor benefits of each of these steps. The study examines several kinds of biomass that are amenable to co-firing. They can be grouped into two categories:

Residues and wastes. Co-firing can take advantage of several byproducts of lumber and agricultural processes, as well as urban-based activities. This labor analysis looks at three specific types of waste:

- *Mill residues* from paper, lumber and wood products operations. Many wood products industries have chippers or hammermills to produce chips from large residues. Some residues such as sawdust are already fine enough for co-firing.
- *Urban wood waste* found in municipal, commercial and industrial solid waste. Urban wood waste encompasses a diverse array of wood byproducts. It is essential to sort waste streams so that power plants burn acceptable, non-toxic forms of biomass, such as pallets, used railroad ties and shipping containers.

- *Silvicultural wood waste* in the form of forest thinnings generated through forest management (e.g., prevention of catastrophic forest fires) and commercial operations. Government agencies and forest companies commonly chip the waste on the site of their operations. Specialty companies that collect various forest products can also chip the waste at wood yards. This form of biomass has aroused controversy among environmentalists concerned about logging, but has also elicited support from parties focused on reducing catastrophic forest fires.

This analysis does not look at a fourth and important form of waste—agricultural residues such as orchard prunings and corn stover—due to time and financial constraints.

Energy crops. Farmers can also grow biomass fuel on plantations. This study looks at three crops—poplar, willow and switchgrass—that are the focus of research, demonstration and commercialization programs funded by the U.S. DOE. Both poplar and willow are tree crops, while switchgrass is a herbaceous crop. Biomass collection in this instance includes all of the activities associated with agriculture, such as field preparation, planting, crop maintenance and harvesting.

Once a farmer, government agency or private firm prepares the biomass, truckers then haul it to the power plant. The general economic rule is that a trucker should not travel more than 50 to 75 miles from the biomass source to the power plant, or else the biomass will become unduly expensive for power generation. This analysis assumes that two truck drivers can deliver eight vans with 25 tons of biomass each in a 10-hour shift.

Finally, the biomass arrives at the coal power plant. There, plant operators unload, stockpile and process the biomass before conveying it to the power plant. Once the biomass is ready for combustion, the power plant operator has two options: mix the biomass directly with the coal and then send the mixture to a boiler for combustion, or run a parallel feeding system that conveys the biomass through a separate boiler for combustion. Today, the second option is most likely, since running biomass along with coal into the same boiler can reduce the capacity of the boiler over time, thereby reducing total electricity output. Thus, this study assumes a separate system that sends crushed biomass pneumatically to biomass burners for combustion.

B. Results

Table 5 shows the direct labor requirements for co-firing six different biomass fuels. The data is based upon a variety of published studies, interviews with utilities and companies and surveys of existing operations. (See Appendix A for information on sources for the biomass co-firing study.) Unlike wind and PV, there are few biomass co-firing projects nationwide, so this labor study relies more on studies of project scenarios, rather than surveys of firms within a well-developed industry.

The table indicates that 1 MW of biomass co-firing capacity over 10 years would employ three to 21 person-years, with a median of 13 person-years. Switchgrass represents that high end. Mill residues and urban wood wastes represent the low end. This is not surprising, since energy crops are considered to be the most expensive form of biomass, though also potentially the most plentiful. Urban wood waste and mill residues are typically the cheapest forms of solid biomass, and the biomass that would be the first to be used in growing biopower markets.

For energy crops and silvicultural wood waste, farmers (for energy crops) and logging equipment operators (for silvicultural wood waste) garner the most work, with the relative labor requirements for truckers and plant operators depending upon project-specific conditions. Truckers are the most frequently employed workers for co-firing mill residues. For urban wood waste, relative labor requirements among different occupations vary according to project-specific conditions.

The survey summarized above does not include the manufacture of biomass feed systems. According to EPRI and U.S. DOE, the capital cost for a separate biomass feed system is about $200 per kW of power generated from co-fired biomass.[20] This translates into $200,000 per MW. If we assume that labor costs equal 20% of the system's total cost, then the labor benefits for a MW-equivalent feeder system is $40,000 or 80% of the loaded cost of one worker for one year (assuming a $50,000 loaded labor cost per full-time employee, including benefits and employer tax requirements). A biomass feeder that enables a 100-

Table 5. Labor Requirements Per Megawatt of Biomass Co-Firing Over Ten Years[a]
(in hours)

Activity	Fuel					
	Switchgrass	Poplar	Willow	Silvicultural Wood	Mill Residues	Urban Wood Waste
Growing, harvesting and/or preparing – Farmers unless noted	0.22 to 0.36	0.26 to 0.35	0.17	0.22 (Logging equipment operators)	0	0.012 to 0.157 (Management, equipment operator laborers)
Transport – Truck Drivers	0.08	0.06	0.051	0.057 to 0.111	0.057 to 0.065	0.065
Receive, inspect, store process and convey at power plant – Mobile and fixed equipment operators, record keeping	0.010 to 0.118	0.010 to 0.118	0.010 to 0.118	0.010 to 0.118	0.010 to 0.118	0.010 to 0.118
TOTAL (in hours/MWh)	0.31 to 0.558	0.33 to 0.528	0.231 to 0.339	0.287 to 0.449	0.067 to 0.183	0.087 to 0.34
TOTAL (in hours/MW)	2,301-4,144	2,450-3,921	1,715-2,517	2,131-3,334	498 1,359	646 2,525
Total Person-Years per MW	1.2-2.1	1.3-2	0.9-1.3	1.1-1.7	0.3-0.7	0.3-1.3
TOTAL Person-Years per MW over 10 Years[b]	12-21	13-20	9-13	11-17	3-7	3-13

a. Hours are for one year of operation.
b.Does not include jobs associated with manufacturing biomass feeder systems.

MW coal power plant to co-fire biomass at 5% of total heat input would therefore support approximately four full-time employees for one year, assuming no economies of scale tied to the size of the feeder.

When the labor requirements for manufacturing feeder systems are considered, the range of total full-time employees rises in the first year of the co-firing operation by 0.8 person-years per MW (0.011 person-years per MWh for the first year of operations), so that the range is 3.8 to 21.8 person-years over 10 years.

C. Trends Affecting Labor Intensity of Biomass Co-Firing in the Future

According to EPRI and U.S. DOE, increased yields will reduce the land required for energy crops over time, even with greater levels of biomass co-firing. EPRI and U.S. DOE assume an 83% linear increase in yields from 1997 to 2020. This trend should reduce the labor requirements for biomass collection, though the extent of the reduction is unclear.[21]

Since biomass co-firing is still in its infancy commercially, the labor results above differ from those for wind and PV in that they rely heavily on technical studies and projections by utilities and companies that have recently begun co-firing projects or are considering them. Therefore, it is difficult to say what opportunities for technological innovation are available at this time. Once projects are running and learning accelerates, such opportunities will become more evident.

Economies of scale should affect the labor requirements for power plant operators. If co-firing occurs at higher volumes, we assume that labor requirements for unloading, stockpiling and conveying the biomass will not rise proportionally. However, the extent of reduced labor requirements is unclear.

V. Summary of Results

Table 6 summarizes the labor requirements for solar PV, wind and biomass co-firing.

Table 6. Labor Requirements for Renewable Energy Technologies

Technology	Scale	Person-Years per MW
Solar PV	Commercial retail operation selling 2-kW systems	35.5
Wind	37.5 MW	4.8
Biomass Co-Firing	100-750 MW (see Appendix A)	3.8-21.8

a. Assumes capacity factors of 18% for PV, 30% for wind and 80% for biomass co-firing.

With the above estimates in mind, the analysis now turns to comparing the labor requirements of renewables with the dominant source of power in the United States—coal-fired power plants.

PART FIVE. A COMPARISON WITH COAL POWER

I. Comparison Between Coal, Wind and PV

This section compares the labor requirements of wind, PV and biomass co-firing with coal-based power. The comparison between wind, PV and coal is based on expenditures. This metric connects jobs with investments in electricity generation. If policymakers are to understand the job implications of different policies to stimulate investment in new power plants, they need to understand what jobs a dollar can support when channeled to different power options.

Coal provides over half of the U.S. electricity supply and represents the old guard of the national electricity infrastructure. However, with natural gas prices rising and falling sharply throughout the United States and expectations of lower natural gas yields in North America in the future, it is highly likely that many utilities will turn to new coal plants to meet future electricity needs.[22] For this comparison of coal with wind and solar energy, we examine the labor requirements for manufacturing coal plant hardware, building the plant itself, operating and maintaining the plant for 10 years, mining coal and transporting coal to the plant.

The methodology for estimating coal power jobs is not an industry survey. Rather, it is based on model plant economics, data from the U.S. Census and other federal sources, and spreadsheet-based modeling. Appendix B summarizes the assumptions and data underlying the jobs assessment for coal power.

Figure 4 shows the results of the comparison. The figure shows that both wind and PV provide more than 40% in employment than coal. Note that PV does not include potential jobs losses from the reduced need for transmission lines. Even if transmission is included in the analysis, PV would likely employ more people than a central-station coal power plant.

Figure 4. Comparison of Coal, Wind and PV (In Person-Years Per $1 Million in Cost Over 10 Years Including Capital and Construction)

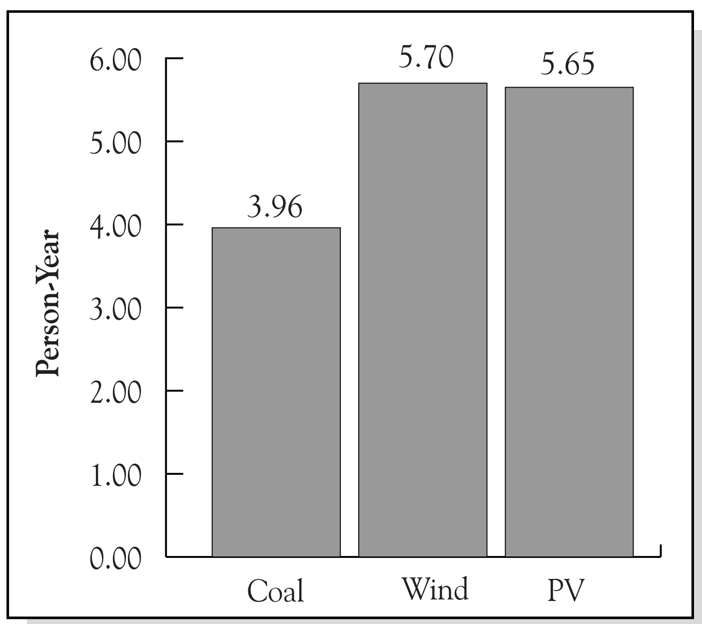
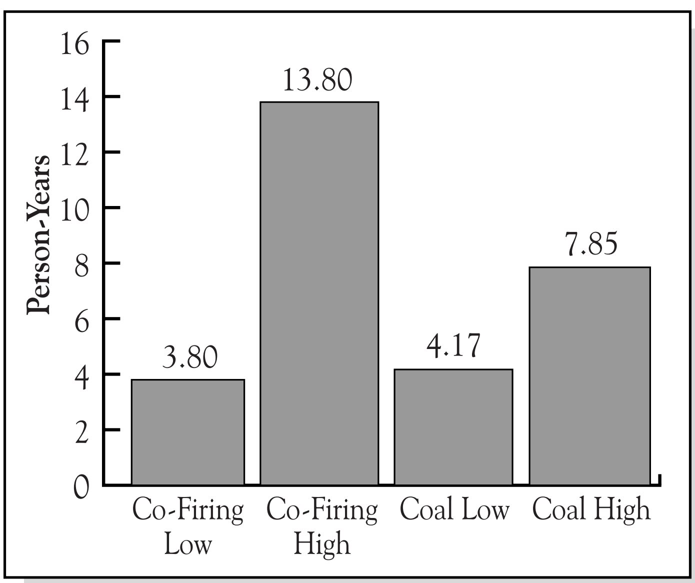


Figure 5 compares jobs for coal versus jobs for biomass co-firing at existing coal plants based on electricity output. We examine electricity output as opposed to expenditures because there is a wide range of potential market values for different forms of biomass that are difficult to associate with the job ranges reached in Table 5. The co-firing estimates include biomass collection, transportation and handling at the plant, plus manufacture and installation associated with a new feeder at the plant site.

The coal estimates include coal mining, transportation and handling at the plant. They do not include the feeder, since it is assumed one is already present at existing plants. The range of coal jobs reflects a range of plant-site job values as a percentage of total job requirements equal to the range plant-site job values for co-firing as a percentage of total job requirements (i.e., 21% to 58% of total job requirements over 10 years are plant-site jobs).

The results show that co-firing will tend to employ more workers than coal-only operations. In some cases, such as the use of energy crops and certain operations involving all other forms of solid biomass examined here, there is the potential for biomass to employ many more workers. In a more limited range of scenarios (i.e., low-labor scenarios for urban wood waste and mil residues), coal can employ more workers. Since the range of co-firing job requirements reflects ranges within different biomass feedstock (e.g., ranges for transportation of forest and mill residues, growing and collection of different energy crops, etc.), it is difficult to say definitively whether one source of biomass will lead to higher labor requirements than other sources of biomass.

Figure 5. Biomass Co-Firing Versus Coal Mining, Transport and On-site Preparation (Total Person-Years Per 1,000 Megawatt-Hours)



II. Coal Mining Trends

The above comparison includes manufacture, installation, operations, maintenance and fuel for the first 10 years of operations. When compared to wind, PV and certain biomass co-firing scenarios, coal appears to employ more workers for O&M and fuel operations. However, an important component of this labor—coal mining—has drastically become less labor intensive. Coal mining firms have steadily reduced labor needs by shifting from unionized, labor intensive operations in the East to surface mining operations in the West, particularly in Wyoming. In the East, firms are also engaging in mountaintop removal—a form of surface mining—rather than traditional underground mining. Table 7 shows job loss and greater productivity in the coal mining industry from 1988 to 1998 and predicts another 36% drop in coal mining jobs from 1998 to 2008.

Table 7. Fewer Jobs and Greater Productivity in Coal Mining

Data	1988	1998	2008	% Increase in Output Per Employee: 1988-2008[a]
Employment (in 1,000s)	151	92	59	19%
Rate of Job Loss		39%	36%	

a. Based on dollars of output associated with each employee.
Source: REPP with data from Bureau of Labor Statistics, *Employment Projections—Industry Data*. ftp://ftp.bls.gov/pub/special.requests/ep/ind.employment/indout4.txt., viewed December 5, 2000.

Thus, it is almost certain that labor intensity for coal power will continue to drop. Based on the results of this analysis, coal mining represents 46% of all non-manufacturing jobs associated with coal power—that is, mining, transportation and plant O&M jobs for coal plants. A 36% drop in coal mining labor intensity alone in 10 years will cut total labor for both fuel and O&M by 17% in 10 years.[23]

PART SIX. WHAT CAN ORGANIZED LABOR BRING TO THE RENEWABLE ENERGY INDUSTRY?

The labor estimates in the previous section point to a nascent industry that can become a significant source of jobs in the United States. While renewable energy has important labor benefits, labor—particularly organized labor—also brings important benefits to the renewable energy industry. This section outlines two of these benefits.

I. Certified Skills

While the number of renewable energy installations grows, questions about the installations' quality and performance continually arise. Skepticism, particularly for small-scale, distributed renewables, stems primarily from the early experiences of the industry. In particular, the boom market for solar water heaters and wind energy in the 1980s, fed by generous government tax credits, was followed by a sharp contraction in the industry as incentives disappeared and without such incentives, project developers lost interest in projects.

Fortunately, the renewable energy industry today is typified by firms that sell products certified by nationally recognized standards groups such as Underwriters Laboratories and the Institute for Electrical and Electronic Engineers. However, the renewable energy industry is still hampered by the lack of skilled installers and servicers. For example, the PV industry lacks a nationwide network of technicians with skills certification specific to PV. In many cases, electricians and roofers can be so unfamiliar with PV that they discourage potential PV buyers in order to avoid the trouble of installing PV.

Labor unions offer a ready-made resource to train and supply skilled technicians who can confidently suggest PV options to potential customers, and then install and service renewable energy systems. The very existence of union technicians who understand renewable energy technology could erase consumer skepticism.

Training funds within labor unions tower above the funds that renewable energy firms can marshal to develop a skilled technician force. For example, unions that are members of the AFL-CIO's Buildings and Construction Trades Department spend over $500 million annually on training in 2,000 training centers across North America. The department estimates that 180,000 apprentices (new workers) and thousands of journeymen (experienced workers) receive training each year.[24] Overall, the U.S. DOL's Bureau of Apprenticeship and Training estimates that 431,797 U.S. apprentices received registered apprenticeship training in 36,903 programs in 1999.[25]

Union training programs garner respect among corporate managers and consumers by submitting curricula to federal standards for quality. In particular, for union apprentice programs to produce nationally recognized journeymen, they must register with the U.S. DOL, which registers only those programs meeting federal standards.[26] Since the U.S. DOL consults with employers as well as unions on apprenticeship standards, renewable energy firms can actually help shape programs that bring the most benefits to their industry.

II. Marketing Benefits

Workers who are trained to install technology will encourage consumers to buy that technology. Conversely, those who do not understand a technology will either discourage or at least be too ambivalent to help a consumer with an interest in renewable energy. For the PV, solar water heater or geothermal heat pump industries, the reliance on a far-flung network of technicians without institutional training programs—and therefore with limited understanding of these technologies—has certainly cut sales and industry growth, though it is impossible to determine to what extent.

Beyond knowledgeable technicians who are ready to get a job done, skilled labor offers other marketing benefits. For example, union-made products receive the "Union Label" that unions promote to consumers. The AFL-CIO houses a Union Label and Service Trades Department to market products with the Union Label at fairs, on television and through newsletters and union member outreach. A label on renewable energy products such as voluntary "green power" offers will only strengthen their appeal to consumers who have different criteria for judging products. The label could be particularly important in states in the Midwest, Northeast and Far West that have strong union representation in the workforce. For example, as green power markets grow throughout the United States, union involvement in renewable energy projects supplying power could lead to "blue-green power" that is appealing to union members and other Americans concerned about preserving family-wage jobs.

CONCLUSION

Both labor unions and the renewable energy industry have good reason to work together. Renewable energy such as solar, wind and biomass offer a diverse array of jobs. They also offer more jobs per dollar than coal power. Labor unions' ability to bring skills and recognition to the renewables sector should complement other market, technology and policy trends that point to the continued growth of renewable energy in the United States

APPENDIX A. INFORMATION SOURCES AND ASSUMPTIONS FOR BIOMASS CO-FIRING STUDY

Growing, Harvesting and Preparing

- Data for energy crops is based on Oak Ridge National Laboratory's BIOCOST program, an "Excel-based program with a graphical interface that lets the user select a region and then specify values for several variables including expected yields, land rents, labor costs, and chemical, fertilizer, fuel, and planting stock prices. The user can also choose among several key management options." (Quote from bioenergy.ornl.gov/papers/misc/biocost.html)

- Data for silvicultural wood is based on a typical whole tree chipping operation in the Northeast where a crew consisting of a shearer operator, two skidder operators and a rotary chipper operator can produce 200 tons of silvicultural wood in a 10-hour shift.

- It is assumed that the labor requirement for mill residues is zero since firms producing the byproduct must manage their waste for disposal or another use regardless of co-firing.

- Data for urban wood waste is based on a survey of three types of operations: a tubgrinder at a landfill that runs 85% of the time, has a capacity of 20 to 75 tons per hour and is run by one to two operators; a large wood waste processing facility based on data provided in CONEG Policy Research Center, Inc. *Using Recycled Wood Waste as Fuel in the Northeast*; and a chipping operation at a pallet recycling facility. In the last operation, it is assumed that grinders installed at the facility have a capacity of 25 to 135 tons per hour and ground pallets have a typical density of 4.5 tons per cubic yard. An operator is present when the grinder is running, and the grinder is down for maintenance 10% of the time.

Biomass Fuel Transportation

Estimates of labor hours for all fuels, except for switchgrass, are based on two sources: Empire State Biopower Consortium, *Economic Development Through Biomass Systems Integration*. Electric Power Research Institute and U.S. DOE, 1995, and "Silvicultural Wood Waste," a survey of a whole tree chipping operation. It is assumed that a truck can transport the same amount of switchgrass as wood chips—20 to 25 tons.

Power Plant Operations

Estimates of labor hours are based on interviews with staff of utilities and companies that are co-firing, have completed co-firing tests, are planning co-firing or are running a large wood-only power plant. The labor study includes several assumptions about power plant operations:

- For plants with multiple boilers, co-firing occurs in only one boiler.

- Boiler capacities ranges from 100 to 750 MW.

- The capacity factor for baseload plants is 85%.

- The capacity factor for peaking plants is 60%.

- The labor requirement in baseload plants is 12 hours per day, seven days per week.

- The labor requirement in peaking plants is eight hours per day, five days per week.

- Biomass fuels are co-fired at 5% of total heat input.

APPENDIX B. ASSUMPTIONS FOR COMPARISON OF WIND AND SOLAR WITH COAL POWER

The analysis of jobs generated by coal-fired power plants includes the following assumptions:

Coal Plant Components and On-site Activities, Not Including Operations and Maintenance

- The capital expenditure of the coal plant is $1,400 per kW, with $196 per kW devoted to financing and insurance. We only examine the labor impacts of components manufacture, plant construction, plant project management and plant engineering. We do not include financing and insurance expenditures in this analysis, so the remaining capital expenditure is $1,204/kW. (This analysis also does not include labor for financing and insurance services for wind, solar and biomass.)

- O&M and fuel expenditures average 2.94 cents per kWh per year.

- The size of the coal plant is 200 MW, while the capacity factor is 80%.

- We examine the labor created by the manufacture of the following *components*, and their share of total coal plant capital expenditures: boilers (24%), fabricated structural metal (15%), turbines (6%) and industrial controls (6%). We also examine the labor associated with the following *on-site activities*, and their share of total capital costs: construction (28%), engineering (5%) and project management (2%).

- We then estimate the average annual salary for a worker in each sector based on total payroll and employment in that sector. Payroll and employment are based on 1997 U.S. Economic Census data, with each activity associated with a Standard Industrial Classification code that best captures that activity. Where possible, this analysis found five- or six-digit SIC codes that could be linked to activities. In most cases, it employs four-digit SIC codes.

- Next, we estimate the average annual salary for all jobs associated with component manufacture and on-site activity at the plant. Annual salary is based on the weighted average of average annual salaries by sector. For example, boilers represent 27.7% of the costs of components and on-site activities (24% of total plant capital costs, with component manufacture and on-site activities representing 86% of capital costs). The average salary in the SIC code that includes boilers is $33,160, which is multiplied by 27.7% and added to the weighted averages of the other sectors to reach the average annual salary for the plant. The average annual salary for jobs associated with the coal plant is $36,116 per person-year.

- We reach a figure for the percentage of plant expenditures that goes to salaries. As with annual salaries, the percentage is based on the weighted average of average percentages by sector. Thus, for each of the components and activities above, we estimate the percentage of expenditures for each component/activity that would go to salaries, and then weight each percentage by each component/activity's share of total capital costs. Total expenditures and salaries for each sector are based on 1997 U.S. Census data. The average is 25.08%.

- Next, the percentage of expenditures spent on salaries is multiplied by the per-MW capital cost for the coal plant, financing and insurance costs excluded ($1.2 million per MW). Thus $302,000 per MW is spent on labor.

- The total payroll per MW is divided by the average annual salary ($36,116) to reach a total labor estimate for the coal plant—8.5 person-years per installed MW.

Coal Plant Operations and Maintenance (Not Including Fuel)

- To estimate labor for O&M, we assume that $13.28 per MWh is spent on O&M. With an 80% capacity factor and 200 MW of installed capacity, this translates into $18.6 million spent on O&M in the first year of the coal plant. This is equivalent to approximately $93,000 per MW.

- We then estimate average salaries and the percentage of revenues spent on salaries in SIC code 2211121—electric services for fossil fuel power generation. We apply these figures to total O&M spending in the first year to reach a labor estimate per MW—0.18 person-years. Assuming an 80% capacity factor, we estimate 0.025 jobs per 1,000 MWh.

Coal Mining

- We estimate total coal consumed by the electricity sector in 1998 and power generated by coal-fired power plants that year to reach a figure of short tons of coal consumed per MWh. Data was obtained from the U.S. EIA *Annual Energy Review 1999*. Washington, DC, July 2000. DOE/EIA-0384(99), Table 7.2 and 7.3.

- We then reach average tons of coal mined by each miner (provided in U.S. EIA's *Annual Energy Review 1999*, Table 7.6) and apply it to coal consumed per MWh to reach an estimate of miners associated with each 1,000-MWh block of power generation from coal plants—or 0.039 person-years.

Coal Transportation

- To estimate jobs associated with the transportation of coal, we first estimate the share of annual ton-miles represented by rail (95.9%), barge (3.8%) and truck (0.4%). (These percentages include proportional allocation to these three categories of 12% of total ton-miles classified by U.S. EIA as "other.") Data based on *Energy Policy Act Transportation Rate Study: Final Report on Coal Transportation*. Washington, DC: October 2000. DOE/EIA-0597(2000).

- Next, the average annual salary for transportation is reached based on a weighted average annual salary for the rail, barge and trucking sectors, using data on salaries and employment from the 1997 U.S. Economic Census. Similarly, average percentage of revenues going to labor is also estimated, with percentages within each of the three transportation sectors serving as the basis.

- We apply the above averages (i.e., for annual salary and percentage revenues spent on salary) to total revenues for shipping coal to utilities in 1995, thereby yielding labor estimates for coal transportation in 1995—30,757 workers.

- We divide the above labor estimate by total MWh generated by coal plants, according to *EIA Annual Energy Review 1999* data for 1997, to reach an estimate of coal transportation jobs per 1,000 MWh—0.02 person-years.

Wind Estimates Based on Expenditures

- For wind, we employ our estimates reached in the survey and summarized in Table 4.

- We assumed that capital cost for wind is $749,000 per MW per year, with $10,000 in annual O&M expenditures per MW. These assumptions are based on estimates for wind in 2000 in *Renewable Energy Technology Characterizations* by EPRI and the U.S. DOE. Palo Alto, Calif. and Washington, DC, 1997. TR-109496.

Solar Estimates Based on Expenditures

- For PV, we employ the estimates reached in our survey and summarized in Table 3.

- We assumed that the capital expenditures for residential PV are $6.30 per installed Watt, or $6.3 million per MW, with O&M expenditures at 0.01 cents per kWh, or $154 per MW. These assumptions are based on estimates for residential PV in 2000 in *Renewable Energy Technology Characterizations* by EPRI and the U.S. DOE. Palo Alto, Calif. and Washington, DC, 1997.

END NOTES

[1] Bureau of Economic Analysis, *Industry Accounts Data*, <http://www.bea.doc.gov/bea/dn2/gpoc.htm>, viewed November 30, 2000. This does not include the manufacture of durable goods for the industry, such as power plant equipment, which is an important component but difficult to isolate.

[2] Bureau of Labor Statistics, Employment Projections—Industry Data. <ftp://ftp.bls.gov/pub/special.requests/ep/ind.employment/indout4.txt>, viewed December 5, 2000.

[3] WEFA. *Global Warming: The High Cost of the Kyoto Protocol*. 1998. The study asserts that the U.S. would lose 2.4 million jobs from 1999 to 2010 if the Kyoto Protocol went into effect. For a brief critique of the WEFA study see James Barrett. "The High Cost of Distorted Economic Modeling." Economic Policy Institute *Viewpoints*. Posted February 22, 1999 at <http://www.epinet.org/webfeatures/viewpoints/distorted.html>, viewed July 31,2001.

[4] National Renewable Energy Laboratory (NREL). *Dollars from Sense: The Economic Benefits of Renewable Energy*. Washington, D.C.: U.S. DOE, September 1997. DOE/GO-10097-261.

[5] Electric Power Research Institute and U.S. DOE (EPRI/DOE). *Renewable Energy Technology Characterizations*. EPRI TR-109496, December 1997. Available at <http://www.eren.doe.gov/power/techchar.html>.

[6] Raymond Costello. "Biomass Co-firing Offers Cleaner Future for Coal Plants," *Power Engineering*, January 1999, as quoted in Steve Clemmer, Union of Concerned Scientists, in correspondence with Meredith Wingate, Center for Resource Solutions, April 30, 1999.

[7] EPRI/DOE, op. cit note 5.

[8] Virinder Singh. *Blending Wind and Solar into the Diesel Generator Market*. Washington, DC: Renewable Energy Policy Project, 2000. Available at www.repp.org.

[9] For example, a consumer survey by The National Conference of State Legislatures and the National Association of Regulatory Utility Commissioners found that solar scored highest among 10 electricity sources. The preferences for power closely correlated with the subjects' perception of environmental impact, with those sources with the lowest impact scoring the highest. Kenneth Winneg et al. *Summary Report, Baseline Survey Consumer Knowledge, Practices, and Attitudes, Electric Utility Restructuring and Consumer Choice*. Denver, Colo: NCSL, January 1998.

[10] Electric utilities are responsible for a quarter of all NOx emissions, two-thirds of sulfur dioxide emissions, a third of all mercury emissions and a third of all CO_2 emissions in the U.S.

[11] See Fredric Beck, Virinder Singh, Jan Hamrin, Kirk Brown and Richard Sedano. *Renewables for California: Benefits, Status and Potential*. Washington, DC: Renewable Energy Policy Project, forthcoming.

[12] Lori Bird and Blair Swezey. *Estimates of Renewable Energy Developed to Serve Green Power Markets*. December 2000. Available at <http://www.eren.doe.gov/greenpower/new_gp_cap.shtml>, viewed July 13, 2001.

[13] International Energy Agency website, <http://www.iea.org/statist/keyworld/keystats.htm>, viewed December 1, 2000.

[14] Assumes $6.25 per installed Watt. U.S. firms shipped 60.8 MW of PV in 1999. *PV News* (Paul Maycock, ed Volume 19, No. 3).

[15] 5,000 MW of wind capacity is expected worldwide in 2001, with 1,300 MW in the United States. Total cost is assumed to be $749,000 per MW.

[16] PV, wind and geothermal data from Adam Serchuk and Virinder Singh. *A Sustainable Energy Cluster for Mesa del Sol*. Washington, DC: Renewable Energy Policy Project. January 2000. Available at <http://www.repp.org>. Biomass information from U.S. DOE, <http://www.eren.doe.gov/biopower/ basics/ ba_bmo.htm>, viewed December 1, 2000.

[17] This estimate is based on labor data from U.S. EIA (Renewable Energy Annual 1999. Washington, DC, March 2000. DOE/EIA-0603(99)) and data on U.S. PV production from *PV News* (Paul Maycock, ed. Vol. 19, No. 3). According to this estimate of direct labor, the labor intensity of PV manufacture was 64 person-years per MW in 1993 and 33 person-years per MW in 1998. Note that the last figure is much higher than the figure reached in this report for cell manufacturing and module assembly—approximately 2 person-years.

[18] American Wind Energy Association (AWEA) *Wind Energy Fact Sheet*. *Wind Energy and Economic Development: Building Sustainable Jobs and Communities*. Washington, DC, viewed December, 2000 at http://www.awea.org/pubs/factsheets/EconDev.PDF

[19] NREL, op. cit. note 4. AWEA, op. cit. note 18.

[20] EPRI/DOE, op. cit. note 5.

[21] EPRI/DOE, op. cit. note 5.

[22] For more on changes in natural gas supply and price, see U.S. EIA. *U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves, 2000 Annual Report*. Washington, DC, November 2001.

[23] Coal mining represents 0.24 person-years per installed MW, while transportation is 0.18 person-years and plant O&M is 0.18 person-years.

[24] AFL-CIO Construction and Building Trades Department. http://www.buildingtrades.org/training/train.html, viewed December 4, 2000.

[25] U.S. DOL, Employment and Training Administration. http://www.doleta.gov/atels_bat/bat.asp, viewed December 4, 2000.

[26] Title 29 Code of Federal Regulations, Part 29.5.

The Renewable Energy Policy Project (REPP) supports the advancement of renewable energy technology through policy research. We seek to define growth strategies for renewables that respond to competitive energy markets and environmental needs. Since its inception in 1995, REPP has investigated the relationship among policy, markets and public demand in accelerating the deployment of renewable energy technologies, which include biomass, hydropower, geothermal, photovoltaic, solar thermal, wind and renewable hydrogen. The organization offers a platform from which experts in the field can examine issues of medium- to long-term importance to policy makers, green energy entrepreneurs, and environmental advocates.

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New York State RPS--Direct Jobs Analysis with PV Set-Aside

By the Renewable Energy Policy Project for SEIA
September 23, 2003

At the Solar Energy Industry Association's (SEIA's) request, the Renewable Energy Policy Project estimates the number of direct jobs in manufacturing, installation, and operations and maintenance in the renewable energy sector that would result from the NY RPS as proposed in the New York Renewable Portfolio Standard Cost Study Report. [1] This estimation is based on REPP's survey of direct jobs in the U.S.-based renewable energy industry. [2] Because the REPP survey currently contains data for only wind, PV, and biomass co-firing with coal, direct jobs were estimated only for these three technologies, and not for the hydropower, landfill methane, and digester gas resources also identified in the NY RPS proposal.

Applicability

This analysis is for NY State RPS demand only, which is the total NY RPS Increment less the SBC-like Tier. Resources required to meet NY Executive Order 111 Demand and New England RPS Demand in NY State are not included in the analysis.

Job creation for two cases are analyzed:

CASE I: Generation mix as published in the NY RPS Cost Study Report
CASE II: Generation mix modified to include a specific amount of PV as specified by SEIA.

Methodology

To calculate direct jobs from wind we need the incremental capacity (MW) of wind installed each year to satisfy the NY State RPS Demand. Because this was not published, in the NY RPS Cost Study Report it had to be derived from the tables of Total Resources Reached for all purposes for 2006, 2009, and 2013. These tables were used to calculate the capacity factor and % generation from wind for these three years. These values were then interpolated to provide the capacity factor and % generation from wind in each year. Finally, these were used to calculate the incremental installed wind capacity for each year. A similar process was used for biomass co-firing, but only required that the incremental generation (MWh) of biomass co-firing be calculated, as the REPP biomass labor data is based on MWh of generation, not capacity.

While the RPS runs from 2006-2013, SEIA believes that incentive buydown programs for quick-deploying PV systems are simpler to administrate than the RPS itself and will lead to 6.98 MW of installed PV capacity prior to 2006. This capacity and associated generation are allocated to 2005 and included in the Case II analysis.

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[1] New York Renewable Portfolio Standard Cost Study Report, prepared by New York State Department of Public Service, New York State Energy Research and Development Authority, Sustainable Energy Advantage, LLC, and La Capra Associates for NYPSC Docket # 03-E-0188. July 28, 2003.

[2] For further information on direct jobs analysis in the renewable industry see the Renewable Energy Policy Project web site at www.repp.org

For case II, it is assumed that PV displaces utility-scale wind generation in the following amounts:

Table A. PV Set-Aside Capacity and Generation by Year

Year	Cumulative Capacity (MW)	Annual Generation (MWh)
2005	7.0	9,783
2006	14.3	20,071
2007	22.1	30,905
2008	30.2	42,314
2009	38.8	54,326
2010	47.8	66,968
2011	57.3	80,270
2012	67.3	94,272
2013	77.8	109,016

Table B. Percent Total Incremental Demand Provided by Renewables: Interpolation of Values from NY RPS Cost Study

	NY RPS Cost Study			NY RPS Cost Study				NY RPS Cost Study
Technology	2006	2007	2008	2009	2010	2011	2012	2013
Wind	61.0%	55.5%	50.1%	44.6%	45.8%	47.1%	48.3%	49.5%
Biomass Co-Fire	7.7%	7.2%	6.7%	6.2%	8.4%	10.7%	13.0%	15.2%
Hydro	5.7%	17.0%	28.3%	39.6%	37.1%	34.6%	32.1%	29.6%
Landfill gas	25.7%	20.3%	15.0%	9.6%	8.6%	7.6%	6.5%	5.5%
Digester gas	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.2%

Table C. Wind Capacity Factor Interpolation Based on NY RPS Cost Study Tables of Resources Reached in 2006, 2009, and 2013

Year	Cumulative Capacity (MW)	Cumulative Generation (MWh)	Capacity Factor
2006	434	1,259,513	33.1%
2007			32.3%
2008			31.6%
2009	1,475	3,976,602	30.8%
2010			31.0%
2011			31.1%
2012			31.3%
2013	3,279	9,040,846	31.5%

Results

Table 1: Generation By Technology for NY RPS Demand (MWh)

CASE I--No PV Set-Aside	2005	2006	2007	2008	2009	2010	2011	2012	2013
Wind	-	1,162,097	2,273,310	3,292,935	4,229,066	5,209,799	6,222,086	7,251,200	8,333,953
Biomass Co-Fire	-	145,970	289,195	424,691	553,743	733,891	963,844	1,240,113	1,573,305
Hydro	-	109,149	449,690	1,025,953	1,856,252	2,649,729	3,393,954	4,078,336	4,726,130
Landfill gas	-	489,303	896,007	1,200,862	1,402,729	1,586,677	1,749,583	1,889,164	2,009,970
Digester gas	-	-	-	-	-	956	2,879	5,737	9,649
		1,906,519	3,908,202	5,944,440	8,041,789	10,181,052	12,332,346	14,464,550	16,653,008

CASE II--With PV Set-Aside	2005	2006	2007	2008	2009	2010	2011	2012	2013
Wind	-	1,151,809	2,252,188	3,260,404	4,184,523	5,152,614	6,151,600	7,166,711	8,234,720
PV	9,783	20,071	30,905	42,314	54,326	66,968	80,270	94,272	109,016
Biomass Co-Fire	-	145,970	289,195	424,691	553,743	733,891	963,844	1,240,113	1,573,305
Hydro	-	109,149	449,690	1,025,953	1,856,252	2,649,729	3,393,954	4,078,336	4,726,130
Landfill gas	-	489,303	896,007	1,200,862	1,402,729	1,586,677	1,749,583	1,889,164	2,009,970
Digester gas	-	-	-	-	-	956	2,879	5,737	9,649
	9,783	1,916,302	3,917,985	5,954,223	8,051,572	10,190,835	12,342,129	14,474,333	16,662,791

Table II: Labor Impacts of NY RPS for Wind, Biomass Co-Firing, and PV

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Case I--No PV set-aside

Renewable Generation (MWh)

	2006	2007	2008	2009	2010	2011	2012	2013
Wind	1,162,097	2,273,310	3,292,935	4,229,066	5,209,799	6,222,086	7,251,200	8,333,953
Biomass Cofiring	145,970	289,195	424,691	553,743	733,891	963,844	1,240,113	1,573,305

Cumulative Renewable Capacity (MW)

	2006	2007	2008	2009	2010	2011	2012	2013
Wind	400	793	1,161	1,509	1,870	2,242	2,617	3,010
Biomass Cofiring	17	33	48	63	84	110	142	180

Annual Job Creation (FTE)

	2006	2007	2008	2009	2010	2011	2012	2013
Manufacturing-Wind	1,253	1,228	1,154	1,087	1,132	1,162	1,175	1,229
Installation-Wind	268	263	247	233	242	249	251	263
O&M-Wind	38	75	110	143	178	213	249	286
O&M-Biomass Cofiring*	17	34	50	65	86	113	146	185
Total	1,577	1,600	1,562	1,528	1,639	1,737	1,821	1,963

Cumulative Job Creation (FTE)

	2006	2007	2008	2009	2010	2011	2012	2013
Manufacturing-Wind	1,253	2,481	3,635	4,722	5,854	7,016	8,191	9,420
Installation-Wind	268	531	778	1,011	1,253	1,502	1,753	2,016
O&M-Wind	38	113	224	367	545	758	1,006	1,292
O&M-Biomass Cofiring*	17	51	101	166	253	366	512	698
Total	1,577	3,177	4,738	6,266	7,905	9,642	11,463	13,427

*Non-energy crops only, average of low and high estimates

Table III: Labor Impacts of NY RPS for Wind, Biomass Co-Firing, and PV

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Case II--With PV set-aside

Renewable Generation (MWh)	2005	2006	2007	2008	2009	2010	2011	2012	2013
Wind	0	1,151,809	2,252,188	3,260,404	4,184,523	5,152,614	6,151,600	7,166,711	8,234,720
PV	9,783	20,071	30,905	42,314	54,326	66,968	80,270	94,272	109,016
Biomass Cofiring	0	145,970	289,195	424,691	553,743	733,891	963,844	1,240,113	1,573,305

Cumulative Renewable Capacity (MW)	2005	2006	2007	2008	2009	2010	2011	2012	2013
Wind	0	397	785	1,150	1,493	1,850	2,216	2,586	2,974
PV	6.98	14.32	22.05	30.19	38.76	47.78	57.27	67.26	77.78
Biomass Cofiring	0	17	33	48	63	84	110	142	180

Annual Job Creation (FTE)	2005	2006	2007	2008	2009	2010	2011	2012	2013
Manufacturing-Wind	0	1,242	1,216	1,141	1,073	1,118	1,147	1,159	1,212
Installation-Wind	0	266	260	244	230	239	245	248	260
O&M-Wind	0	38	75	109	142	176	211	246	283
Manufacturing-PV	175	184	194	204	215	226	238	250	264
Installation-PV	51	53	56	59	62	65	69	72	76
O&M-PV	2	4	6	8	10	12	14	17	19
O&M-Biomass Cofiring*	0	17	34	50	65	86	113	146	185
Total	227	1,804	1,840	1,816	1,796	1,922	2,037	2,138	2,299

Cumulative Job Creation (FTE)	2005	2006	2007	2008	2009	2010	2011	2012	2013
Manufacturing-Wind	0	1,242	2,458	3,599	4,672	5,790	6,937	8,095	9,308
Installation-Wind	0	266	526	770	1,000	1,239	1,485	1,733	1,992
O&M-Wind	0	38	112	222	363	539	750	995	1,278
Manufacturing-PV	175	359	553	757	972	1,198	1,436	1,687	1,950
Installation-PV	51	104	160	219	281	346	415	488	564
O&M-PV	2	5	11	18	28	40	54	71	91
O&M-Biomass Cofiring*	0	17	51	101	166	253	366	512	698
Total	227	2,031	3,871	5,687	7,483	9,406	11,443	13,581	15,880

*Non-energy crops only, average of low and high estimates

Table IV. Summary of Cumulative Direct Job Impacts in Wind, PV, and Biomass Co-Firing (FTE)

	Case I: Standard NY RPS	Case II: NY RPS with SEIA PV Set-Aside
Wind	12729	12578
PV	0	2605
Biomass Co-Firing with Coal	698	698

The SEIA PV set aside results in the loss of approximately 150 jobs in the wind industry and a gain of 2600 jobs in the PV industry.

Mid-Atlantic States Cost Curve Analysis

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Mid-Atlantic States Cost Curve Analysis

Introduction

This report was prepared to analyze the impact of load reduction on reducing the cost of electricity in the context of the PJM utility system. In essence, when consumption is reduced, particularly during peak periods, the market price of electricity is reduced for all consumers. The consumers who reduce their usage receive the benefit of reducing their total consumption multiplied by the market price (with a real time pricing meter), or the load reduction multiplied by a monthly average price (for load-profiled customers), even though they are providing greater benefits to the system as a whole.

To undertake this quantitative analysis, it is first necessary to estimate a supply or cost curve for the PJM market using econometric techniques. That supply curve then becomes the basis for analysis of the relationship between the market price and the value of load reduction at various load levels, by time-of-use period, and for various types of conservation or distributed generation with specialized load shapes.

The value of load reduction was found to be about 24 cents/kWh on summer weekday afternoons in the year 2000 – compared to a market price of 5 cents/kWh.[1] In other summer heavy load hours (6am-10pm except peak hours), load reduction was worth almost 14 cents, with a market price of 4 cents/kWh. Off-peak and in the winter, the value of load reduction was less, but still ranged from 3.5 to 6 cents/kWh, with market prices in the range of 1.5 to 3 cents/kWh.

An example of the value of photovoltaic generation is presented by applying supply curve information to data from a PV installation near Philadelphia. Because photovoltaics generate a large fraction of their energy during summer on-peak periods, PV generation had a market price of 3.2 cents/kWh, approximately 33% more than baseload power for the 12 months ending September, 2000. The value of load reduction for PV generation was 10.0 cents/kWh, 58% above the value of load reduction for baseload generation (6.5 cents/kWh)

Estimating Cost Curves for the PJM Market

The PJM market is a power pool with prices established in a relatively large number of zones. While recognizing that zonal differences may be important in setting short-term prices in some regions, the average PJM price was used to obtain a generalized regional relationship between price and load. Only energy prices were included in this analysis, because of the complexity of managing data for ancillary services, and the relatively small increment of price represented by ancillary services. A similar investigation of

[1] Prices were considerably higher in 1999 due largely to higher loads.

California prices found that the cost of ancillary services (reserves and regulation) was only 1-3% of the energy cost at low load levels and 3-8% of the energy cost for loads during the summer 2000 peak. (Marcus and Ruszovan, 2000)

Regression equations, which related observed prices to demand were used to estimate cost curves. A typical "hockey stick" relationship was observed, with relatively low prices at low load levels. Prices rise slowly as load increases at low load levels and then rise more rapidly as loads reached peak levels.

On the PJM system, a "family" of curves was observed, with lower prices for the same load level in the peak winter and summer months than in March through May and October and November (when maintenance levels were high), and slightly higher prices on weekends than on weekdays (reflecting that fewer units were running). Several curves had to be fit at different load levels, because the PJM system was relatively insensitive to gas prices at low load levels but became sensitive to gas prices above 30,000 MW (in approximately 40% of hours).

Appendix A provides details on the development of energy cost curves for PJM.

Value of Load Reduction (Energy Conservation and Distributed Generation)

Introduction

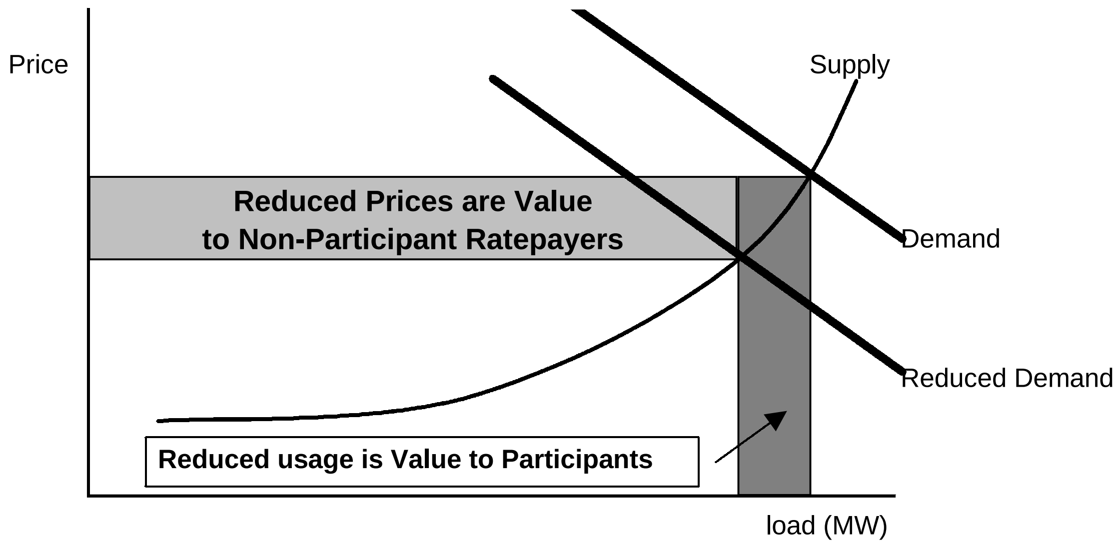
In addition to the direct cost of energy prices, load reduction, energy conservation, and distributed generation all have a significant value in reducing the overall system cost of electricity.

In the old world, in a given hour the marginal cost of energy of a bundled utility was the price of the last most expensive unit of the utility's generation. But the cost was only incurred for that last unit. Thus, the marginal cost was the value of demand reduction, because the last unit's generation was avoided.

In the new world of power pools (in places such as PJM, New York, New England, California, and Alberta) the price for all units of energy traded through the pool is set on an hourly basis by the market-clearing bid price for the last unit (of generation or load reduction) bid in to serve demand. As demand rises, the total revenue received by all generators rises. Thus the value of demand reduction from the perspective of ratepayers is not just the market price (bid price of the last unit). It is the market price plus the increase in the bid price multiplied by all other generators except the last unit.

As demand rises, particularly in peak periods, the price of energy rises relatively rapidly. If demand can be reduced, for example due to the installation of more efficient appliances, the price will tend to fall as demand falls, benefiting not only the customer whose demand is reduced but all other customers who receive the lower prices of spot market energy. Figure 1 shows the effect graphically for a given hour.

Figure 1: Market Price and Value of Load Reduction



The reduction in usage multiplied by the original market price is a benefit to the customer(s) reducing load. The reduced price multiplied by the usage after the reduction benefits all other loads. The sum of these two shaded blocks is the total value of load reduction. Dividing the sum of the blocks by the MWh of load savings gives a value in $/MWh that is higher than the market price.

The argument made here is not a new one. In the context of the world oil market, several studies in the past 20 years have identified the significant monetary value to consumers of demand reductions that can cause price reductions.[2]

This effect was first pointed out quantitatively by Rich Ferguson of the Center for Energy Efficiency and Renewable Technologies (Ferguson, 1999). This issue was further analyzed, using data through mid-1999, by Marcus (2000) in testimony opposing fixed customer charges in a San Diego Gas and Electric Company rate design case.

The California ISO recognizes that the lack of demand responsiveness by customers has an impact on price performance in the California market, (Wojak et al, 2000) although it is largely considering real-time responses rather than investments in efficiency or distributed generation to reduce demand at all load levels.

How Hedging of Power Prices and Long-Term Generation Construction Affect the Results

To review this issue further, we must consider the impact of hedging the short-term market price. There are two different kinds of hedges – physical hedges and contractual hedges. Under a physical hedge, a utility may own a plant which delivers power under a price based generally on a cost of service approach and gives the preponderance of excess

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[2] See, for example Broadman and Hogan, 1988, Stobaugh and Yergin, 1980, pp. 57-60.

revenue earned in the market to ratepayers, or a third party sells power at levels that are at least in part tied to the cost of the generating plant. For example, in California, hydroelectric power is likely to end up being a physical hedge.

Contractual hedges, by contrast, are market-based prices established by the market, and locked in for a varying period of time from a week to several years. Theoretically, these hedges are based on expectations of future market prices plus an insurance premium. Economic theory suggests that the pricing of contractual hedges are based on all information available to the participants in those hedges regarding future market trends. If a credible program of efficiency, load shifting, and DG is undertaken, backed by physical investments, market participants should take those programs into account.

As a result, we now conclude that the value of demand reduction in reducing prices applies to contractual hedges but not to physical hedges.

In addition, one must examine longer term considerations. In the longer term, the price-reducing impact of demand-reduction may be less than in the short term, because price reduction induced by efficiency or DG investments may reduce the amount of generating plant that is built, which could create some countervailing upward price pressure. As a result, the higher value of demand reduction that is clearly present in the short term – particularly under conditions of short supply – is likely to weaken over time.[3]

As a result, we analyze two cases – an "unhedged" case where the price reduction applies to 100% of generation. This is a short-term polar case assuming that no generation is provided on cost-based terms and there is no erosion of the effect as efficiency displaces new construction. The second case assumes that price reduction applies to 50% of generation, taking into account physical hedges and long-run reductions in the magnitude of the effect.

<u>Example of Calculation Method</u>

An example of the method used to calculate market prices and the value of load reduction is shown below. These types of calculations, from the supply-demand equation, are used throughout the analysis.

[3] Eric Hirst also suggested (in a personal communication) that changes in unit commitment caused by load reduction may affect prices, particularly at lower load levels, causing some erosion of the effect. There is no good way to test such a hypothesis with the data at hand. In an hour-ahead market, such impacts are likely to be larger than in a day-ahead market.

An example of the method used to calculate market prices and the value of load reduction is shown below. These types of calculations, from the supply-demand equation, are used throughout the analysis.

Table 1: Calculation Example

	MW	Price *	Pool Revenue
Load	40000	45.5364	1821454
Reduced load	39000	41.2771	1609808
Difference	1000		211646
Value of load reduction unhedged			211.646
Value of load reduction 50% hedge **			128.591

* Summer/winter weekday, $4.00/MMBtu gas
** 50% of VLR unhedged + 50% of original market price

With a 1000 MW load reduction, the market price falls from 45.53/MWh to $41.28/MWh, generating a reduction of $211,646 in the hour if all costs were exposed to the pool price, or a value of load reduction of over 21 cents/kWh. With 50% of generation hedged, the value of load reduction is slightly less than 13 cents/kWh, 282% of the market price.

Overall Results

Figure 2 compares the value per kWh of a (1000 MW) reduction in energy use from all load levels to the energy price, with no hedging, and with 50% hedging.[4] It shows that, including the impact on the market price, even with 50% physical hedging the value of load reduction is at least 170% of the value of energy at all loads. Above 30,000 MW, both prices and the value of conserved energy rise rapidly, but the value of load reduction rises faster. The value of load reduction rises from 217% to 294% of the market price of energy from 31,000 to 40,000 MW and then rose faster to reach 3-1/2 times the market price at 45,000 MW and 8 times the market price at 50,000 MW. Without hedging, the figures are even higher**.**

[4] The gap at 30,000 MW is shown on this figure because of the shift between two separate cost curves.

Figure 2

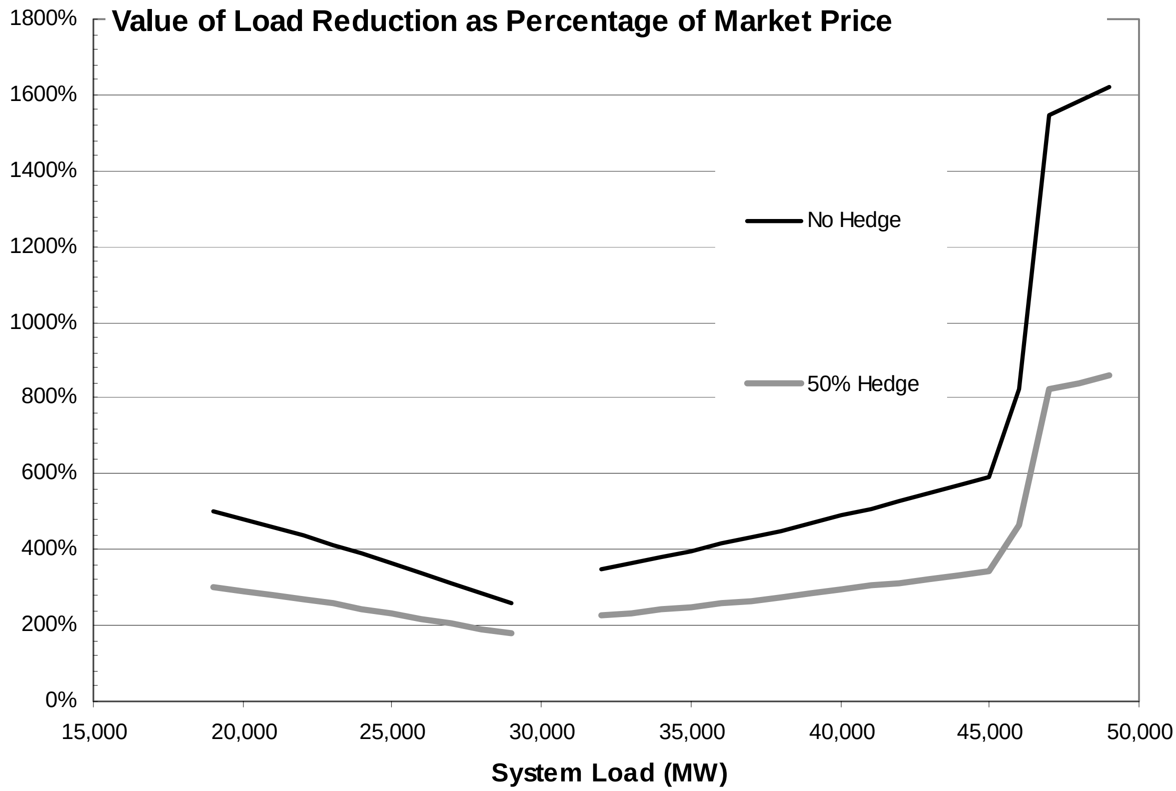

Figure 3 compares the unhedged and 50% hedged value of load reduction to the market price (assuming gas at $4/MMBtu). At the lowest load levels, the unhedged value of load reduction is about $20-$25/MWh, but it rises rapidly to reach $40/MWh at 24,000 MW (with market prices of $10-$13/MWh), $70 at 32,000 MW, $100/MWh at 35,000 MW, $200/MWh at 40,000 MW, and in excess of $1000/MWh at about 45,000 MW.[5] With a 50% hedge, the values are lower, but are still in the $25-$35 range between 20,000 and 30,000 MW, $60 at 35,000 MW, $100 at 39,000 MW, and $200 at 44,000 MW, spiking to more than $1000 at the top of the peak**.**

[5] The value of load reduction below 40,000 MW is higher than reported figures in April and May.

Figure 3

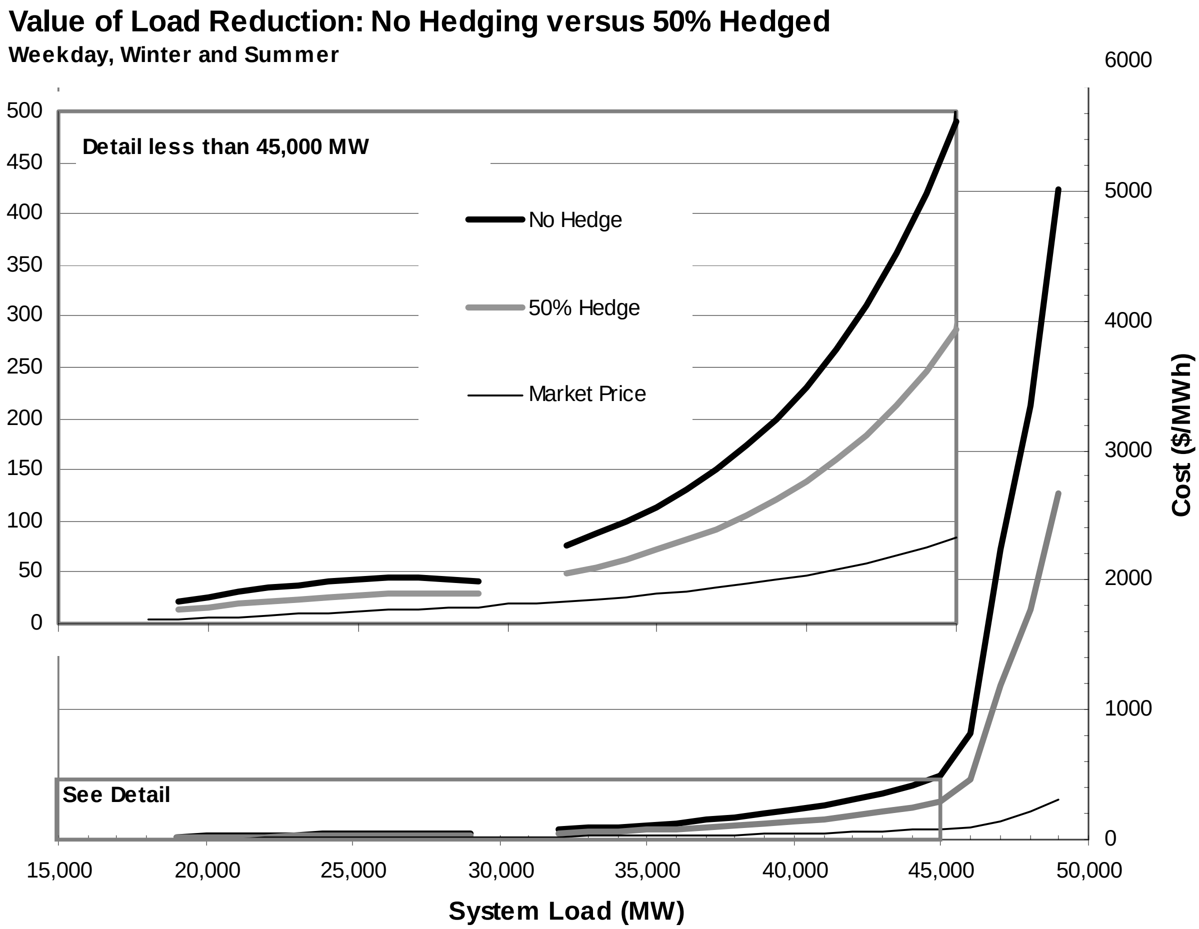

Table 2 below extracts similar information for all four cases, with no hedge and a 40% physical hedge.

Time of Use Analysis

A comparison of the actual market prices, the prices predicted by the supply curve model, and the value of energy reduction was also developed by time-of-use period for a 12-month period from October, 1999 through September 2000.[6] (Table 3)

Table 3

Time of Use Analysis of Market Price and Value of Load Reduction

	Actual Market Price	Market Price Calculated from Regression	Value of load reduction 50% hedged	Load Reduction as % of market price
Summer (June-September)				
On-Peak (weekday 12pm-6pm)	4.90	5.28	24.51	464%
Mid-Peak (Mon thru Sat 6am-10pm except on-peak)	3.15	2.97	8.17	275%
Off-Peak (10pm-6am plus Sunday)	1.71	1.64	3.86	235%
Season total	2.83	2.79	9.13	327%
Other (All Other Months)				
Mid-Peak (Mon thru Sat 6am-10pm)	2.85	2.76	6.30	228%
Off-Peak (10pm-6am plus Sunday)	1.55	1.56	3.59	230%
Season total	2.27	2.23	5.09	228%
Annual total	2.46	2.43	6.51	268%

This table shows that:

1. With the exception of the very high prices in the summer peak of 1999, the model generally predicted seasonal costs within 2%. No time period was off by more than 6%.[7]

2. The value of load reduction during summer peak hours is almost 25 cents per kWh – 4.6 times the market price of power calculated from the regression equation. During summer mid-peak hours, the value is 8.2 cents/kWh. Due

[6] To reflect current conditions, a gas price of $4/MMBtu was used in the regression to develop the market price by time of use. It should be noted that similar calculations using the 1999 load curve, with higher loads, are considerably higher, particularly on-peak. Thus, if loads in the summer of 2000 are recognized to be lower than average, its prices are also significantly lower than could be expected in an average year.

[7] The model did not track the very high prices in the summer of 1999 well, under predicting costs in the very highest peak hours that drove up PJM prices, suggesting that other factors such as generation shortages or market power may have had an influence in those hours. PJM suggests that generating outages were higher at the time of the 1999 peak than the 7.5% projected on a planning basis for 2000. (PJM, 2000a, 2000b).

to warmer temperatures in 1999, the value of load reduction in the summer of 1999 was higher, reaching 46 cents/kWh on-peak and 14 cents/kWh mid-peak.

3. During off-peak and other mid-peak hours, the value of load reduction is 3.5 to 6 cents/kWh – 228% to 235% of the market price.

Case Study: Analysis of Photovoltaic Generation

A specific analysis of photovoltaic generation was conducted as an example of how the value of load reduction may affect planning for peak-oriented investments that reduce customer loads. A qualitative analysis (JBS Energy, 1996), integrated PV generation with system and class load curves for a California utility to show the benefits of PV generation.

The actual output curve for a PV generator in Plymouth Meeting, PA (near Philadelphia) was used[8]. The PV has a nameplate AC rating of 53 kW, but empirically has experienced a limit on hourly output of approximately 40 kW (both actual and modeled). It produced 47,000 kWh (for a capacity factor of 14% based on 40 kW maximum output) in 8328 hours since mid-October, 1999.[9]

The load factor varies significantly by season and time of use, as shown in Figure 4.

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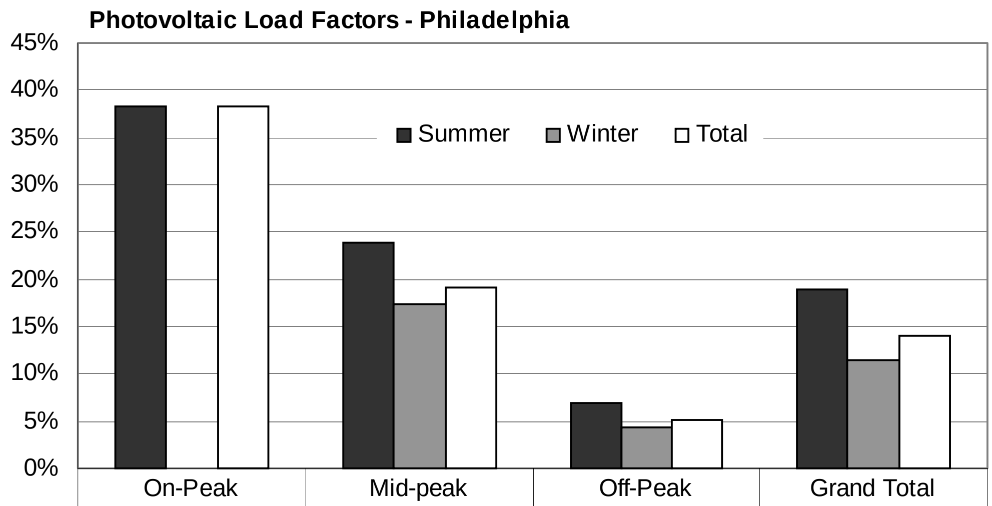
8 Data was obtained from the Utility Photovoltaic Group's TEAM-UP PV system performance database available on the Internet at http://www.ttcorp.com/upvg/sindex.htm.

9 As actual output was used, and this is a relatively new facility, the impact of start-up on performance cannot be ruled out, and actual performance in excess of 14% may be expected.

Figure 4



	On-Peak	Mid-peak	Off-Peak	Grand Total
Summer	38%	24%	7%	19%
Winter		17%	4%	11%
Total	38%	19%	5%	14%

Capacity factors reach 38% in the summer on-peak, but are only 5% year round in the off peak hours (largely Sunday daytime output). During mid-peak hours (6am-10pm Monday-Saturday except summer peak), the PV capacity factor is 24% in the summer and 17% in the winter).

Because its output is weighted toward daytime hours, a PV has both a higher market price and a higher value of load reduction than a more baseload supply reduction (e.g., a DSM program to retrofit exit signs or traffic lights, or improve residential refrigerator efficiency), as shown in Figure 5 and Table 4.

Figure 5: Comparison of Market Prices and Value of Load Reduction for Baseload Application and Plymouth Meeting Photovoltaic

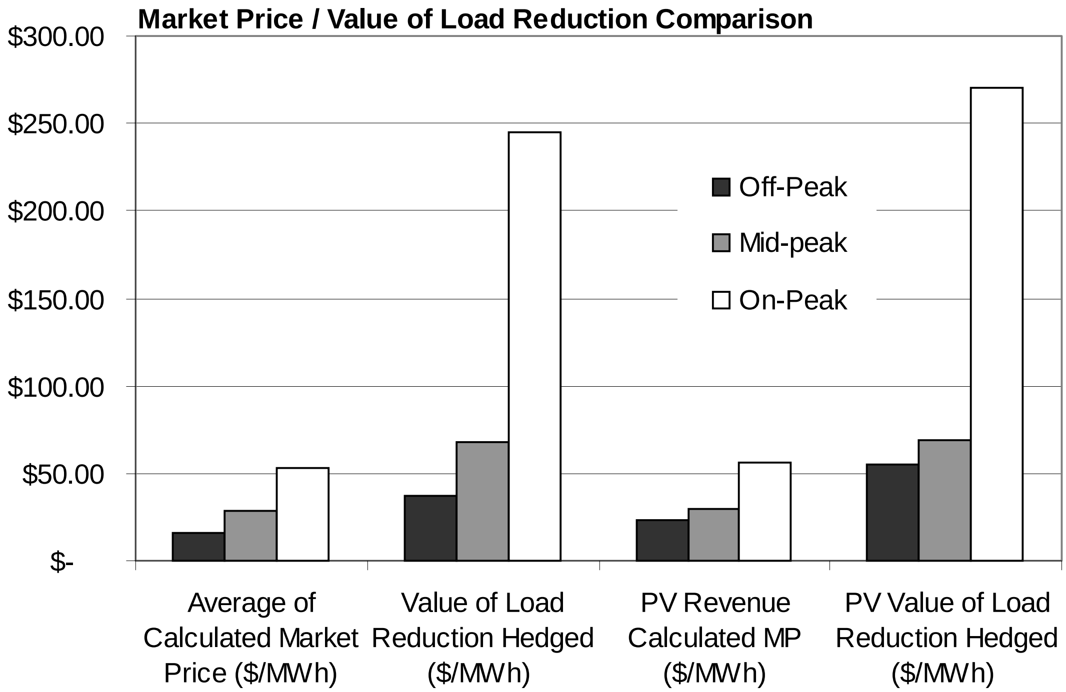


Table 4

Time of Use Analysis of Market Price and Value of Load Reduction: Photovoltaic Generation Pattern

	Actual Market Price	Market Price Calculated from Regression	Value of load reduction 50% hedged	Load Reduction as % of market price
Summer (June-September)				
On-Peak (weekday 12pm-6pm)	5.02	5.64	27.07	480%
Mid-Peak (Mon thru Sat 6am-10pm except on-peak)	3.28	3.04	8.10	266%
Off-Peak (10pm-6am plus Sunday)	2.69	2.55	6.38	250%
Season total	3.80	3.88	14.51	374%
Other (All Other Months)				
Mid-Peak (Mon thru Sat 6am-10pm)	2.91	2.86	6.27	219%
Off-Peak (10pm-6am plus Sunday)	1.95	2.07	4.68	226%
Season total	2.75	2.72	6.01	221%
Annual total	3.25	3.27	10.02	306%

PV generation is worth 32% more than baseload generation (3.25 cents/kWh vs. 2.46 cents/kWh) because its generation load profile is more oriented toward the summer daytime period.[10] The costs in the on-peak and mid-peak periods are only slightly higher than baseload power, but the off-peak value is much higher (because it is largely made up of Sunday daytime generation and includes almost no loads between 10pm and 6am), and the amount of off-peak generation is low.

Because the value of load reduction is higher during summer peak periods when the PV is producing power, it exceeds 10 cents/kWh in the year 2000 period, 306% of the market price of energy and 58% above the value of load reduction associated with baseload generation.

It should be noted that with the much higher loads and market prices experienced in 1999, the value of PV generation would have been considerably higher – likely in the range of 15 cents per kWh. However, the value of PV generation could not be analyzed using real facility data because the Plymouth Meeting PV data only began to be collected in October, 1999.

Policy Implications

This information runs counter to conventional wisdom. Energy efficiency and distributed generation is not necessarily a breeder of rate increases. At all load levels, the potential for rate increases is greatly mitigated by the reduced commodity prices for everyone that result from reducing load. Conservation in peak hours, by all customers, but most particularly by load profiled residential and commercial customers, can provide major rate savings.

Energy efficiency is of critical importance now, but it is not just a way to get through a crunch of tight supply and high gas prices. Even in the "good-old-days" scenario of $2.44 gas and with a 50% physical hedge, energy efficiency would still be worth at least 2 cents per kWh in the deepest off-peak, 3-4 cents per kWh in typical off-peak periods, 4-6 cents per kWh in mid-peak periods, and 6-12 cents from 35,000-40,000 MW, rising drastically to 25 cents/kWh at 45,000 MW and several dollars per kWh at peak.

The analysis shown above does not mean that all of the numbers calculated from this particular cost curve will remain correct if the cost curve shifts again (e.g., because of the addition of new generators). However, the analysis demonstrates the reasonableness of the concept**– that demand reduction has a value to society on the order of more than twice the market price of power during most hours of the year, and that it rises to being three to eight times as valuable as the (increased) market price during the 10% of hours closest to the peak.**

The shape of the curve depends on the specifics of supply, demand, and market power of the system. However, the fact that conservation is worth more than the market price is structural – based on the workings of the new market.

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[10] With the higher loads experienced in 1999, the value of PV generation would increase even more.

The lesson to be learned from this information is not necessarily to pursue all energy efficiency and distributed generation options that are less than the value of load reduction calculated above, or to assume that calculations such as those presented in this report are precise estimates with no margin of error. Rather, it is important to use the information to gain several key qualitative and policy insights:

1. That decision-makers should be less concerned about rate impacts of spending money on load reduction, such as investments in energy efficiency and distributed generation, because rate increases will be mitigated or even reversed (with savings achieved during peak periods) by the price reductions created by such investments.

2. To focus more spending on peak conservation and load shifting where the impact of price reduction is stronger, while continuing to recognize that the effect is present, though less pronounced, off-peak. This information provides a strong impetus for programs such as replacing inefficient window air conditioners and air conditioner and water heater cycling, as well as ratcheting up Federal energy efficiency standards for air conditioners.

3. To encourage large customers to become more price-responsive because of system-wide benefits generated from such price responses.

At the same time, the data clearly demonstrate that the market price by itself does not represent the full value of energy conservation, distributed generation, and load reduction. The contention of Shimon Awerbuch (2000) and economists at the California Energy Commission [for example, Goeke (1996)] that society would be better off with price signals such as customer charges that encourage purchase of more kilowatt-hours and fewer energy-saving devices ignores this significant financial externality.

Conclusion

The value of load reduction from the perspective of ratepayers (in reducing the prices paid by everyone) is at least twice as great as the market prices themselves, and it rises dramatically as load increases.

It is clearly in the best interest of society to spend money and send price signals beyond the market price to encourage energy efficiency and load shifting, particularly during the summer peak. Distributed photovoltaic generation, with its relatively strong correlation with peak loads, could be particularly important in this regard. This finding that conservation not only benefits the conserver but everyone else should become the cornerstone of a new public goods imperative and the associated rate design policy.

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Appendix A Development of PJM Supply Curves

A supply curve was fit piecewise using three separate regressions for PJM using data for the period from April 1, 1999[11] to July 28, 2000. This type of analysis using separate regressions is required because:

(1) PJM prices are almost insensitive to gas/oil prices if load is either very low or very high, but are more sensitive to gas/oil prices in an intermediate range (i.e., from 30,000 to 45,000 MW). Gas/oil units are the marginal units at high load levels, but not at low load levels. A single equation will not capture this phenomenon.

(2) At the highest load levels, PJM prices increase dramatically near the system peak, but are not as sensitive to gas, being more heavily based on shortage values.

As a result of these two phenomena, a single equation cannot be fit. A single equation will overestimate low-end prices and underestimate peak prices, while at the same time underestimating the gas sensitivity of prices during normal intermediate and peak operation.

Three separate curves were therefore fit, including limited amounts of overlapping data:

1) Load below 30,000 MW (6390 data points or 54.9% of hours)

2) Load from 30,000 to 45,000 MW[12] (5040 data points or 43.3% of hours)

3) Load above 43,000 MW (387 data points including 289 over 45,000 MW or 3.3% of hours above 43,000 MW and 1.8% above 45,000 MW)[13]

All equations were fit to a logarithmic form and were run using a Prais-Winsten transformation to correct for autocorrelation of residuals.[14] The results were:

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[11] Prior to April, 1999, there were restrictions on bidding. (Van Vactor, 2000) Our regression analysis showed that prices were higher prior to April, 1999, at load levels below 43,000 MW.

[12] Tests were run in 3000 MW increments to determine where gas price sensitivity first appears. The 30,000-33,000 MW load level was the first appearance of significant sensitivity to gas prices.

[13] Because the period before and after April 1999 had an insignificant impact on prices in the high load hours, and there were relatively few data points in this curve, the entire period was used to estimate this curve.

[14] Autocorrelation of residuals is a significant issue when using time-series data because factors which cause the price to be unusually high or low in a given hour (e.g., unusually small or large amounts of generation available) tend to persist over a number of hours or days.

Below 30,000 MW

$$\ln(\text{price}) = -93.2762 + 10.1958 * \ln(\text{load}) - 0.00030 * \text{load}$$
(11.43) (11.40) (8.38)

$$+ 0.1212 * (\text{dummy } 1 = \text{weekend } 0 = \text{weekday}) + 0.23999 * (\text{dummy } 1 = \text{March } 0 = \text{other})$$
(5.71) (4.81)

$$+ 0.46173 * (\text{dummy } 1 - \text{Apr. or May } 0 = \text{other}) + 0.10429 * (\text{dummy } 1 = \text{Oct. or Nov. } 0 = \text{other})$$
(15.78) (2.83)

Rho = 0.6615 Adjusted R-squared = 0.210

30,000 to 45,000 MW

$$\ln(\text{price}) = 1.3490 + 0.13288 * (\text{LOAD}/10000)^2 + 0.27408 * \text{LN(SPOTGAS)}$$ [15]
(20.97) (38.94) (5.77)

$$+ 0.07282 * \text{WEEKEND} + 0.37291 * \text{MARCH} + 0.52463 * \text{APRMAY} + 0.29763 * \text{OCTNOV}$$
(2.99) (7.99) (15.98) (7.52)

Rho = 0.5771 Adjusted R-squared = 0.246

Over 43,000 MW

$$\ln(\text{price}) = 1.87111 + 0.11604 * (\text{LOAD}/10000)^2$$
(1.71) (2.09)

$$+ 0.000269 * (\text{Load} - 45000 \text{ MW, zero if negative})$$
(3.81)

Rho = 0.7673 Adjusted R-squared = 0.185

Analysis of Regression Equations

The three equations give relatively straightforward results. Figure A-1 shows an example of how the three equations fit together at average ($2.445/MMBtu) gas prices experienced over the period and higher ($4.00) gas prices consistent with current conditions for winter and summer weekdays.

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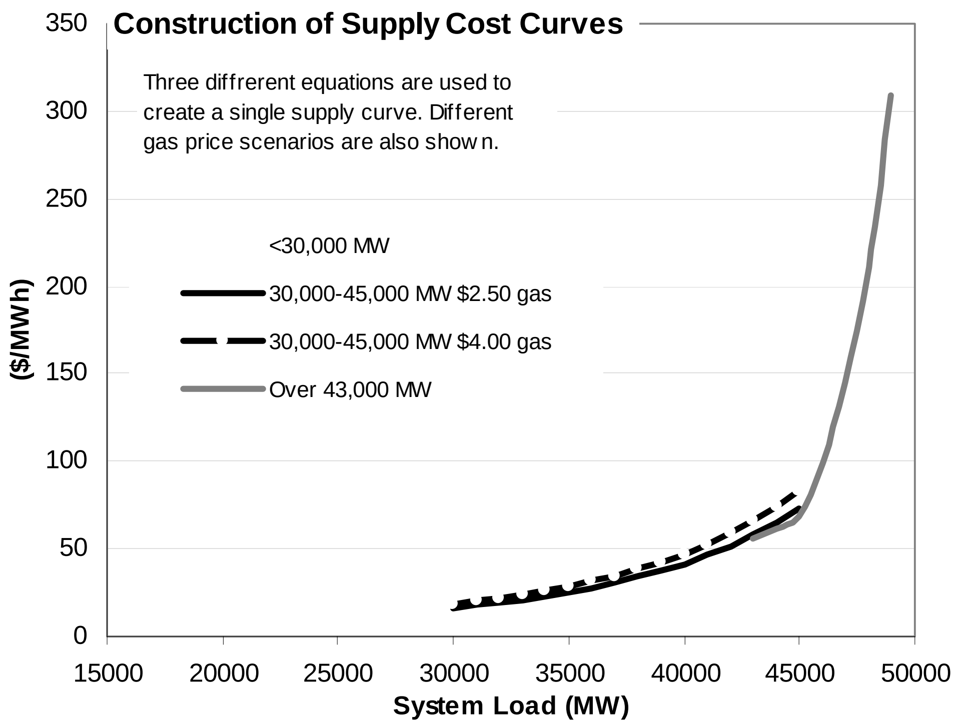
[15] Measured at Henry Hub.

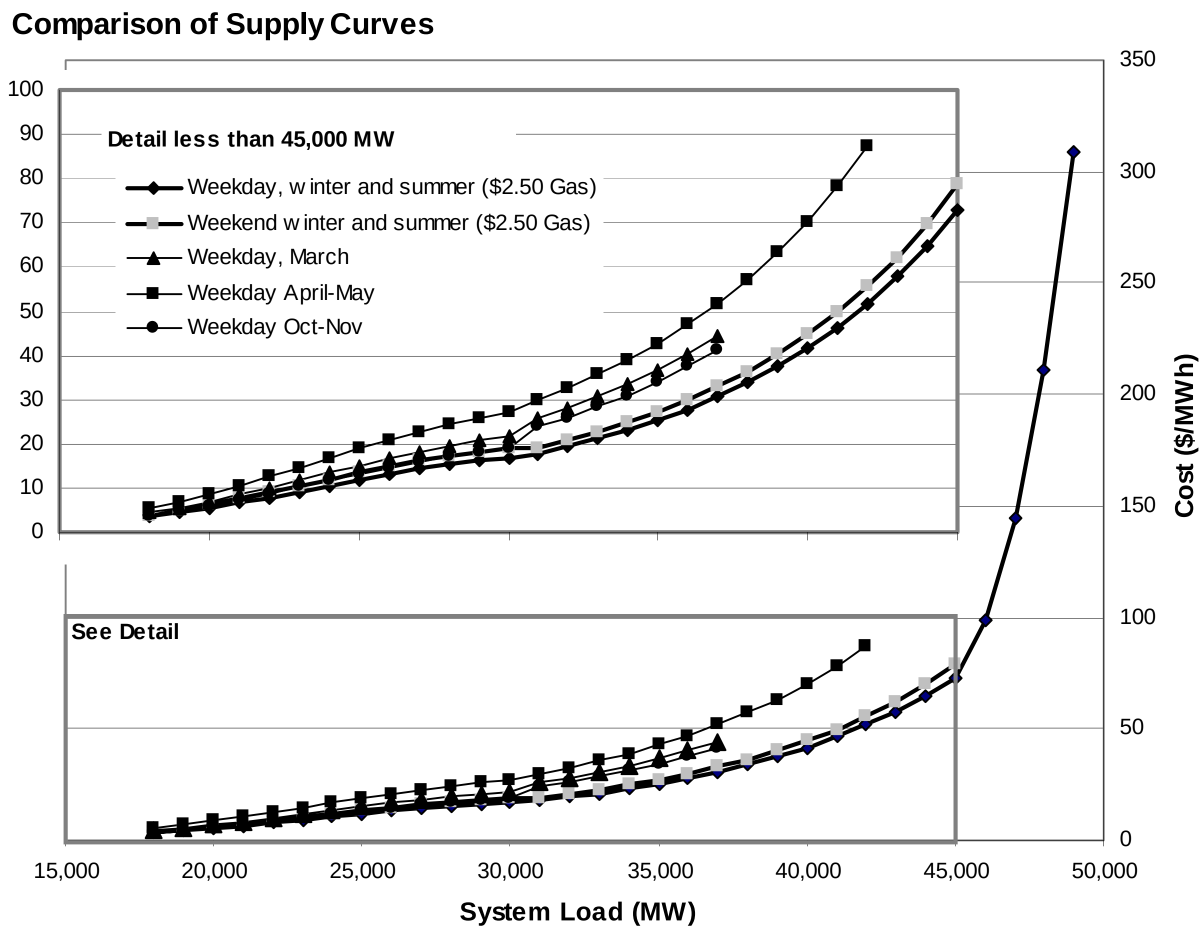
Figure A-1



Controlling for load levels and gas prices, energy market prices were higher in the off-peak months of March through May and October and November, reflecting that more generation is on maintenance in those months. Similarly, energy prices were higher on weekends after controlling for loads and gas prices, reflecting that generators which are run on weekdays to meet loads may be taken off line on weekends for economic reasons.[16] Figure A-2 illustrates this phenomenon.

[16] The weekend and seasonal variables were deleted in the equation above 43,000 MW, because there were no hours with load over 38,000 MW in March, October and November, and very few hours in April, May, and on weekends over 43,000 MW.

Figure A-2



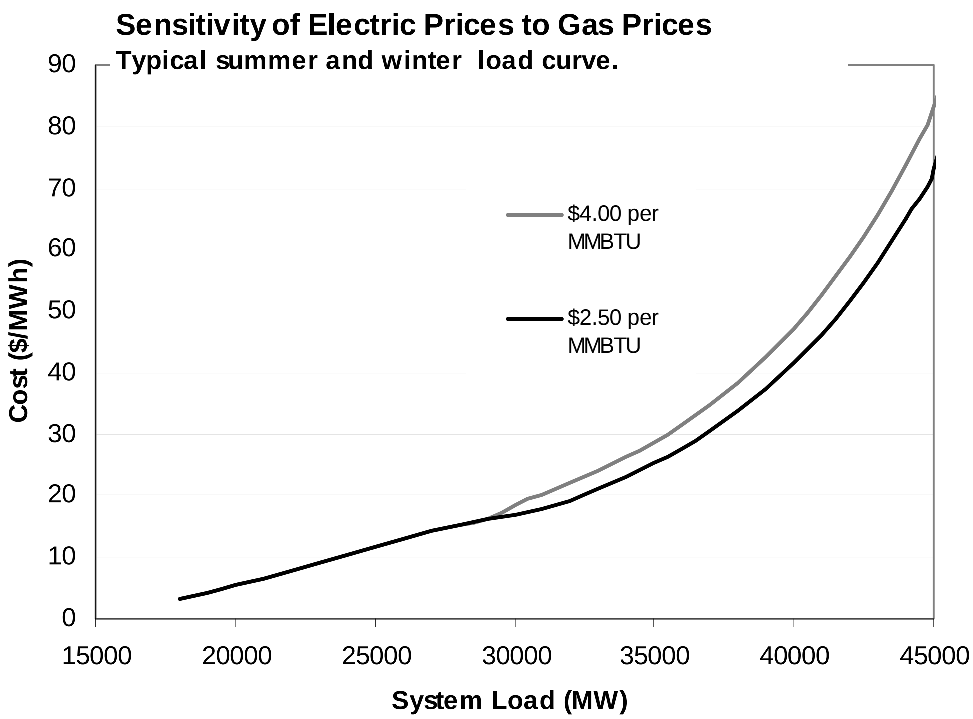
In all three equations, prices increased relatively rapidly as load rises.

In over half of the hours (up to 30,000 MW), prices are largely based on coal generation, with costs of less than $22/MWh (except in April and May). Above 30,000 MW, some gas and oil-fired generation comes into the mix. At the average level of gas prices over the time period ($2.445/MMBtu), prices rise rapidly, reaching levels equal to the cost of gas-fired steam generation in summer and winter months at about 34,000 MW (at lower load levels during off-peak months). Prices rise to $30/MWh at 37,000 MW, $40 at 40,000 MW, and $70 at 45,000 MW. In the few hours with loads above 45,000 MW, prices spike to $450/MWh near the top of the peak at 50,000 MW.

The elasticity of price with respect to gas price for loads over 30,000 MW is 0.27, meaning that for every 10% increase in gas prices, energy prices at loads greater than 30,000 MW rise by 2.7%. Review of data in 3000 MW increments suggest that the elasticity of electricity prices with respect to gas prices is not constant but increases between 30,000 and 40,000 MW, as would be expected as more gas- and oil-fired generation enters the mix, but the statistical estimation of this phenomenon is not straightforward. At current prices in the vicinity of $4/MMBtu, prices in the 30,000-

45,000 MW range average 17% above prices consistent with average ($2.445/MMBtu) gas prices. Figure A-3 shows the sensitivity of electric prices to gas prices for a typical (summer and winter) load curve.

Figure A-3



Equations showed somewhat weak R-squared results, fitting 20-25% of the variation, for several reasons. First, explicit generation supply variables were not included. Second, these are hour-ahead markets, where prices are often quite volatile, related to constraints such as unit commitment and ramping.[17] In addition, it was determined empirically that a somewhat higher R-squared could be derived by including a variable for the previous day's peak load (which reflects that more generating units are committed to run for a higher peak, depressing off-peak prices), but the interpretation of such a variable in a supply/cost curve analysis would be difficult.

[17] Analysis of California's markets showed more volatility and higher standard errors in regressions estimating the hourly ISO imbalance market than the day-ahead PX market. (Marcus and Ruszovan, 2000)