

**Economic Impact Analysis of New Jersey's  
Proposed 20% Renewable Portfolio Standard**

Prepared for NJ Board of Public Utilities - Office of Clean Energy

**December 8, 2004**



**CENTER FOR ENERGY,  
ECONOMIC & ENVIRONMENTAL POLICY**

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# Economic Impact Analysis of New Jersey's Proposed 20% Renewable Portfolio Standard

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# Executive Summary

Many states, including New Jersey, have adopted a Renewable Portfolio Standard (RPS) and others are considering such measures. Although the specifics vary by state, a RPS requires that a certain percentage of the electricity sold in the state be produced from renewable resources. In April of 2003, the New Jersey Governor's Renewable Energy Task Force recommended that the existing Class 1 RPS be increased to 20% by the year 2020 from the existing level of 4% in 2008. The Board of Public Utilities (BPU) decided to conduct an economic impact analysis prior to considering such an increase.

The BPU, Office of Clean Energy engaged the Center for Energy, Economic and Environmental Policy (CEEPP) at the Bloustein School of Planning and Public Policy at Rutgers, the State University of New Jersey, to conduct an economic impact analysis of increasing the RPS to 20% in 2020 (proposed 20% RPS) compared to the existing RPS. CEEPP enlisted the participation of the Rutgers Economic Advisory Services, and formed an interdisciplinary team to perform this analysis.

This report discusses, and where possible, quantifies the incremental costs and benefits between the proposed 20% RPS and the existing RPS. Increasing the amount of electricity sold in the state that is generated by renewable technologies would increase the cost of electricity. This additional cost would, in theory, reduce the expected growth rate of the state's economy. On the other hand, reducing emissions from fossil fuel generation, primarily at plants fired by natural gas, would reduce harmful emissions and provide a benefit by avoiding the associated costs due to those emissions. Increasing the RPS would, if combined with the state's economic development policies, also attract jobs in the renewable sector of the economy. It would also provide some price pressure on the cost of natural gas, might avoid some transmission and distribution expenditures, and increase reliability for those facilities with solar photovoltaic (PV) panels.

Projecting the future over a period of 15 years is a difficult exercise and requires making assumptions regarding many key parameters that are inherently uncertain. The analysis contained in this report constructs several different scenarios regarding expected fuel prices and technological improvements. The base case assumes increasing real fuel prices and expects technological improvements that lead to cost reductions based on the renewable market assessment that is part of this project.

The costs of requiring additional renewable resources beyond the existing standard are relatively easy to quantify compared to the benefits of such a policy. There is a large degree of uncertainty within the proposed 20% RPS of quantifying benefits. Those benefits are primarily but not exclusively avoided environmental costs. Nonetheless, the wide range in available estimates of benefits should not be construed as implying that these benefits are "less real" than the costs. Clearly, policymakers must consider the associated uncertainties of both the costs and benefits in their deliberations.

Under the base case, the proposed 20% RPS compared to the existing RPS would raise electricity prices approximately 3.7% by the year 2020 but have a negligible impact on the growth

of New Jersey's economy. Under the proposed 20% RPS, the location in New Jersey of all of the manufacturing, operations, and maintenance facilities and employees needed to support the PV and wind infrastructure would add approximately 11,700 jobs and augment the economic benefits to the New Jersey economy in the year 2020. The proposed 20% RPS would cause natural gas prices to edge slightly downward for New Jersey consumers by reducing the use of this fuel in power generation. Finally, the proposed 20% RPS would increase reliability by providing electricity from PVs when the grid power is not available and may reduce expenditures on transmission and distribution (T&D) within the state.

The economic and electricity price impacts of the proposed 20% RPS, however, depend substantially on whether expected technological improvements and other factors occur that reduce the cost of PVs and wind power. For instance, if additional cost reductions do not exceed the pace of those that have historically occurred to date in PV and off shore wind technologies, the proposed 20% RPS would raise electricity prices by approximately 24% in the year 2020 and have a measurable, negative impact on the state's economy.

The proposed 20% RPS would also reduce the emission of many pollutants in the region. The marginal fuel in the region used to generate electricity is primarily natural gas, and a proposed 20% RPS avoids the emission of many major air pollutants from natural gas powered plants. Quantifying in dollars the incremental avoided cost of the proposed 20% RPS requires many assumptions, New Jersey specific data, and extensive modeling. Using estimates of externality "adders" - estimates of the additional costs due to emissions - that are found in the literature, illustrative calculations suggest that the avoided costs due to a proposed 20% RPS are in the range of several hundred million dollars in 2020.

The amount of the environmental benefits also depends on the policy interaction between the proposed 20% RPS and existing environmental policies. For instance, under the emission cap and trade programs for sulfur dioxide (SO<sub>2</sub>) and nitrogen oxides (NO<sub>x</sub>), these environmental externalities are internalized. Additional policy measures are needed in conjunction with the proposed 20% RPS to maximize its environmental benefits.

There are other initiatives that New Jersey policymakers should consider in order to maximize the benefits of the proposed 20% RPS, should it be adopted. These include taking measures to coordinate with other states and the federal government and to promote measures that lead to the anticipated decline in the costs of renewables.

# Chapter 1: Introduction to the Economic and Environmental Assessment of a Renewable Portfolio Standard for New Jersey

## I. Overview of New Jersey's Renewable Portfolio Standard

Many states, including New Jersey, have adopted Renewable Portfolio Standards (RPS) and others are considering such measures. Although the specifics vary by state, a RPS requires that a certain percentage of the electricity sold in the state be produced from renewable resources. New Jersey's RPS divides renewable resources into two classes. Class 1 includes PVs, solar thermal electric, wind, geothermal, fuel cells, landfill gas recovery and sustainable biomass. Class 2 technologies are hydroelectric and waste-to-energy. Within Class 1, there is a separate PV requirement, which requires 90 megawatts (MW) of capacity (equivalent to approximately 180,000 megawatts-hours (MWh) of PV) by the year 2008. Class 2 technologies can make up no more than 2.5% of a suppliers total RPS obligation, which is 6.5% in the year 2008. Load serving entities (LSEs) are permitted to meet their RPS commitments through facilities located within the state, within the Pennsylvania-New Jersey-Maryland (PJM) wholesale market, or from facilities that can demonstrate delivery to PJM.

The enforcement mechanism for the RPS is Renewable Energy Credits (RECs). To satisfy their specific RPS amount, LSEs must acquire a sufficient number of RECs for each type of resource requirement. They can obtain RECs by operating renewable resources or purchasing them from the market. Owners or operators of renewable projects will be issued RECs based on the production of their facilities, which they can sell in order to finance their projects. Also, LSEs that have more RECs than their specific requirement can sell them to other LSEs that cannot meet their requirements.

In April 2003, the Renewable Energy Task Force appointed by Governor McGreevey recommended i) the existing Class 1 RPS be increased from 2% to 4% in 2008, and ii) that the Class 1 RPS be increased to 20% by the year 2020. The Board of Public Utilities (BPU) acted upon the first recommendation. This increased the total Class 1 and Class 2 RPS to 6.5% in 2008. The BPU also decided to have an analysis of the economic impact of the proposed 20% RPS conducted before acting on the Task Force recommendation. The BPU engaged the Center for Energy, Economic, and Environmental Policy at the Bloustein School of Planning and Public Policy at Rutgers, the State University of New Jersey, to conduct an economic analysis of increasing the RPS to 20% in 2020 (proposed 20% RPS) compared to the existing RPS. The Center for Energy, Economic and Environmental Policy (CEEPP) enlisted the Rutgers Economic Advisory Service to form an interdisciplinary team to perform this analysis.

The purpose of this report is to conduct an economic assessment of the proposed 20% RPS, which includes identifying and, where possible, quantifying the incremental costs and benefits of the proposed 20% RPS compared to the existing RPS. The costs to the New Jersey economy of requiring additional renewable resources beyond those in the existing standard are relatively easy to quantify compared to the benefits of such a policy. Projecting costs of technologies, some of which are still maturing, some fifteen years into the future remains a difficult exercise, however. The uncertainties in quantifying the benefits of the proposed 20% RPS, particularly those that are avoided environmental costs, are large but the wide range of estimates available for the task should not be construed as implying that these benefits are "less real" than the more readily quantified

costs. Clearly, policymakers must consider the associated uncertainties of both the costs and benefits in their deliberations.

The analysis of whether to adopt the proposed 20% RPS should not be limited to a comparison of its costs and benefits. Policymakers legitimately may want to also consider a strategic perspective and think about whether existing electricity markets should be transformed and whether the proposed 20% RPS is an appropriate means to do so. This strategic view could consider the shaping and acceleration of an electric power system based on sustainable resources rather than on depleting fossil fuels as policy objective, a goal that the proposed 20% RPS would seem to advance.

## II. Organization of this Report

This report is organized into four chapters. The remainder of this chapter reviews several selected studies of the impacts of proposed RPS in other states. While comparing studies across states is difficult as explained further below, it is important nonetheless to understand previous work in order to place the approach and results of this report in context.

Following this introductory chapter, Chapter 2 presents the economic assessment of adopting the proposed 20% RPS compared to the existing RPS. It investigates the statewide and renewable-sector economic impacts of the proposed 20% RPS. The analysis is based primarily upon the use of the Rutgers Economic Advisory Service Econometric Model of the New Jersey Economy (R/ECON™). This economic forecasting model has been widely used in other New Jersey-based studies to forecast key macroeconomic variables such as gross state product, employment levels, and prices. It can also be used, as in this report, as a tool to understand the economic implications of various policies. To provide detail on the economic impact of the proposed 20% RPS on the renewable resource sectors of the New Jersey economy, additional economic analyses were conducted. Chapter 2 presents the overall results and analysis first, and then proceeds to report on the more detailed assumptions and modeling issues

Chapter 3 analyzes the environmental benefits of the proposed 20% RPS. By avoiding the use of traditional fuels to generate electricity, the proposed 20% RPS provides environmental benefits by reducing emissions that result in health, environmental, and economic damage. The chapter thoroughly reviews the environmental externality literature, which can be divided into two parts. First, externality adders are presented and discussed. These adders include environmental costs associated with the use of a particular generation resource, for example natural gas, which are not internalized as part of the producer's cost structure. They are then applied to the proposed 20% RPS to illustrate the quantification of the possible range of incremental environmental benefits compared to the existing RPS. The remainder of this chapter presents a review of the "bottom-ups" literature that is used to determine these environmental adders. Similarly to Chapter 2, this chapter presents the overall results and key analysis first, and leaves the more detailed discussions to later sections.

Chapter 4 discusses the policy implications of the proposed 20% RPS. To capture fully the potential benefits of this increased standard, policymakers may have to take additional measures beyond its adoption. This chapter describes several policy initiatives for consideration and presents them in several contexts. The first context includes measures that New Jersey could adopt unilaterally to improve the effectiveness of the RPS. The second context is cooperation and coordination among states within the region. This requires New Jersey to participate in coalitions and in some cases to develop and lead coalitions to persuade the federal government and governments of other states to change specific policies both to avoid eroding the benefits of the proposed 20% RPS and to enhance its effectiveness. The chapter also highlights the importance of coordination between and among existing policies and these proposed initiatives. Chapter 4 concludes the report. Two appendices provide additional analysis and description of the economic assessment conducted in Chapter 2 and the environmental benefits of the proposed 20% RPS conducted in Chapter 3.

### III. Review of Selected Renewable Portfolio Studies from Other States

#### Development of Renewable Portfolio Policies in Different States

Interest in renewable energy resources has been growing for many reasons beyond those of the increasing economic viability of related electricity generation technologies. One is the increasing stringency of environmental regulations covering electricity generation, starting with the Clean Air Act of 1970. Another, and one that has been heightened in the wake of the tragedy of 9/11/01, is a national security policy goal. This goal is to reduce the nation's reliance on foreign-based energy resources, particularly crude oil, although oil-fired generation is only a small percentage of the nation's total production of electricity. Of course, the reality of uncontrollable vicissitudes in oil prices and past experience with supply disruptions due to embargos also play a role in this regard. A third reason is the concern with the safe operation nuclear energy facilities after the Three Mile Island meltdown. Safe disposal of nuclear waste, which caused the costs of electricity based on nuclear fuel to skyrocket, discouraged plans for more such plants.

These rationales culminated in support for two key pieces of legislation that aided in the adoption of renewable energy: the Public Utility Regulation and Policy Act of 1978 (PURPA) and the Energy Policy Act of 1992 (EPAAct). PURPA requires electric utilities to purchase from non-utilities any renewable electricity generated below the utility's prevailing electricity costs, typically in long-term contracts. When these contracts became uneconomical, the resulting legacy for policymakers was a reluctance to use long-term contracts to achieve their policy objectives. EPAAct has a provision for production tax credits for wind power, which facilitates financing of new wind turbines.

Finally, federal dollars in the 1980s underwrote much of the early development of renewable energy technologies, with the intent of jump-starting them. That early vision and investment has made it possible for some technologies, like wind, to be economically viable now in certain areas of the country and in most areas within the foreseeable future. Even long-awaited

active-solar technologies appear to be on the verge of being economically practical nationwide.

Despite the viability of some renewable energy technologies, the market has been slow to embrace them. This may in part be because to the now deregulated electric generation market. Market participants may be cautious about long-term power purchase agreements with generators in general and the use of unproven technologies with high capital costs (wind power fits into this category), in particular. On the other hand, a guaranteed demand for power generated by a specific type of technology could, to some degree, force the hand of suppliers in favor of such technologies.

An RPS is viewed by some as just the champion needed for renewable technologies. An RPS, which is specified by a state, is designed to require that a certain percentage of electric power supplied, must derive from defined renewable resources. An RPS has become an effective and popular tool for promoting renewable energy. RPS policies tend to be structured with some flexibility with regard to the precise technology set to be used to achieve their mandates. This is important because states are not equally endowed with the same renewable resources. Maine, for example, has long successfully relied on renewable resources to generate electricity needs. Not only does it have ample hydroelectric resources, but among all states obtains the largest proportion of its electricity from biopower – non-hydro, non-wind, non-solar renewable resources – due to the strength of its forestry-related industries. Meanwhile, due to a lack of pertinent resources, New Mexico cannot possibly have much hydro-electric or biomass power generation. On the other hand, most of that state receives a lot of sun and heating-degree days, and geothermal energy is not far from the surface there. Hence, geothermal and solar power generation technologies tend to be more economical in New Mexico than they are in Maine. In Pennsylvania, waste coal qualifies under its proposed RPS.

Many states have adopted an RPS, and more will do so. Because of variations in climate and natural resource endowments, to date each state has opted to specify its own unique RPS. Some states, like Maine, started off by specifying a high RPS in part because,

prior to specifying its RPS, renewable energy use there was already well underway. Others, like California, specified an aggressive RPS (one that phases in renewables rather quickly) because of the heightened need and demand there to achieve environmental goals. Yet others, like Hawaii, did so because in the process of establishing their RPS they discovered that renewable electricity generation was more practical from an economic standpoint, even presently, than were traditional fossil-fuel technologies.

Other states currently are identifying an appropriate RPS because it is only now and with a minor subsidy that renewable energy is economically feasible. Some states intend to adopt renewables rather slowly since they prefer to wait until solar photovoltaic power becomes more practical

This report is not the first of its kind. Other states also have undertaken studies of their proposed RPSs. Iowa, for example, enacted legislation as early as 1983 in the support of renewable energy and revised it in 1991 in part due to its ethanol policies. Minnesota, adopted a similar law in 1994. And while nationwide economic impact studies of renewable energy technologies were undertaken by early as the 1980s, it seems not to have been until a 1995 study for the State of Wisconsin that any state-based RPS economic impact studies were conducted. That study and two other early ones on Arizona and Minnesota appear well summarized in the study for Hawaii by GDS Associates (2001), so they are not reviewed here. These studies enumerated the tons of various pollutants that would not be discharged and how the new technologies would affect electricity rates and monthly bills. Arizona's study also estimated the number of additional jobs and income that would occur from operating the new plants compared to conventional alternatives that otherwise would have come online.

In the following sections, seven more recent studies are summarized—those for Massachusetts, Hawaii, Maryland, New York, Vermont, Pennsylvania and Colorado. Interestingly, each study takes a different tack, even the three performed by the same study team. These studies were selected on three grounds (1) the state's geographic proximity to New Jersey, (2) the originality of the analysis, and (3)

the comprehensiveness of the study. The reports are summarized below in order of the date they were published. The focus of each summary is the RPS definition, its practical implementation in terms of technology, the nature of scenarios used in the study, and a basic summary of the findings.

Comparing different states' RPS and associated analyses is difficult to do for several reasons. First, the RPSs of states vary in the definition of what constitutes a renewable, the percentage of required renewables, and implementation schedules. Second, the cost structure of existing electricity resources and of renewables varies among states. Third, the studies analyze different RPS impacts using different methods. With these limitations in mind, there are several observations that can be made based upon the subsequent review of different RPS studies.

With the exception of that for Hawaii, the reviewed studies conclude that an RPS would increase electricity production cost and its price, although the rate increases are slight. Economic impact analyses due to these increases are not typically performed. If reductions in emissions are discussed in a study, quantifying the avoided costs in human, economic, and ecological terms is not performed. Again except for the case of Hawaii, natural gas fired generation is assumed to be the fuel-technology combination that would be displaced by an RPS. Wind power generally was found to be the dominant renewable technology alternative in meeting each RPS. This was particularly the case in the eastern coastal states and for Colorado. Solar does not tend to be significant in any of these reports because solar technologies are too expensive even through 2020. In the absence of a solar RPS requirement, solar would not be able to compete with other renewable technologies such as wind. Moreover, except for the case of Colorado, none of the state reports specify a separate solar-RPS such as New Jersey's RPS has. Perhaps one of the most common findings, again outside of those for Hawaii, was that the economic viability of the RPS relies more on the cost of natural gas than it does on the size of the RPS to be met.

## Massachusetts

One of the earlier studies that analyzed a state's electric-power renewable portfolio standard was that for Massachusetts (Smith et al., 2000). According to the report, the RPS schedule in Massachusetts was to meet a 1% requirement before December 2003, increasing by increments of 0.5% through 2009, and then increase by 1% through 2012, more or less back-loaded schedule.

The real wholesale price of natural gas was projected using the PROSIM model, an economic dispatch model, to be relatively flat starting at \$3.32 per million Btu (MMBtu) in 2003 and rising to only \$3.55 per MMBtu by 2009. As a result of this and the assumption that in the absence of renewables natural-gas-fueled turbines would meet any added demand, average real electricity prices were expected to rise from \$0.0334 per kWh in 2003 to \$0.0355 per kWh in 2012.

Based on these prices, landfill gas in New England is expected, in the base case, to be the main basis for meeting the RPS through 2009 at which point wind power and co-fired biomass will take over, in part because land-fill gas will be near the region's capacity. The real excess cost of renewable electricity generation at the margin is estimated at \$0.0210 per kWh in 2003, rising to \$0.0232 by 2012 per kWh. Of course, after factoring in their relatively low percentage of the fuel set, renewables will increase net customer costs only slightly even by 2012: a 0.4% increase in 2003 to about a 2.2% increase in 2012.

The Massachusetts report goes on to investigate in some detail the effect of uncertainty in the assumptions regarding the costs and, hence, supply of the various renewable technologies. The authors also examine demand-side variations, changes in RPS requirements, variations in retail electricity demand, and changes in non-RPS demand for renewables. Higher-than-expected costs of compliance with the RPS were perceived to drive the added cost premium of wholesale electricity prices as high as \$0.05 per kWh in 2009 and \$0.06 per kWh in 2012. If lower-than-expected costs of compliance occur, then the cost premiums of wholesale electricity prices could be dampened to as low as \$0.01 per kWh over the entire

study period, according to the simulations conducted by the authors

## Hawaii

Hawaii is unusual in that it currently relies heavily on oil as an energy resource to produce electric power, which must take place within the island state. Moreover, according to the study by GDS Associates (2001), the delivered price of oil to generation facilities in Hawaii is on the order of 20% higher than the U.S. average to all electric power generators. Plus, as a primary resource, oil leaves Hawaii uniquely vulnerable among the states to the whims of supply disruptions and the environmental risks of oil spills that are almost unique for states of the union. Thus, among all U.S. states Hawaii is a prime location for enhancing its renewable portfolio.

The GDS report analyzed the economic impacts of both a 9.5% and 10.5% RPS for 2010 using two different oil price forecasts (baseline and low). In all scenarios, the percentage of renewable sources was forecast to increase in a straight line from 3% in 2003. Forecast targets of the RPS were broken out by utility. World oil prices were forecast in the baseline case at \$25 per barrel and in the low oil-price case at \$22 per barrel in 2003 well below the current price of oil. In both cases oil prices were forecast to rise at rates established in the Gas Research Institute's 2000 Baseline Projection of oil price growth for its Pacific 2 energy demand region, composed of California and Hawaii. These oil forecasts were broken out into delivered costs by Hawaii electric utility.

While Hawaii has some geothermal and hydroelectric sources that it can and will bring on line by 2010, wind turbines will fulfill the bulk of its new RPS. The projected costs for 2010 per kWh for wind power ranged from \$0.036 at Kohala Wells on the Big Island to \$0.069 at Puunene on Maui. Also no new renewable projects were projected to be installed after 2010. On the other hand, the explicit technology plan laid out in the report made it possible to add in each facility in an order based on the net cost of electricity that each produced – lowest cost first, of course.

Since almost all renewable resources except a few pending solar units produced electric power

at rates below prevailing ones that use fossil fuels in Hawaii, all of the RPS scenarios yielded lower net electric power prices through 2020. Indeed, because of this, high-cost fossil fuel scenarios were not examined. Finally the relative benefits over the alternative of fossil fuel sources of the installation, maintenance, and operation of the renewable power facilities were not considered in the scenario calculations. Also the environmental benefits were not evaluated or for that matter even assessed thoroughly. In part this is because of the prevailing friendliness of Hawaii's economic climate to the use of renewable energy resources.

The net present value of estimated savings under Hawaii's RPS ranged from \$27.8 to \$43.1 million for the period from 2001-2010 and from \$62.4 to \$98.4 million through 2020. While important these costs were deemed small. At their highest, they were only about 2.6% of the total baseline costs of generation over the ten-year period (\$3.2 billion).

### Maryland

The Maryland study by Synapse Energy Economics (Chen et al., 2003) presumed that its state would have to meet a 7.5% RPS by 2013. They examined five scenarios, defined by conditions at the end of the study period, the year 2013: (1) natural gas prices rise by 25%, (2) natural gas prices rise by 50%,

**Table 1.1 Projected RPS Premium and Percent Change to Maryland's Average Retail Cost of Electricity (\$/kWh)**

	2006		2010		2013	
	\$/kWh	% Change	\$/kWh	% Change	\$/kWh	% Change
Baseline	0.0095	0.1	0.0093	0.5	0.0081	0.8
Gas price rises 25%	0.0056	0.0	0.0030	0.1	0.0012	0.1
Gas prices rise 50%	0.0017	0.0	-0.0034	-0.1	-0.0058	-0.4
Gas price falls 2%	0.0098	0.1	0.0098	-0.3	0.0087	-0.6
Gas price falls 4%	0.0101	0.1	0.1029	-1.1	0.0093	-2.0
RPS penalty	0.0200	0.1	0.0200	1.1	0.0200	1.9

Source: Synapse Energy Economics (2003a, Table 6.1)

(3) natural gas prices fall by 2%, (4) natural gas prices fall by 4%, and (5) a \$0.02 per kWh fee for supplier noncompliance with the RPS. In cases (3) and (4), the fall in the delivered price of natural gas was assumed to be due to the application of the new RPS. The

study did not make clear its RPS assumptions for intermediate years.

The costs of renewable energy sources were \$0.045 per kWh for wind turbines running at 34% of capacity; \$0.053 per kWh for landfill-gas fueled turbines; \$0.070 per kWh for direct biomass; and \$0.281 per kWh for solar photovoltaic panels from the Energy Information Administration's *Annual Energy Outlook 2003*. Prevailing 2002 wholesale electricity generation costs in Maryland applied in the study were \$0.035 per kWh. It was deemed to hold at \$0.035 per kWh through 2006 and then increase to \$0.040 per kWh by 2013 in the baseline case, which assumes that all marginal energy in PJM will be produced via natural-gas-fueled turbines. Credit trading within PJM was assumed.

Wind power was supposed to be the first renewable resource of choice due to its lower costs. With that, costs of electricity through the RPS were estimated in the baseline case to rise to \$0.045 per kWh by 2006 and further to \$0.047 per kWh by 2013. The following table summarizes the impacts of the various scenarios on electricity prices in Maryland.

### New York

Synapse Energy Economics (Keith et al., 2003) also performed a study for the State of New York. It is strictly a review of pre-existing literature on the subject. It concludes that there are many important benefits of an RPS: (1) emissions reduction programs in the state will provide significant environmental and health benefits, (2) gas prices are volatile and may be higher than average during the coming years, and (3) studies of other areas show investments in renewable power generation yields more and better-quality jobs than do fossil-fuel alternatives. The New York Public Service Commission adopted an RPS of at least 25% by 2013 on September 22, 2004.

## Vermont

Synapse Energy Economics' analysis of Vermont's RPS (Woolf et al., 2003) has three RPS scenarios that flow through 2015. The first calls for a new renewable power generation target of 0.5% in 2006 that increases by 0.5 percentage points annually. A second begins at 1% in 2006 with annual 1.0 percentage point increments. The third starts at 2% in 2006 with annual increases of 2.0 percentage points. Natural gas combined-cycle facilities are assumed to be the alternative to renewables for increasing power generation in the future. The future cost of electricity in Vermont was obtained by costing out such a plant and assuming at least one would start operation in 2010. Electricity prices for intermediate years were estimated as linear interpolations.

Vermont is considering whether to include co-fired biomass as eligible under its RPS. If so, it will be the only state in New England to do so. Moreover, the economics of technology makes co-fired biomass among the cheapest electric power fuels for this region. Because of the large number of dairy farms in the state, manure digestion was also deemed economically viable. Hence, in the early years of the Vermont RPS, the report assumes biomass technology will dominate through the expansion of existing co-fired facilities and the installation of manure digesters.

While wind is expected to be a major factor in the supply of power to New England beginning in about 2010, its effect on the supply to Vermont was deemed to be small. The ready availability of the hydroelectric power across the border in Quebec and a better-supported RPS in New York State are expected to make imports to New England important to its Vermont customers. Moreover, regulatory barriers to new hydroelectric dams in New England were perceived to price this option out of economic feasibility. On the other hand, it may be that imports from new facilities in Quebec could be constrained by politics and transmission losses. Hence, extra scenarios were developed by including and excluding this low-cost option in the original one. The scenarios were further modified to consider what would happen if the state's RPS mandated that it pertained to Vermont-based production only or more generally to New England.

In the end, the Vermont report examines the difference between electricity prices that result from the two alternative scenarios to the baseline—that of an RPS with 1.0 percentage point increments. Of course, this is done in each case for three different conditions: (1) assumes the eligibility of low-cost renewables not eligible under the RPS of other New England states (henceforth called, "VT-only eligible") (2) VT-only eligibles but excluding the possibility of importing from Hydro-Quebec, and (3) a New England RPS perspective. Two cases where wholesale electricity prices became 20% lower or higher were also examined.

The impact of the various alternatives on electricity prices was determined to be small, increasing average electricity prices only by 1.5% from the baseline case in 2015 when only a New England eligible 2% annual increase in the RPS was considered. Not surprisingly, the volatility of prevailing electricity prices was deemed more likely to have an impact on the economic viability of a new Vermont RPS than would the various percentages of renewables that were considered. Prices 20% lower than those of the baseline forecast were perceived to make the 1% increment in the RPS enhance average electricity prices by only 1.4% in 2015. On the other hand, 20% higher wholesale prices essentially made the 1%-incremented RPS virtually costless.

## Pennsylvania

Pennsylvania's RPS study (Black and Veatch, 2004) is the most recent among member states of PJM. The Pennsylvania RPS is projected to be 1% in 2006 rising a percentage point per year to a total of 10% by 2015 at which point it will level off through 2025. Starting in 2015, biomass co-firing is expected to meet about 21% of the RPS (at an average cost of \$0.0366 per kWh), wind 46% (\$0.0825 per kWh), hydroelectric power 14% (\$0.0576 per kWh), and landfill (\$0.0482 per kWh) and digester gas (\$0.0837 per kWh) fuels combined about 5%. Of course, the capacity mix is somewhat more slanted toward wind power due to the lower capacity utilization of that technology. Solar-photovoltaic-generated electric power was deemed not to be economically viable during the study period.

In the study, the technologies were scheduled by permitting only the lowest-cost alternatives to be built first. Two different wind-power technologies were allotted equal percentages of the “market share,” one costing \$0.07 per kWh and the other \$0.095 per kWh. The report is detailed in its costing of the technologies as well as in its pointing out the respective probable geography of each technology’s installations.

Costs of the RPS were compared to a baseline that assumed the current mix of fossil-fueled plants. Over a 20-year period the RPS was deemed to cost \$1.23 billion or 36 percent more than the baseline case for new installations in present value terms. This, however, equates to an average rate premium of only 0.036 cents per kWh or a 0.46% increase over Pennsylvania’s average retail price of \$0.0786 per kWh in 2001.

Of course, new investments in the RPS can create economic activity in as much as they yield more economic benefits than the baseline alternative. RIMS II multipliers produced by the US Bureau of Economic Analysis were applied to this analysis [1]. Although not clear in the report, the multiplier used are presumably those for Pennsylvania. On a per MW basis, the analysis reveals that wind power and biomass co-firing yield greater annual returns to that state than do conventional technologies. Unfortunately, the analysis mixes numbers of one-time construction impacts with recurring annual impacts from operations and maintenance of the facilities, which makes the summary numbers difficult to interpret. Nonetheless, unlike prior studies at least some effort was undertaken to capture these benefits.

As in prior studies some effort was also made to summarize benefits obtained by possible reductions in the prices of fossil fuels, given that demand for them effectively will decline via the RPS. While not articulated with any detail, the report summarizes that natural gas prices should decline by 3% with what must be assumed to be nationwide RPS-based pressures. Since natural gas maintains but a 3% fuel share in Pennsylvania electric-power generation

(although the percentage of natural gas generation in PJM is substantially larger), the effect of such a small price change would in all likelihood be minimal.

## Colorado

Among the most recent reports is one for Colorado (Binz, 2004). It is an investigation into the potential impacts of what Colorado residents call Amendment 37, an initiative on the Colorado ballot in November 2004. This amendment will affect 80% of Colorado electricity consumers, since it pertains to Colorado utilities with 40,000 or more customers. Currently all renewable electric power generation supplies about 1.8% of the power base. The initiative for Amendment 37, which was approved by voters in November 2004, seeks to establish the RPS to 10% by 2025. Moreover, 4% of the RPS (0.4% of all electrical power by 2025) must be met by solar energy sources.

The study uses unsubsidized costs for wind power of energy reported by the US Department of Energy (specific report uncited) of \$0.05 per kWh and falling to \$0.035 by 2023. It admits that this estimate is likely to be conservative based on some anecdotal evidence. Integration and transmission costs add another \$0.008 per kWh. The costs of a central-station solar power from a Sargent and Lundy report for the National Renewable Energy Laboratory are similarly cited. The costs in 2004 are taken to be \$0.14 per kWh and expected to fall to \$0.055 by 2020. These costs are expected to be on the high side, since the report suggests the same study for identified solar technologies that start off costing less and dropping more steeply over the forecast period. The same DOE EIA 2004 forecast for natural gas prices as applied in the present study are used to price the baseline fuel in this one for Colorado. With this information in hand nine scenarios were investigated based upon three different forecasts of natural gas costs and three different possible futures for the federal Production Tax Credit (PTC): no extension, an extension through the end of 2006, and an extension through the end of 2010.

The scenarios were carried out for Xcel Energy, the largest utility in Colorado. Results reveal that, regardless of the scenario, the impacts upon a typical monthly residential utility bill are likely to

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[1] RIMS II is a set of state input-output multipliers produced by the U.S. Bureau of Economic Analysis. See Appendix A for more details.)

be very small—at most \$0.63, the case of low gas prices with no extension of the PTC. The aggregate impact over the 20-year period was \$190 million for this same case. Meanwhile certain other cases presented possible economic gains (price drops) with the adoption of renewables. To get a better sense of things, probabilities were assigned to each scenario such that the sum across them was 100%. The net present value of the merging of the scenarios is \$12.6 million in 2004 dollars or about a \$0.01 increase in a typical monthly residential bill.

As in other reports, the RPS was assumed to have significant environmental effects as well. In particular in Colorado water is in many places a scarce resource. Given that it will replace natural gas and coal-fired plants, renewables electricity generation is deemed to reduce water consumption in electricity production by one to two million cubic feet (3.25-6.40 thousand acre-feet) per year.

# Chapter 2: Economic Assessment of the Proposed 20% Renewable Portfolio Standard

## I. Introduction and Findings

This chapter reports on the incremental economic impacts of the proposed 20% RPS compared to the existing RPS from now until the year 2020. The analysis is based on the R/ECON™ model and additional and more detailed economic analysis of the PV and wind sectors. The R/ECON™ model is a widely accepted economic model that is frequently used to forecast the economic performance of the New Jersey economy. It analyzes growth in such variable as gross state product, employment, income, and prices. It models the economy using a system of econometric equations that have been developed and tested over many years. In addition, it can be used to compare the economic impacts of different policies such as the existing RPS versus the proposed 20% RPS.

This economic analysis starts by forecasting the additional annual cost to the production of electricity due to the proposed 20% RPS compared to the existing RPS from now through the year 2020. To do so, the analysis reviews key national and economic factors and different fossil fuel price projections. (Prior RPS studies of other states have neglected such possible economic repercussions.) The impacts these additional electricity costs have on the New Jersey economy are then determined. Since the proposed 20% RPS, if combined with appropriate economic development policies, could increase employment and associated economic activity in the New Jersey renewable sector, these effects are also quantified.

There are three subsequent sections to this Chapter. Section II describes the R/ECON™ model and its results. It provides the baseline economic assumptions that the

model uses including a high, low and expected fossil fuel price projections. This section also discusses and quantifies the economic implications of two 20% RPS scenarios compared to the existing RPS. The future cost of renewable resources depends substantially upon technological progress, engineering improvements, and learning gained by more and more experience with these technologies. The expected scenario, based on a New Jersey specific renewable market assessment commissioned as part of this project, is that these costs decline faster than they have in the recent past in New Jersey.

An alternative scenario is that renewable costs decline as they have done historically. Section III reports an additional and more detailed economic assessment of the proposed 20% RPS on the New Jersey PV and wind industries. To the extent that construction, operation, and maintenance facilities and personnel are located in New Jersey, the proposed 20% RPS would provide additional jobs and economic activity in these areas compared to the existing RPS. Section IV concludes this chapter.

This chapter finds the following:

1. Under the expected case assumptions, the proposed 20% RPS compared to the existing RPS would raise electricity prices approximately 3.7% in the year 2020 and have no measurable impact on the growth of New Jersey's economy;
2. If natural gas prices rise to levels assumed in the High Energy Price scenario, the proposed 20% RPS has a positive economic impact on the New Jersey economy because electricity

prices would be lower than under the existing RPS scenario;

3. The economic and electricity price impacts of the proposed 20% RPS depend substantially on whether expected technological improvements occur that reduce the cost of PVs and wind power;
4. Under the proposed 20% RPS, the location in New Jersey of all of the manufacturing, operations, and maintenance facilities and employees needed to support the PV and wind infrastructure, for instance if New Jersey developed its off-shore wind capability or if the regional wind infrastructure is located in New Jersey, would add approximately 11,700 jobs and attenuate economic benefits to the New Jersey economy between 2008 and 2020;
5. The proposed 20% RPS would lower natural gas prices consumers pay by reducing the burning of this fuel in power generation; and
6. The PV portion of the proposed 20% RPS would increase reliability by providing electricity when grid power is not available and may reduce expenditures on T&D within the state.

## II. Description of the R/ECON™ Model and its Results

The Rutgers Economic Advisory Service Econometric Model of the New Jersey Economy (R/ECON™) is an econometric model comprised of over 150 equations the solutions of which are solved simultaneously. The equations are based on historical data for New Jersey and the US. The historical data used to produce the model covers the period from 1970 to the second quarter of 2003. The sectors included in the model are:

- Employment and gross state product for 40 industries
- Wage rates and price deflators for major industries
- Consumer price index
- Personal income and its components
- Population, labor force and unemployment
- Housing permits and construction contracts
- Motor vehicle registrations, and
- State tax revenues by type of tax, and current and capital expenditures.

The heart of the model is a set of equations modeling employment, wages, and prices by industry. In general, employment in an industry depends on demand for that industry's output, and on the state's wages and prices relative to the nation's wages and prices. Demand can be represented by a variety of variables including (but not limited to) New Jersey personal income, population, or US employment in the sector. Demand for retail trade is represented by published New Jersey retail sales [2]. For the construction sector it is represented by the value of construction contracts. Growth in population is driven by total employment in the state and by state wages and prices relative to national wages and prices.

As part of this project the model was extended to include several equations related to the energy sector. The equations in this new model sector are:

- electric price per kilowatt hour, residential and other (commercial and industrial);
- electricity usage per 1000 megawatt hours, residential;
- electric revenues in billions of dollars residential and other;
- energy taxes in millions of dollars, sales and corporate business; and
- employment at electric utilities and other utilities [3].

To be consistent with this classification system, *the term utility used in this chapter also encompasses the generation sector of the supply chain and not just the traditionally regulated transmission and distribution functions.* As used in this report utilities include "electric power, natural gas, steam supply, water supply, and sewage removal," as per the industrial definition in the North American Industry Classification System [4]. The employment data for

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[2] State retail sales were published on a monthly basis by the US Department of Commerce until 1995. Later data is estimated by R/ECON™.

[3] The employment data, like all other New Jersey employment data used in the model, comes from the New Jersey Department of Labor.

[4] North American Industry Classification System, p. 85.

electrical utilities includes jobs in “establishments primarily engaged in generating, transmitting, and/or distributing electric power” [5].

Other information added to the model for this project includes variables showing the fraction of electricity used in New Jersey that is produced by renewable resources, both PVs and other renewable sources. This fraction influences the price of electricity.

The data for electric prices, usage, and revenues were developed from monthly data for 1990 to current supplied by four utilities operating in New Jersey: PSE&G, JCP&L Energy, Connectiv, and Orange and Rockland. The reports from the utilities contained megawatts used and revenues per month by type of user including: residential heat and other, commercial firm and other, industrial firm and other, other, and sales for resale. The megawatts and revenues per month were aggregated to total residential and total other. Electricity prices were calculated as revenue per month divided by megawatts per month for total, residential, and other.

Energy taxes were developed from the monthly collections data [6] for the period from 1998 to current. The taxes include corporate business and sales taxes for energy and Transitional Energy Facilities Assessment (TEFA). The TEFA is assumed to phase out through FY2006 and then not be renewed.

Besides adding these equations and data to the model other changes were made to incorporate output from the new equations into other parts of the model. For instance, the equation estimating the consumer price index for New Jersey was modified to include the price of electricity for residential use.

## The Baseline (BASELINE) Forecast

R/ECON™ produces four forecasts each year of the New Jersey economy using the econometric model. This study used the April 2004 R/ECON™ forecast, modified to include the new energy sector, as its baseline (referred hereafter as BASELINE). The baseline forecast goes out to 2020. It is the underlying economic forecast of macroeconomic variables for this study. The data for the US used in BASELINE comes from the Global Insight, Inc. forecast of February 2004. Global Insight, Inc. is a national leader in economic forecasting and is used in other studies conducted at the Bloustein School [7].

## Overview of the US Forecast

The Global Insight February 2004 forecast looks for slow, steady growth after 2005, with slower

**Table 2.1 Summary of U.S. Economic Forecast, 2003 to 2020**

	2003	2004	2005	2005 to 2020
<b>Annual Percentage Growth</b>				
Nonagricultural Employment	-0.3%	1.2%	2.1%	1.1%
Real Domestic Product	3.1%	4.9%	3.8%	3.0%
Personal Income	3.3%	5.7%	5.6%	5.9%
Consumer Price Index	2.3%	2.7%	1.5%	2.4%
Producer Price Index: Energy	21.2%	9.6%	-5.3%	1.0%
<b>Percentage</b>				
Unemployment Rate (year)	6.0%	5.5%	5.3%	4.7%

Source: Global Insight, U.S. Economic Outlook, February 2004.

growth in output and employment than in the past two decades, but also less inflation. Real gross domestic product (GDP) growth of 4.9% in 2004 is the strongest performance during the forecast period. Growth will return to a more sustainable rate in 2005, and average 3% a year from 2005 to 2020, somewhat lower than the average of 3.3% per year experienced over the past 2 decades. (See Table 2.1.)

Nonagricultural employment will rise by 1.2% in 2004. Peak growth in the cycle will occur in 2005, and then job growth will average 1.1% a year. This

[5] North American Industry Classification System, p. 85.

[6] Comparative Collection Summary, 1998 to present.

[7] More information can be found at Global Insight, Inc. website: <http://www.globalinsight.com/>.

long-term average growth rate is considerably lower than the 1.8% average growth rate experienced over the past two decades. The unemployment rate will fall to 5.5% in 2004, 5.3% in 2005, and will average 4.7% between 2005 and 2020.

Consumer prices are expected to rise 2.7% this year, fall back to 1.5% in 2005 with declining oil prices, and average 2.4% a year from 2005 to 2020. The producer price index for energy (PPI Energy) is expected to rise 9.6% in 2004 after an even greater rise in 2003. According to this forecast, it will fall with declining oil prices in 2005 and the increase at an average rate of 1% a year over the rest of the forecast period. As of the writing of this report, oil prices are at an all-time high of \$50 per barrel. The PPI Energy forecast, which was developed prior to the recent run-up in oil prices, is used in order to have an internally consistent set of energy and other economic assumptions. Different fossil fuel price projections from the ones that form the BASELINE forecast are also considered and discussed below.

**Overview of the Forecast for New Jersey**

The forecast for the state is similar to that for the nation. Nonagricultural employment is expected to

increase 1.3% this year and at an average rate of 1.2% a year for the rest of the forecast period. The growth in real gross state product will rise to 3% this year as the economy expands strongly, fall back slightly in 2005, and then increase at an average of 3.1% a year in the rest of the forecast period. Consumer prices [8] are expected to rise a bit more slowly than in the US in the forecast period. The unemployment rate will fall to 5.2% in 2004 and 2005 and then fall during most of the rest of the forecast period, averaging to 4.9% from 2005 to 2020. (See Table 2.2.)

BASELINE for New Jersey includes the assumption that the Renewable Portfolio Standard will conform to current regulations. That is, Class 1 renewables in 2004 (calendar year) will be 0.75%, rising to 4% in 2009 and remaining at 4% through 2020. Class 2 renewables will remain at 2.5% throughout the period. (Summaries of the BASELINE forecast and other scenarios can be found in Appendix A.)

In BASELINE electric prices rise by 8% from \$0.10 per kilowatt-hour in 2004 to \$0.108 in 2020. The small rise is not surprising since the producer price index for energy declines sharply between 2004 and 2008, and is only 11% higher in 2020 than in 2004. Over the 2004 to 2020 period electric usage rises by 36% and electric revenues by 46%. Total taxes attributable to electric utilities fall slightly because of the TEFA phase-out, but exclusive of TEFA they rise by 24%. Table 2.3 summarizes these figures.

**Economic Analysis of the Impact of Other Energy Producer Price Scenarios on the New Jersey Economy**

In BASELINE for the US and New Jersey, the producer price index for energy (PPI Energy) for fuels, related products, and power, rose from 1.24 [9] in 2004 to 1.37 in 2020. That 10.5% growth, however,

**Table 2.2 Summary of New Jersey Economic Forecast, 2003 to 2020**

	2003	2004	2005	2005 to 2020
<b>Annual Percentage Growth</b>				
Nonagricultural Employment	-0.1%	1.3%	1.2%	1.2%
Real Gross State Product	2.1%	3.0%	2.7%	3.1%
Personal Income	3.2%	5.4%	5.0%	5.6%
Consumer Prices	2.5%	2.0%	1.4%	2.3%
<b>Percentage</b>				
Unemployment Rate(year)	5.9%	5.2%	5.2%	4.9%

Source: R/ECON™

[8]The consumer price index for New Jersey is calculated for the purposes of the R/ECON™ as a population weighted average of the New York-New Jersey-Connecticut CPI and the Pennsylvania-New Jersey CPI.

[9] The base year for the producer price index is 1982.

**Table 2.3 New Jersey Electric Utilities: Prices, Usage, and Taxes**

	2004	2020	Growth 2004-2020
Electric Price per Kilowatt Hour	\$0.100	\$0.108	8%
Electricity Usage in 1000 Megawatt Hours	66,537	90,539	36%
Electric Revenues (\$ Billions)	\$6.66	\$9.85	48%
Energy Taxes (\$ Millions)	\$1,108.3	\$1,060.3	-4%
Energy Taxes - TEFA (\$Millions)	\$858.8	\$1,060.3	23%

masks a decline of 14.9% during the period from 2004 to 2008. The coal component of the index increased 9.1% over the 16-year period with a minor decline in 2005, while the natural gas component increased 5.3% over the period with a decline of 19.8% between 2004 and 2008. The top half of Table 2.4 presents energy price indices, and its lower half presents the annual escalation rates.

In an attempt to see what will happen to the New Jersey economy if energy prices rise either more or less than in the BASELINE, two energy price scenarios were created. In the first (Low Energy Price) the producer price index for coal (PPI Coal) remains fixed from 2004 to 2020 and the producer price index for natural gas (PPI NG) increases 1% a year beginning in 2009. In the second (High Energy Price) PPI Coal increases 1% a year beginning in 2005 and PPI NG increases 3% a year beginning in 2005. The growth rates of all other components of the PPI

Energy remain as they were in the BASELINE forecast. Figures 2.1 through 2.3 show the PPIs for coal, natural gas, and energy for the baseline, Low Energy Price, and High Energy Price assumptions. These alternative scenarios were formulated from a review of other fuel forecasts (EIA, 2004; National Petroleum Council, 2003).

Because of the decline in PPI NG between 2004 and 2008 in BASELINE we begin to let PPI NG grow at 1% beginning in 2009. Otherwise, the level of PPI NG in the low growth scenario would be higher than in BASELINE.

A comparison, shown in Table 2.5, of the high growth PPI Energy scenario with the BASELINE shows very little difference between the two. In the High Energy Price scenario, electric prices in New Jersey are 2.9% higher than in BASELINE by 2010 and 4.6% higher in 2020. This leads to a projected reduction in electricity usage of .04% in 2010 and .02% in 2020, and an increase of 2.3% in electric revenues in 2010 and 4.9% in 2020. Projected state tax revenues from electric companies would be 1.4% higher in 2010 and 2.6% higher in 2020. There would be a small decline in gross state product at utilities and a negligible decline in overall gross state product and

**Table 2.4 Annual Wholesale Energy Price Indices and Escalation Rates for the US**

Baseline																	
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total	1.24	1.17	1.08	1.06	1.05	1.06	1.08	1.12	1.14	1.17	1.20	1.22	1.25	1.28	1.31	1.34	1.37
Coal	1.05	1.04	1.04	1.07	1.08	1.08	1.08	1.09	1.10	1.10	1.11	1.12	1.12	1.13	1.13	1.14	1.15
Natural Gas	1.86	1.81	1.61	1.55	1.49	1.51	1.55	1.62	1.65	1.71	1.75	1.78	1.81	1.85	1.88	1.92	1.96
Total	9.6%	(5.3%)	(8.0%)	(1.6%)	(0.7%)	0.9%	1.9%	3.1%	2.2%	2.4%	2.3%	2.3%	2.3%	2.3%	2.3%	2.3%	2.3%
Coal	5.1%	(1.1%)	0.4%	2.4%	0.7%	0.1%	0.8%	0.7%	0.6%	0.5%	0.5%	0.4%	0.5%	0.5%	0.5%	0.5%	0.5%
Natural Gas	8.4%	(2.7%)	(11.1%)	(3.8%)	(3.6%)	1.4%	2.7%	4.6%	2.0%	3.3%	2.3%	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%

Figure 2.1 PPI for Coal, 2004 to 2020

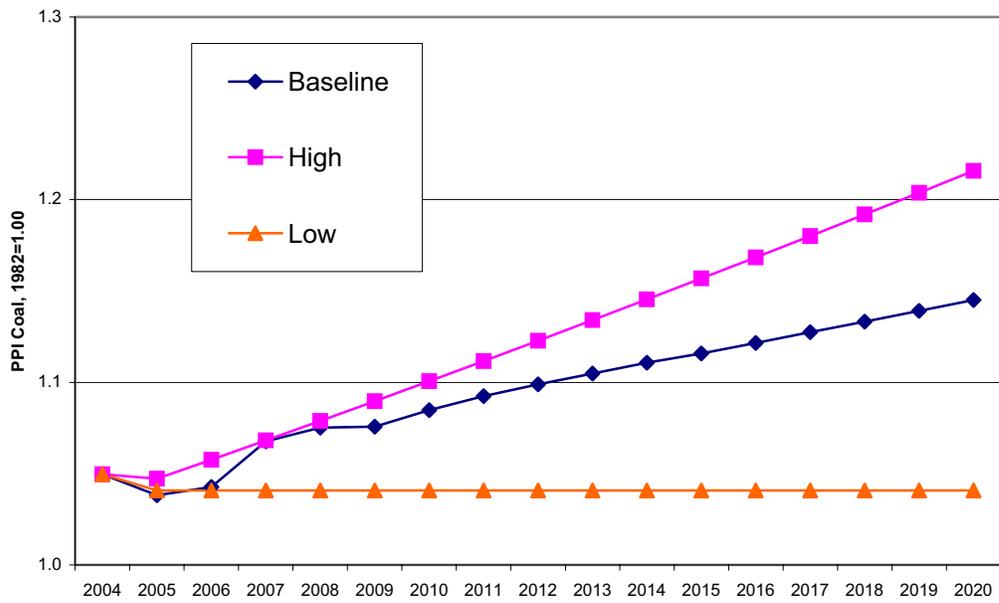
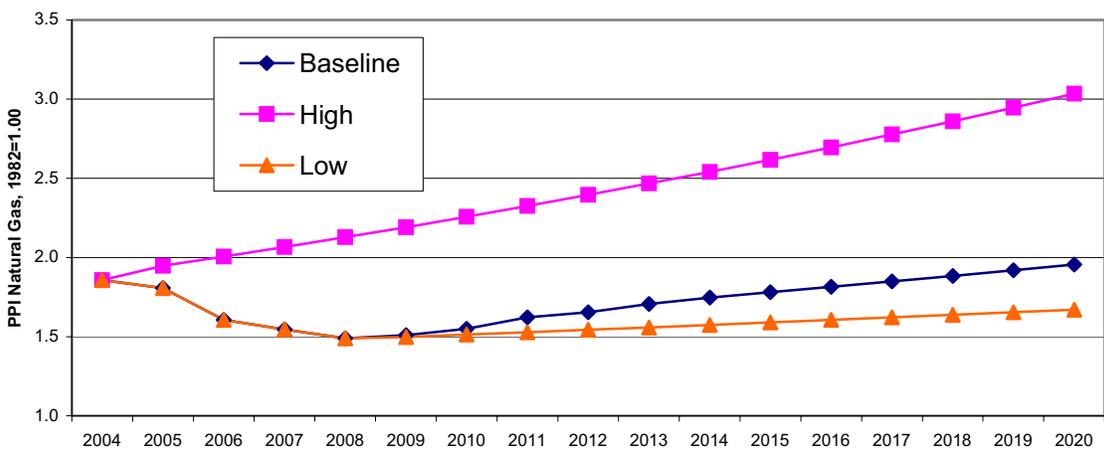
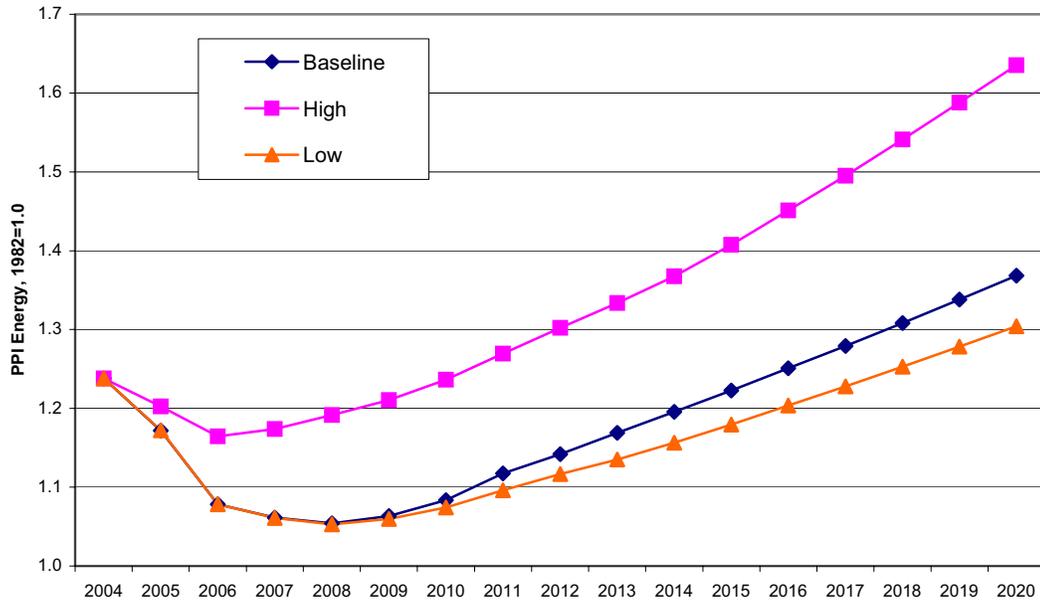


Figure 2.2 PPI for Natural Gas, 2004 to 2020



**Figure 2.3 PPI for Energy, 2004 to 2020**



**Table 2.5 Comparison of High Growth PPI Energy vs. BASELINE**

Comparison Points	Percentage Difference		Total Difference 2004 to 2020*
	2010	2020	
Electric Price per Kilowatt Hour	2.941%	4.630%	
Electricity Usage in 1000 Megawatt Hours	-0.037%	-0.022%	-403.6
Electric Revenues (\$ Millions)	2.262%	4.912%	\$4,247.8
Energy Taxes (\$ Millions)	1.422%	2.559%	\$241.9
Gross State Product for Utilities (\$ Millions 2000=100)	-0.213%	-0.045%	-\$0.2
Gross State Product (\$Millions 2000=100)	-0.053%	-0.039%	-\$3.2
Employment at Electric Utilities (Thousands)	-0.026%	-0.033%	-0.05
Nonagricultural Employment (Thousands)	-0.012%	-0.011%	-7.53
Consumer Price Index (1982=100)	0.132%	0.103%	

\*All total differences reported in this chapter are the sum of the annual values and are not discounted.

non-agricultural employment.

The differences between the Low Energy Price scenario and the BASELINE are even smaller than between the High Energy Price scenario and the BASELINE because there is less difference in the

additional scenario of back loading the proposed 20% RPS, i.e., having a larger percentage of the proposed 20% RPS requirement occur in later years, was also analyzed, but there was only a slight difference in its impact when compared to the straight-line scenario. The next section, III.D, assumes that there is no

**Table 2.6 Comparison of Low Growth PPI Energy vs. BASELINE**

Comparison Points	Percentage Difference		Total Difference 2004 to 2020
	2010	2020	
Electric Price per Kilowatt Hour	0.000%	-0.926%	
Electricity Usage in 1000 Megawatt Hours	0.008%	0.010%	120
Electric Revenues (\$ Millions)	-0.614%	-1.491%	-\$0.7
Energy Taxes (\$ Millions)	-0.022%	-0.654%	-\$38.3
Gross State Product for Utilities (\$ Millions 2000=100)	0.045%	0.027%	\$0.1
Gross State Product (\$Millions 2000=100)	0.016%	0.013%	\$1.1
Employment at Electric Utilities (Thousands)	0.007%	0.013%	0.02
Nonagricultural Employment (Thousands)	0.004%	0.004%	2.51
Consumer Price Index (1982=100)	-0.043%	-0.034%	

levels of the PPI Energy indexes presented in chart 3. Table 2.6 summaries these differences.

**Economic Analysis the Proposed 20% RPS with Expected Cost Reductions**

This section compares the economic impact of the proposed 20% RPS with the existing RPS, assuming expected cost reductions in wind and PVs. Under the current rules the renewable portfolio standard (RPS) will rise to 6.5% in 2008 (BPU year) or 2009 (calendar year) [10]. A simulation of the R/ECON™ model called 20% RPS Expected Cost Reductions shows the economic impacts of increasing the Class 1 RPS to 20% by 2020 (calendar year). The increases in the RPS are assumed to occur on a straight-line basis (that is by equal amounts each year including for PVs so that PVs are the same proportion as Class 1 renewables in the year 2020 as in 2008) from 2009 to 2020. Figure 2.4 compares the RPS in the BASELINE and proposed 20% RPS scenarios. An

change in the technology beyond the trends embedded in the model of providing renewable sources of energy.

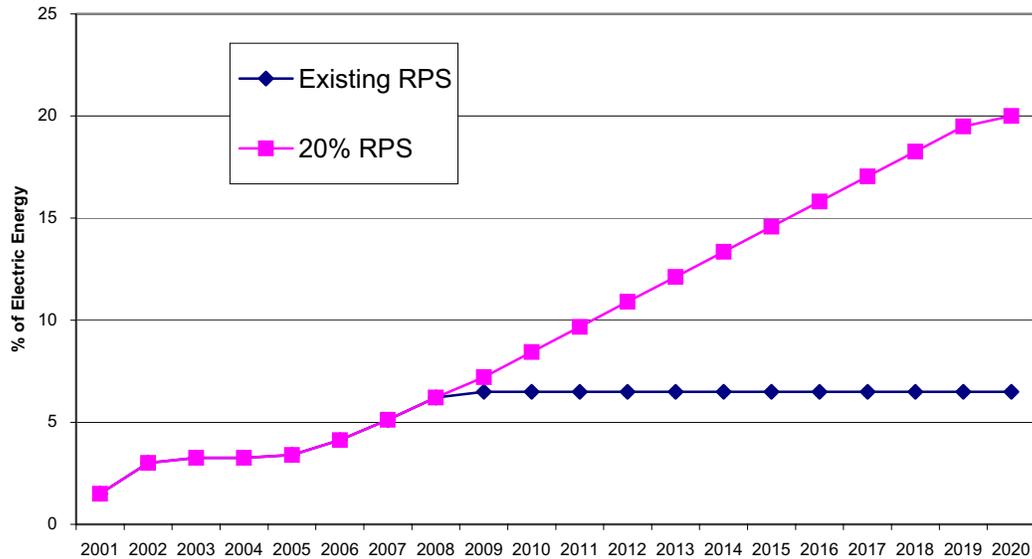
The increase in the RPS is expected to increase the price of electricity for both industrial

and residential use. In general, the increase in electric prices is expected to lead to a decrease in usage and also to a decrease in economic activity in the state. Whether the increase in the RPS would increase or decrease corporation and sales tax revenues from the utilities depends on the elasticity of the demand for electricity. Since electricity demand is relatively price inelastic for the small price changes explored in this report, sales tax revenues should not change substantially due to the reduction in electricity sales caused by higher electricity prices.

The data used in this section derives from a New Jersey Market Assessment for renewable energy commissioned as part of the Comprehensive Resource Analysis proceeding conducted by the BPU (Navigant Report, 2004). The purpose of the proceeding is for the BPU to set the appropriate level of funding for energy efficiency and renewable programs. These advances in technology, engineering improvements, and learning gained by more and more experience with these technologies are expected to result in a considerable decrease in the price of electricity provided by renewable resources, although the price

[10] The RPS program year starts on June 1 and ends on May 31 with the program year being the year as of June 1.

**Figure 2.4 Renewable Portfolio Standard, 2001 to 2020**



would still be higher than it would be using coal, oil, and gas fired facilities. To calculate this additional cost, the market clearing prices for PV and Class 1 RECs are forecasted. In the case of PVs, the REC price is set at the difference between the cost of PVs and the wholesale price for electricity, which was determined as part of the New Jersey Market assessment by a regional economic dispatch model. The price of the Class 1 REC is set at the difference between the cost of the marginal Class 1 resource and the wholesale price of electricity. The marginal Class 1 resource is the most expensive Class 1 resource that is used to satisfy the Class 1 requirement. For the years 2009 and beyond, the marginal Class 1 resource is wind. Although some of the Class 1 requirement that year would be satisfied by landfill gas, biomass and other Class 1 resources, wind power is necessary to meet the requirement. As a result, the price of the Class 1 REC must be sufficient to attract wind resources. Table 2.7

shows the calculation of the increase in electricity prices in 2010, 2015 and 2020 [11].

The first analysis shows the impact of the proposed 20% RPS Expected Cost Reductions on energy prices. (See Table 2.8) Later simulations will add renewable resource facilities construction and maintenance to the analysis.

The slight increase in the price of electricity is forecasted to result in a decline in electricity usage, as well as on gross state product and employment. However, since the decline in usage is very small and demand for electricity is relatively inelastic, the revenues of the utilities and energy taxes increase slightly.

The scenario of higher energy prices showed above that higher producer prices for energy would raise electric prices and reduce electric usage, as well as output and employment in the state. When the proposed 20% RPS Expected Cost Reductions scenario is compared to the High Energy Price scenario, Table 2.9 shows that electricity prices would be lower but electricity usage would not be consistently higher. Overall, however, this proposed 20% RPS scenario

[11] Since the Class 2 requirement is assumed to be the same under the existing and 20% RPS scenarios, there is no difference in costs between them and therefore no difference in economic impact.

**Table 2.7 Summary of the Calculation of the Increase in Electricity Prices between the Existing RPS and Proposed 20% RPS, Selective Years (2004 Dollars)**

	<u>2010</u>	<u>2015</u>	<u>2020</u>
	<b>Existing RPS (6.5%)</b>		
Cost of PV (\$/MWh)	\$504.29	\$390.00	\$31.00
Cost of Wind Resource (\$/MWh)	\$82.50	\$75.00	\$70.00
PV (GWh = 000's MWh)	127.4	135.9	144.9
Class I (GWh)	3,274.7	3,493.4	3,723.1
PV Net Shortfall (millions)	\$58	\$44	\$35
Class I Net Shortfall (millions)	\$124	\$72	\$54
Total Net Shortfall for Existing RPS (millions)	\$181	\$117	\$89
	<b>20% RPS</b>		
PV (GWh = 000's MWh)	147.5	327	724.5
Class I (GWh)	3,790.8	8,405.2	18,619.5
PV Net Shortfall (millions)	\$67	\$107	\$176
Class I Net Shortfall (millions)	\$143	\$174	\$270
Total Net Shortfall for 20% RPS (millions)	\$210	\$281	\$446
Shortfall Difference Between 20% and Base RPS (millions)	\$29	\$164	\$357
Shortfall Different Between 20% and Base RPS (\$/kWh)	\$0.0004	\$0.0019	\$0.0039
Base Case Electricity Price (\$ per kWh)	\$0.102	\$0.105	\$0.108
20% RPS Case Electricity Price (\$ per kWh)	\$0.102	\$0.107	\$0.112
% Change in Electricity Price Between 20% and Existing RPS	0.4%	1.8%	3.7%

**Table 2.8 Proposed 20% RPS Assuming Cost Reductions beyond Historical Trends vs. Existing RPS**

Comparison Points	Percentage Difference		Cumulative Difference 2004 to 2020
	2010	2020	
Electric Price per Kilowatt Hour	0.000%	3.704%	
Electricity Usage in 1000 Megawatt Hours	-0.032%	-0.031%	-408.41
Electric Revenues (\$ Millions)	-0.031%	3.307%	\$1.9
Energy Taxes (\$ Millions)	0.118%	1.964%	\$123.3
Gross State Product for Utilities (\$ Millions 2000=100)	-0.001%	0.000%	\$0.0
Gross State Product (\$Millions 2000=100)	-0.001%	-0.015%	-\$0.7
Employment at Electric Utilities (Thousands)	0.000%	-0.007%	-0.01
Nonagricultural Employment (Thousands)	-0.001%	-0.005%	-1.68
Consumer Price Index (1982=100)	0.035%	0.035%	

would improve the economy in terms of output and employment, but utility revenues and taxes would be slightly lower. This analysis demonstrates that if fuel prices rise to levels beyond those assumed in the BASELINE assumptions, the proposed 20% RPS's economic impact declines. The High Energy

Price scenario is approximately the breakeven point in which the proposed 20% RPS Expected Cost Reductions scenario provides positive impact on the economy compared to the renewable levels in the existing RPS. The above analysis does not include any

**Table 2.9 Proposed 20% RPS vs. Existing RPS Assuming High Energy Price Scenario**

	Percentage Difference		Cumulative Difference 2004 to 2020
	2010	2020	
Electric Price per Kilowatt Hour	-2.857%	-0.885%	
Electricity Usage in 1000 Megawatt Hours	0.005%	-0.009%	-150
Electric Revenues (\$ Millions)	-2.242%	-1.530%	-\$2.0
Energy Taxes (\$ Millions)	-1.286%	-0.580%	-\$105.7
Gross State Product for Utilities (\$ Millions 2000=100)	0.212%	0.045%	\$79.5
Gross State Product (\$Millions 2000=100)	0.051%	0.024%	\$2,065.0
Employment at Electric Utilities (Thousands)	0.035%	0.048%	0.04
Nonagricultural Employment (Thousands)	0.011%	0.007%	4.89
Consumer Price Index (1982=100)	-0.097%	-0.067%	-109.35

positive economic impact due to additional economic activity from the proposed 20% RPS or the benefits from avoiding environmental emissions.

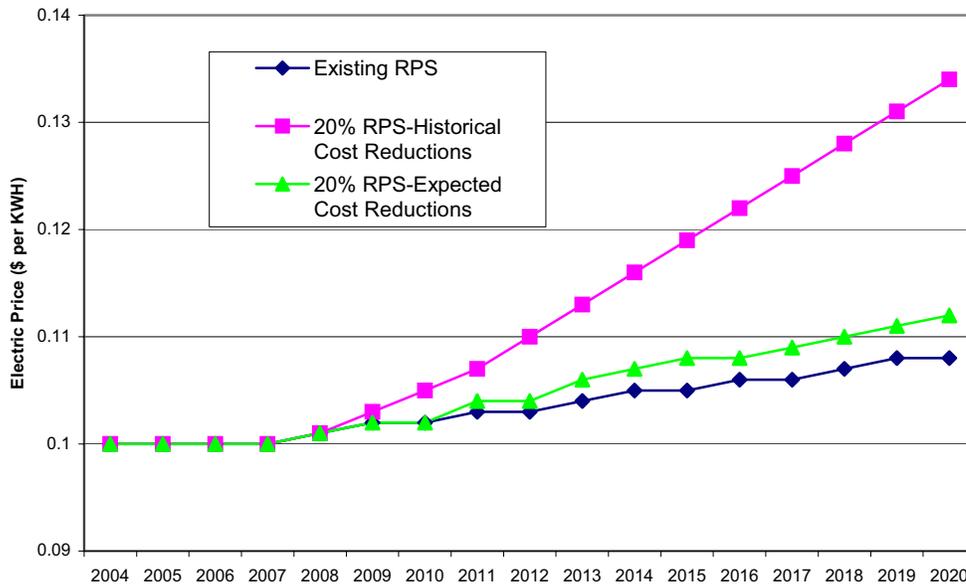
**Economic Analysis of the 20% RPS with Historical Cost Reductions**

Figure 2.5 compares the price of electricity in cents per kilowatt-hour in BASELINE and the proposed 20% RPS scenarios. In the Historical Cost Reduction scenario, the price difference from the

model assumes no improvements in technology, engineering, or from experience occur from that incorporated in the data in the model. This historical cost reduction scenario is therefore a “worst case” scenario because all of the sources of further cost reductions are ignored.

Table 2.10 shows a comparison of the two 20% RPS scenarios (Expected versus Historical Cost Reductions) in years 2010 and 2020 as well as the

**Figure 2.5 Comparison of Electricity Prices under the proposed 20% RPS-Expected Cost Reductions, 20% RPS-Historical Cost Reductions, and Existing RPS**



**Table 2.10 Existing RPS vs.20% RPS-Historical Cost Reductions**

	Percentage Difference		Cumulative Difference 2004 to 2020
	2010	2020	
Electric Price per Kilowatt Hour	2.941%	24.074%	
Electricity Usage in 1000 Megawatt Hours	-0.149%	-0.105%	-1,652
Electric Revenues (\$ Millions)	1.448%	22.660%	\$12,704.4
Energy Taxes (\$ Millions)	1.209%	13.036%	\$785.2
Gross State Product for Utilities (\$ Millions 2000=100)	0.002%	-0.070%	-\$69.5
Gross State Product (\$Millions 2000=100)	-0.008%	-0.145%	-\$4,763.9
Employment at Electric Utilities (Thousands)	-0.007%	-0.086%	-0.05
Non Agricultural Employment (Thousands)	-0.003%	-0.042%	-10.70

total difference in each of the variables over the period from 2004 to 2020 [12].

The expectations regarding the direction of change in the variables mentioned above are borne out in the comparison in the historical cost reduction scenario. The increase in the RPS to 20% by 2020 increases the price of electricity by 2.9% in 2010 and by 24.1% in 2020. The increase in price leads to a small decrease in usage adding up to 1,652 megawatts between 2009 and 2020. Revenues to the utilities increase over the years as much as 22.7% by 2020 and energy taxes increase by 13% by 2020.

In real terms (that is, in constant 2000 dollars) gross state product to the utilities falls slightly as does total gross state product. By 2020 real gross state product is 0.145% lower than it would be if the RPS were not increased. Employment in the state would also be slightly lower. By 2020 the number of jobs in the economy would be 2,000 (0.042%) less than if the RPS were not increased. Chapter 4 discusses the policy implications of the sensitivity of the impact on electricity prices and economic growth due to technological improvements and associated cost reductions in PVs and wind power.

### Detailed Economic Assessment of New Energy Resources in New Jersey

As part of this study the R/ECON™ Input-Output model (I-O) was used to estimate the impact of building various kinds of new electric energy resources in New Jersey. This I-O model allows a more detailed economic impact comparison of the PV and wind sectors between the proposed 20% RPS and the existing RPS. This section of the report considers the economic impact of building and maintaining wind driven power plants in New Jersey. This could occur if New Jersey develops off-shore wind or if the bulk of the facilities needed to support wind are located in New Jersey even if the windmills are located in other states, and separately, at the impact of manufacturing and installing photovoltaic systems in

[12] The differences between STRAIGHTLINE and BASE-LINE all occur between 2009 to 2020. The heading of the last column in the table is for 2004 to 2020 to keep it consistent with the rest of the difference tables in this chapter of the Report.

New Jersey. The systems would be built on a schedule conforming to the need to put new systems in place to meet the proposed 20% RPS requirement when the Class 1 requirement is assumed to go from 4% in 2009 to 20% in 2020 on a straight-line method.

**Table 2.11 Solar PV and Wind Installations Under the proposed 20% RPS**

	Solar PV (MWs Installed)		Wind (MWs Installed)	
	Cumulative	Annual	Cumulative	Annual
2005	6	6		
2006	11	5		
2007	26	15		
2008	56	29	266	266
2009	110	55	513	248
2010	130	19	685	172
2011	152	22	886	201
2012	178	26	1122	236
2013	209	31	1399	277
2014	245	36	1725	326
2015	287	42	2125	399
2016	337	50	2539	414
2017	395	58	3023	484
2018	463	68	3590	567
2019	542	80	4256	666
2020	636	94	4864	608

Table 2.11 shows the number of 8 megawatt solar photovoltaic plants and 60 megawatt wind installations necessary to get to the proposed 20% RPS.

The results from I-O were entered into the R/ECON™ econometric model to get at the long-term impacts of building the renewable facilities in New Jersey. For the purposes of working with the econometric model, it was assumed that the total impacts shown in I-O for each unit put in place would

[13] The results were entered into the econometric model by increasing employment in an industry by the amount of change shown for that industry in the I-O model. Where the I-O change was very small (less than 10) no attempt was made to include it specifically.

occur in 1 year. Thus, if two facilities should be built in a year, the total impact of one unit from I-O would be multiplied by two before adding the impacts into the econometric model [13].

Table 2.12 shows the impact of the 20% RPS standard on the state's economy when the new energy sources are not manufactured in New Jersey. Essentially this simulation shows the impact of installation of PV cells in New Jersey, when they are manufactured elsewhere. This is an extension of Table 2.8 which showed only the impact of the 20% RPS on prices without indicating how the energy would be supplied. In this case, there is an increase in the price of electricity of 3.7 percent in 2020, and a small decrease in total electricity usage of 0.016 percent in 2010 and 0.004 percent in 2020. Revenues to the electrical utility sector would increase by 3.334 percent in 2020, and energy taxes would increase by 0.13 percent in 2010 and 1.982 percent in 2020. It

would decrease jobs in the utility sector very slightly while adding an average of about 700 jobs a year to total employment.

Table 2.13 shows the impact of manufacturing and installing photovoltaic and wind energy facilities in New Jersey according to the schedule shown in Table 2.11, as well the impact of maintaining the systems. The addition of a total of 636 MWs of photovoltaic facilities and 4,864 MWs of wind power as sources of electricity in New Jersey over the period from 2005 to 2020 would increase total electricity usage by 0.071 percent in 2010 and 0.159 percent in 2020. It would increase revenues to this sector by 0.052 percent in 2010 and 3.493 percent in 2020, and increase energy taxes by 0.056 percent in 2010 and .105 percent in 2020. It would add an average of 10 jobs a year to the industry job base while adding an average of about 5,700 jobs a year to total employment. The increase in total jobs would be about 750 in 2005

**Table 2.12 20% RPS-Expected Changes with New Energy Sources from outside New Jersey vs. BASELINE**

	Percentage Difference		Total Difference 2004 to 2020
	2010	2020	
Electric Price per Kilowatt Hour	0.000%	3.704%	
Electricity Usage in 1000 Megawatt Hours	-0.016%	-0.004%	-254.86
Electric Revenues (\$ Millions)	-0.02%	3.334%	\$1.96
Energy Taxes (\$ Millions)	0.130%	1.982%	\$124.50
Gross State Product for Utilities (\$ Millions 2000=100)	0.006%	0.007%	\$0.00
Gross State Product (\$Millions 2000=100)	0.004%	-0.005%	-\$0.35
Employment at Electric Utiliies (Thousands)	0.000%	-0.024%	-0.01
NonAgricultural Employment (Thousands)	0.012%	0.037%	10.78
Consumer Price Index (1982=100)	0.036%	0.036%	

**Table 2.13 20% RPS-Expected Improvements with PVs and Wind Facilities Manufactured and Maintained in New Jersey vs. 20% RPS-Expected Cost Reductions without These Changes**

	Percentage Difference		Total Difference 2004 to 2020
	2010	2020	
Electric Price per Kilowatt Hour	0.000%	0.000%	
Electricity Usage in 1000 Megawatt Hours	0.071%	0.159%	1,060
Electric Revenues (\$ Millions)	0.052%	3.493%	\$0.11
Energy Taxes (\$ Millions)	0.056%	0.105%	\$8.38
Gross State Product for Utilities (\$ Millions 2000=100)	0.037%	0.031%	\$0.03
Gross State Product (\$Millions 2000=100)	0.074%	0.160%	\$7.64
Employment at Electric Utilities (Thousands)	0.000%	0.000%	0.2
Non Agricultural Employment (Thousands)	0.081%	0.236%	86.8
Consumer Price Index (1982=100)	0.000%	0.001%	

The increase in total jobs would be about 750 in 2005 and 2006 and rise to about 11,500 in 2020 when 702 MWs of new capacity would be needed, on top of the increased activity in the state from previous building, installation, and maintenance activities,

Since the R/Econ econometric model is a dynamic model, it assumes that the multiplier effects of the RPS technology will occur for some years following their installation. Alternatively, by virtue of its static nature, the I-O model assumes that all multiplier effects will occur in the year of installation. Thus there is likely to be some difference in the economic impacts estimates that emanate from the two models. In the case of the base scenario where no economic development scenarios are available for NJ-based manufacturing of RPS technology (see Table 12.14), therefore, the total number of jobs created from the installation of PV to meet the 20% RPS is expected to peak at about 2,600 by 2020. In 2020, these jobs would support \$191 million in annual total wealth, including \$142 in job earnings and \$12.9 million in state and local tax revenues in year 2000 dollars.

In meeting New Jersey demand for RPS technology through 2020, the state could implement

economic incentives that would attract pertinent manufacturers and other related employers into New Jersey. If this occurred, the total annual economic impacts of the RPS from the installation and maintenance of both PV and off shore wind power would attain levels show in Table 2.15. That is, by 2020 a total of about 11,700 jobs would be created. In 2020 these jobs would annually support nearly \$1 billion in gross state product for the state, which would be composed, in part, by about \$700 million in job earnings and \$77 million in state and local government tax revenues in year 2000 dollars.

But naturally manufacturers would be unlikely to produce for the New Jersey market only. Indeed, data from R/Econ’s database report that New Jersey industries currently producing technology akin to that to be used to meet the RPS send about 70% of their product out of state and, on average, New Jersey manufacturers tend to ship about 80% of their production beyond New Jersey’s borders. Given that the RPS technology manufacturers would come to the state mostly to produce for that market, we assumed a more conservative level of out-of-state shipping—50%— for RPS technology manufacturers. Applying this assumption, we doubled the production from manufacturing industries to which we had assigned

**Table 2.14 R/Econ I-O™ Annual Total Economic and Tax Impacts of the Installation and Maintenance of PV Panels, 2010 and 2020 (2000 Dollars)**

	2010	2020
<b>Jobs</b>	520	2,600
<b>Earnings</b>	\$28,600,000	\$141,700,000
<b>State &amp; local taxes</b>	\$2,600,000	\$12,900,000
<b>Gross state product</b>	\$38,700,000	\$191,400,000

**Table 2.15 R/Econ I-O™ Annual Total Economic and Tax Impacts of the Installation and Maintenance of RPS Power Generation Facilities All Manufacturing of RPS Technology in New Jersey 2010 and 2020 (2000 Dollars)**

	2010	2020
<b>Jobs</b>	2,700	11,700
<b>Earnings</b>	\$159,200,000	\$694,100,000
<b>State &amp; local taxes</b>	\$17,800,000	\$77,000,000
<b>Gross state product</b>	\$218,800,000	\$956,400,000

**Table 2.16 R/Econ I-O™ Annual Total Economic and Tax Impacts of the Installation and Maintenance of RPS Power Generation Facilities  
50% of NJ Manufacturers of RPS Technology Production to NJ 2010 and 2020 (2000 Dollars)**

	2010	2020
<b>Jobs</b>	4,800	20,750
<b>Earnings</b>	\$267,000,000	\$1,139,000,000
<b>State &amp; local taxes</b>	\$27,000,000	\$111,300,000
<b>Gross state product</b>	\$364,000,000	\$1,567,000,000

purchases to obtain results displayed in Table 2.15. The consequent economic impacts of this scenario are displayed in Table 2.16. Compared to the findings from Table 2.15, those in Table 2.16 show the number of jobs created by 2020 would increase by nearly 80% to 20,750 jobs and the annual gross product associated with those jobs would increase by a bit more than 60% to \$1.6 billion [14]. Annual earnings and state and local taxes revenues would be about \$1.1 billion and \$111 million, respectively. These results reflect the probable total economic impacts of a 20% RPS if New Jersey was able to be the regional center for PV and offshore wind manufacturing, installation and maintenance jobs.

### III. Other Potential Impacts of a 20% RPS

The proposed 20% RPS has several other impacts not directly connected to macroeconomic issues. This section discusses the incremental reduction in natural gas prices and the reliability benefits, including possible reductions in transmission

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[14] This order of increase is explained by several factors. First, manufacturing represents about 75% of the value of goods and services provided by industries during the installation, manufacturing, and maintenance of RPS technology. Second, the assumption that manufacturers ship 50% of their production out of state means that their production levels must be twice that needed to meet New Jersey's RPS demand. These first two factors would have us expect about a 75% increase in the economic measures. The third factor explains the variations around this expectation. The third factor is that manufacturing industries tend to pay workers higher than most others major sectors of the economy, particularly construction sector which comprises most of the rest of the spending for RPS technology installation and maintenance. The fact that manufacturing workers are paid more enables them to support more workers in the retail and personal service sectors, which are paid below the New Jersey worker average. Thus manufacturing jobs tend to support more low-paying jobs.

and distribution costs, attributable to the proposed 20% RPS.

The proposed 20% RPS would reduce the incremental demand for natural gas and therefore provide downward pressure on the price of this commodity. Several studies have quantified the relationship between reduction in natural gas demand and associated price reduction [Wiser et al.]. Based on these studies, each 1% reduction in national demand of natural gas leads to a long-term reduction in average natural gas wellhead prices of 0.75% to 2.5%, and some studies predict even larger reductions [Wiser et al.].

A 20% RPS would also contribute to distribution system reliability. The additional PVs would provide a source of power independent of the grid and local distribution system, assuming that these systems are designed to operate without power from the grid. PVs, however, are a small portion, 3.9% of the total renewables in 2020 under the proposed 20% RPS. PVs, if strategically placed, may avoid some transmission and distribution costs.

Regarding the reliability of the bulk power system, a 20% RPS may not provide any reliability benefits. The two major components of grid reliability are adequacy and security. The PJM capacity market is intended to ensure adequacy. Determining a resource's contribution to adequacy depends on its availability, which for PVs and wind is more volatile than traditional generation due to the random nature of sunlight and wind availability. If PJM appropriately accounts for the availability of PVs and wind, then its capacity requirement would reflect the availability of wind and PV and be sufficient to satisfy PJM's adequacy requirements. Security is the ability of the

grid to continue operating without interruption of service after the failure of generation or transmission elements. Failure of the largest system components are of primary concern. Renewable generation facilities, which are small compared to large power plants and major transmission components, are not likely to provide significant security benefits or concerns.

Having a substantial amount of wind power may pose additional costs related to reliability. According to a recent survey of studies on the reliability impact of wind on the bulk power system, the reviewed studies found that wind integration costs are positive and become more significant as wind power gains a greater share of electricity production, although these costs are small on a per-kWh of wind energy basis [Parsons, et al]. For wind penetrations of 5%, which would be approximately the amount of wind in the PJM region under the proposed 20% RPS, the additional cost are roughly \$2.00/MWh [Parsons, et al., Table 6] [15]. The Navigant Report, which provides the cost estimates for this report, assumes an additional operations and maintenance charge of \$4.00/MWh to account for various grid integration costs such as scheduling, regulation, and reserve requirements [Navigant, p. 23].

#### **IV. Conclusion**

The proposed 20% RPS increases the direct cost of electricity but has a negligible impact on the overall growth of the New Jersey economy. Expected technological advances that reduce the costs of PVs and wind are critical in order to minimize the electricity price impact and therefore the impact on the economy of the proposed 20% RPS. Higher fuel prices, however, reduce the electricity price impact of the proposed 20% RPS and at price levels assumed in the High Energy Price scenario, the proposed 20% RPS is economically more advantageous than the existing RPS.

The ability to locate PV and wind facilities, either from off shore facilities located in New Jersey or the bulk of manufacturing and support facilities for windmills located elsewhere, would contribute to the economic benefits of the proposed 20% RPS, although these benefits are small relative to the whole New Jersey economy. The proposed 20% RPS would also lower natural gas prices for New Jersey consumers, and PVs would provide backup power when the grid is not available.

The analysis conducted in this chapter does not include the environmental and other benefits of the proposed 20% RPS compared to the existing RPS. These additional benefits are discussed extensively in Chapter 3.

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[15] The Navigant Report included interconnection costs of wind up to 0.5 miles from the grid.

# Chapter 3: Environmental Benefits of a New Jersey Renewable Portfolio Standard

## I. Introduction and Findings

A New Jersey RPS will reduce emissions generated by power plants that adversely affect the health and welfare of its population. Conceptually, the benefits from these reductions can be translated into dollar savings stemming from the reduction in mortality, morbidity, economic and other costs due to fewer emissions. This chapter traces the connection between emission reductions and their benefits and discusses approaches how to quantify these benefits.

Although it is possible to develop New Jersey specific estimates of the environmental benefits of its proposed RPS, the discussion in this chapter indicates that this would involve extensive data collection, modeling, and analysis, and is beyond the scope of this study. However, policymakers must make decisions in the interim in the absence of such data. Environmental externalities should not be ignored because of the difficulty in quantifying them. This chapter, therefore, also discusses the use of externality adders found in the literature and used by other policymakers as a substitute for developing New Jersey specific numbers. It also applies various externality adders to the New Jersey proposed RPS. Chapter 4 discusses the associated policy implications and recommendations of the proposed 20% RPS.

This chapter fits within an economic framework of externalities and this study's approach of identifying and quantifying the costs and benefits of New Jersey's proposed RPS. In general, externalities are costs or benefits that are not borne by individual producers or consumers and therefore are

external to their decision-making. In the presence of negative externalities such as emissions, market-based outcomes alone will result in more emissions being produced than socially optimal [16].

This chapter finds the following:

1. There are many and substantial health and environmental effects due to air emissions from power plants;
2. The health and environmental benefits from a RPS result from and depend on the reduction in the atmospheric concentration of emissions, which are (with the exception of carbon dioxide) geographic specific;
3. The health and environmental benefits of reduced emission concentrations are positive and span a wide range of values;
4. Quantifying the health and environmental benefits associated with a New Jersey RPS involves many detailed assumptions and using prior studies that may not be completely relevant to New Jersey. Therefore

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[16] Although the approach of this report is to determine whether these non-market benefits can be monetized in the context of NJ RPS policymaking, there are other ways of accounting for these benefits in policymaking without monetization. One method is tradeoff analysis. If this approach were to be applied to this analysis, then each of the non-market benefits would be quantified separately and not combined into a dollar value. Tradeoffs between different impacts, such as costs and illnesses due to sulfur dioxide emissions, would be evaluated. This analysis can also be informed by stakeholders' values. Another approach involves using a deliberative process, for example one mandated by law, in which various stakeholders provide input.

a New Jersey analysis requires additional research and modeling in order to quantify these benefits;

5. Existing cap-and-trade emission allowance policies for sulfur dioxide and nitrogen oxides act in combination with a RPS so that the RPS may not alone result in reduced levels of these emissions but will lower the price of emission allowances;
6. Other policymakers use a wide range of externality values that may have limited application to New Jersey but these values are used in this report for illustrative purposes; and
7. Illustrative calculations using generic environmental externality adders indicate that in the year 2020 the environmental benefits of the proposed 20% RPS are in the range of several hundred million dollars.

Section II of this chapter describes the methodology used to quantify and monetize the health and environmental benefits of a New Jersey RPS. It consists of an overview of this methodology, a description of the New Jersey context, an analysis of the interaction between a RPS and emission allowance policies, and a summary of the literature of environmental externalities and electricity generation. This section also calculates the reductions in air emissions expected from a RPS and then uses the data presented to illustrate the calculation of the associated health and environmental benefits of air emission reductions.

Section III is a detailed review of the scientific and economic literature associated with quantifying the health and environmental effects of air emissions. It analyzes each emission, traces its health and environmental impact, and discusses how to quantify these impacts. Since the literature being reviewed is extensive, a detailed technical Appendix is also provided. Appendix B is a stand-alone document that also contains sample calculations that illustrate the types of calculations and their steps if New Jersey specific health and environmental effects from air emission reductions were to be conducted.

## II. Monetizing the Benefits of Reducing Power Plant Air Emissions

### Overview of the Methodology

Power plants have air, water, and solid waste emissions that adversely affect human health and the environment. The focus is on air emissions because the largest reductions in emissions due to a RPS are anticipated to occur in this category [17]. The air emissions that are of concern are carbon monoxide (CO), carbon dioxide (CO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), particulate matter (PM), sulfur dioxide (SO<sub>2</sub>), and mercury.

Figure 3.1 illustrates the steps this report follows to estimate non-market benefits of air pollution abatement: 1) identifying benefits, 2) quantifying benefits, and 3) monetizing benefits. The first step involves describing a qualitative relationship between changes in pollutant emissions and ambient concentrations, and subsequently between ambient concentrations and health and environmental effects. Identifying the benefits of air pollution abatement is equivalent to identifying the damages that are reduced or avoided. These damages fall into three broad categories (Freeman, 1993):

1. Direct damages to humans (e.g., increased asthmatic attacks);
2. Indirect damages to humans through ecosystems (e.g., reduced crop yields);
3. Indirect damages to humans through nonliving systems (e.g., damage to buildings).

Direct damages to humans include health damages, as well as aesthetic damages such as unpleasant odor, noise or poor visibility. Indirect damages to humans through ecosystems consist of productivity damages in the form of crop reduction, damages to forests and commercial fisheries, recreation damages (lakes, rivers, etc.), and intrinsic or

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[17] Power plants may also emit solid wastes and liquid effluents that may contain toxic substances. According to one source [Bent et al], these are not generally an issue with existing environmental regulations. In addition, some power plants return water at different temperatures to rivers or other water bodies that harms plant and animal life. There are other possible environmental impacts as well.

nonuse damages. The latter are damages to ecological resources that are not motivated by people's own use of these resources. For example, people value endangered species or rare ecosystems, even though they do not have the intention to ever see or experience them. Finally, indirect damages to humans that occur through nonliving things include damages to materials and structures, such as soiling and corrosion.

The second step, quantifying benefits, involves establishing a functional relationship between environmental effects and the reduction in air pollution. Although an RPS policy reduces the amount of emissions, it is the reduction in concentration that results in the environmental benefits. Concentration-response functions quantify the relationship between the impact and emission concentration. For example, these functions describe the change in a health effect such as asthma attacks, and the concentration of the pollutant that causes the effect. In order to calculate the number of cases that will be avoided due to an RPS, a baseline exposure (number of people affected, and the level of pollution they are subjected) must be established and the baseline number of cases for each quantifiable health effect and for each pollutant. These numbers are then contrasted with the number of cases for each quantifiable health effect with the RPS regulation, to calculate the number of cases avoided as a result of the RPS.

The third step, monetizing or valuing the benefits, is typically specific to the environmental effect under consideration. Further below, we describe the most common valuation methods that have been used in the literature for each effect separately.

Understanding the benefits of reduced air emissions due to RPS policies requires tracing the emission pathways from the power plant to the damage site, illustrated in Figure 3.2. Starting at the top of this figure, a RPS policy reduces air emission by replacing existing sources of electricity with renewable resources. The reduced levels of emissions are transported through the atmosphere and deposited. This transportation process is affected by numerous conditions, such as the type of emission, weather conditions, the presence of other compounds in the atmosphere, etc. The result is a change in concentration of various emissions in the atmosphere. In most cases,

a reduction in emissions results in a reduction in concentration of the associated compound that results in damage. It is possible, however, to increase the level of ozone by reducing the concentration of  $\text{NO}_x$ , which combines with volatile organic compounds (VOCs) to form ozone. More details on specific emissions and their associated effects are discussed below.

As indicated in the middle of Figure 3.2, the benefits, i.e., avoided damages, of reducing air emissions from power plants result from the reduction of the concentration of air emissions not in the reduction in emissions. The benefits also depend on the level of concentration of the emission in the atmosphere as well as the amount of reduction from the initial concentration. As noted above, the relationship between the avoided damage and the change in concentration is the dose-response relationship. The damage due to emissions may be local, regional, or global.

Finally, as the bottom of Figure 3.2 indicates, to compare damages on a common scale, they need to be monetized. There are several ways to do so such as contingent valuation, travel cost, hedonic prices, market prices, and replacement costs. We discuss below each of these methods and their application to a New Jersey RPS policy. The sum of the monetized benefits, that is the costs associated with emissions that are avoided due to a RPS policy is the total environmental benefit.

## Overview of Air Emissions in New Jersey

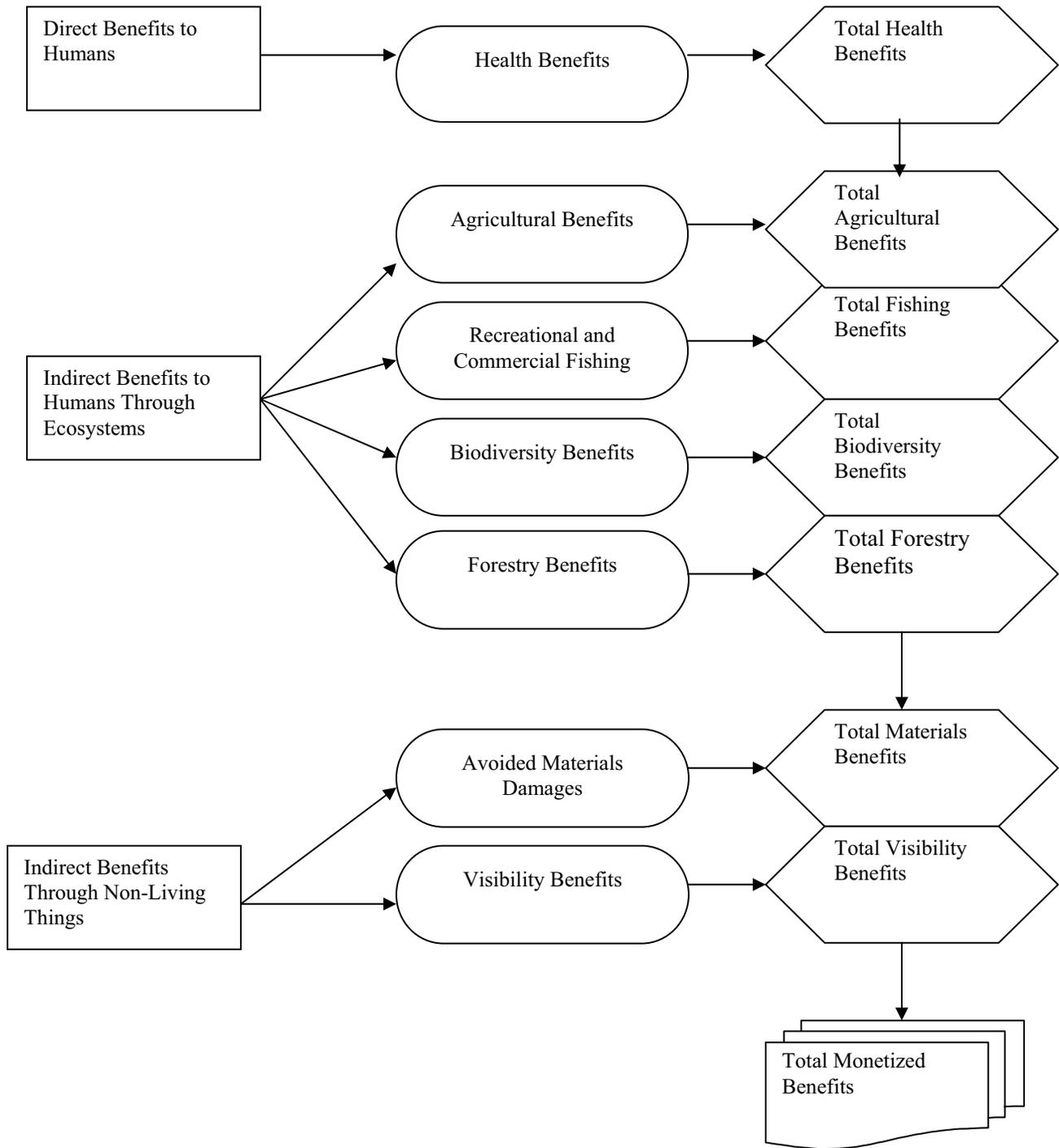
According to the most recent Air Quality Report published by the New Jersey Department of Environmental Protection (NJ DEP) [18]:

“Air Quality in New Jersey has significantly improved since the passage of the Clean Air Act in 1970....These improvements are the result of aggressive pollution control programs implemented in New Jersey as well as regional emission reduction strategies involving other states. But air quality problems do remain in the state.”

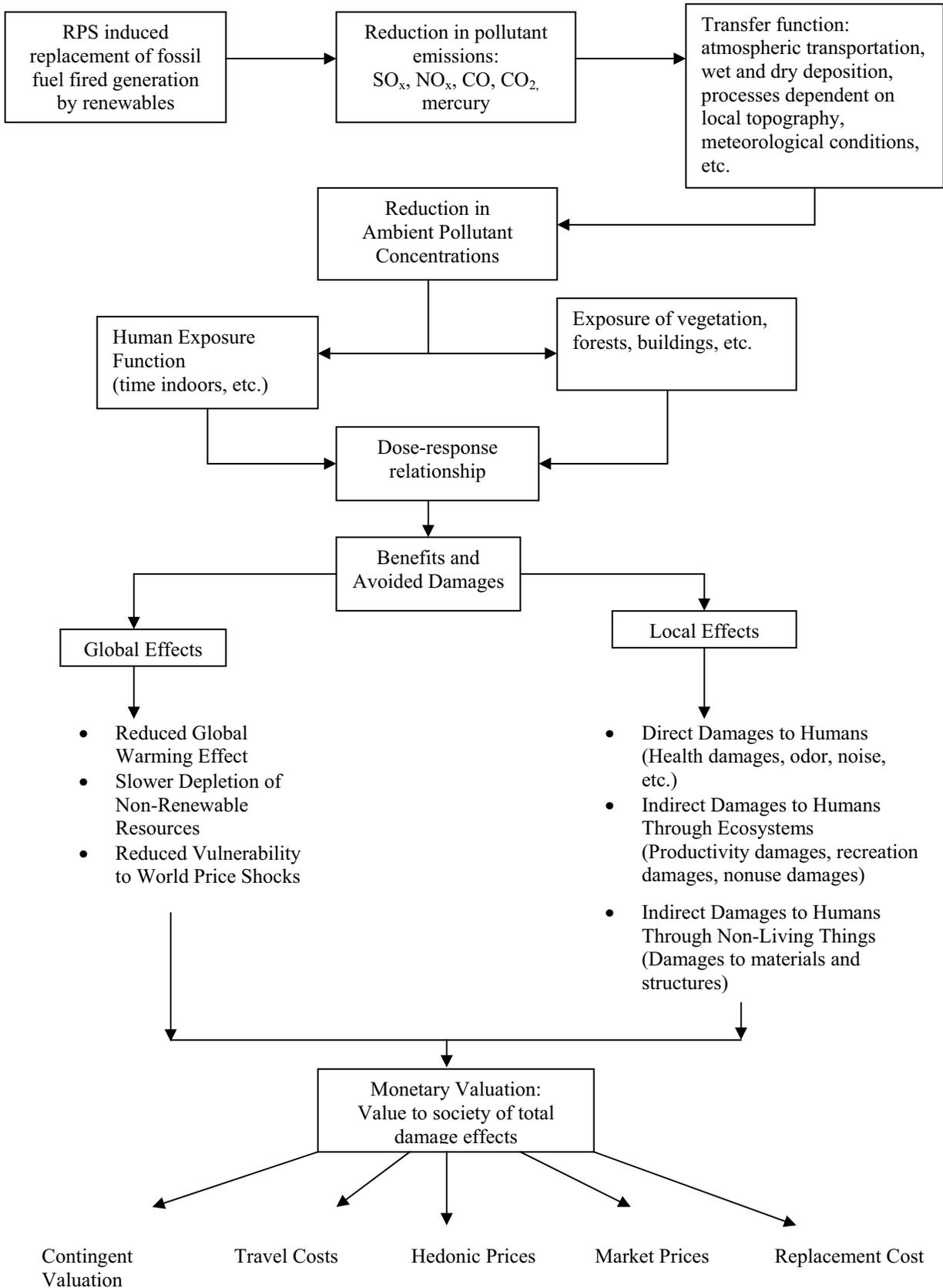
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[18] Available at <http://www.state.nj.us/dep/airmon/02rpt.htm> as of September 23, 2004, Introduction, p. 1.

**Figure 3.1: Taxonomy of Major Non-market Benefits of Air Pollution Abatement**



**Figure 3.2: Links in the Environmental Chain Associated with RPS**



In April 2004, the NJ DEP concluded that air pollution is a serious public health and environmental problem in the state, and highlighted three pollutants (ozone, fine particulates, and air toxics) that require immediate attention [19]. This section provides a high-level overview of air emissions from power plants, their pathways, their health and environmental effects, and the existing regulatory framework [20]. A complete discussion of these issues can be found in the New Jersey Department of Environmental Protection references cited below.

### *Air Toxics*

Air pollutants can be divided into two categories: the criteria pollutants (ozone, sulfur dioxide, carbon monoxide, nitrogen dioxide, particulate matter, and lead) and air toxics. Air toxics are all other chemicals that can be released into the air and can cause adverse health effects in human (NJ DEP, 2002). In New Jersey, roughly 7% of air toxics come from major point sources, which include factories and power plants (NJ DEP 2004). Mercury is an air toxic that creates serious health problems. Over 2,000 pounds of mercury are emitted each year by sources in New Jersey, including its coal-fired power plants as well as municipal solid waste incinerators and scrap-melters (NJ DEP, 2004). Unlike criteria pollutants, for which the U.S. Environmental Protection Agency (EPA) has set National Ambient Air Quality Standards (NAAQS) and are subject to monitoring, reporting, and control requirements, there are no NAAQS for air toxics [21].

### *Carbon Dioxide (CO<sub>2</sub>)*

Carbon dioxide is produced as a by-product of the combustion process in coal, oil, and natural gas-fired power plants. CO<sub>2</sub> is a major greenhouse gas, which is widely believed to contribute to global warming. The amount of global warming is related to the concentration of CO<sub>2</sub> in the earth's atmosphere. Therefore, the location of the CO<sub>2</sub> emission and its

pathway, which is released immediately into the atmosphere, does not affect its contribution to global warming. Currently, there is no legal or regulatory restriction on the emission of CO<sub>2</sub> in the United States, although the governor of New Jersey has recently declared carbon dioxide a public hazard [22].

### *Carbon Monoxide (CO)*

Carbon monoxide is a colorless, odorless and poisonous gas that is formed when carbon in fuels is not burned completely. It is a relatively unstable gas and its impacts are generally local to the source. About 82% of all CO emissions nationally are from the transportation sector, although CO is also produced in generating electricity from fossil fuels [23]. Nationwide, approximately 4% of CO comes from non-transportation, fuel-combustion sources such as boilers and incinerators (NJ DEP 2002). CO levels are typically higher in the winter because motor vehicles do not burn fuel as efficiently when they are cold and because atmospheric inversions that trap CO are also more frequent in the winter. CO exposure can cause headaches and nausea, is a threat to those that suffer from cardiovascular disease, and has other less severe effects such as reduced work capacity and decreased learning ability (NJ DEP, 2002).

### *Nitrogen Oxides (NO<sub>x</sub>)*

Nitrogen oxides are released as part of the combustion process in power plants, motor vehicles, and other sources of combustion. NO<sub>x</sub> itself causes health and environmental damages but also combines with volatile organic compounds (VOCs) in the presence of sunlight to form ozone in the lower atmosphere. NO<sub>x</sub> exposure can cause health effects such as respiratory problems and contribute to damage to ecosystems (NJ DEP, 2002). NO<sub>x</sub> is regulated under emission allowance program administered by the U.S. Environmental Protection Agency [Ellerman et al]. The total amount of NO<sub>x</sub> emissions is capped in the Northeast, and emitters buy emission allowances in order to emit NO<sub>x</sub> or can sell any extra allowances to other emitters [24].

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[22] The Record, Hackensack, NJ, September 17, 2004.

[23] NJ DEP, 2002, p. 1.

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[19] NJ DEP, 2001, p. 1.

[20] See EIA, 1995 for a more complete treatment of the regulation of environmental externalities in U.S. electricity generation

[21] In 1990 the U.S. Congress directed that the EPA begin to list approximately 200 air toxics, known as Hazardous Air Pollutants (HAPs) (NJ DEP, 2004).

## *Ozone (O<sub>3</sub>)*

The formation of ground-level O<sub>3</sub> is a complex process requiring NO<sub>x</sub>, VOCs, and sunlight. Man-made sources of VOCs include motor vehicles, chemical plants, factories, and consumer and commercial products. Ozone and its precursor pollutants can be transported hundreds of miles. According to the NJ DEP, much of the state's ozone comes from NO<sub>x</sub> emitted upwind of the state from the Midwest and Southeast [25]. In 2002, the previous ozone standard was exceeded on 16 days and the new standard was exceeded on 44 days in New Jersey [26]. The NJ DEP concludes that attaining the new federal ozone standards in New Jersey would eliminate about 40,000 asthma attacks each year and substantially reduce hospital and emergency room admissions (NJ DEP, 2004).

## *Particulate Matter (PM)*

Particulate air emissions refer to both solid particles and liquid droplets suspended in the atmosphere, and particulates can either be emitted directly or be formed from gaseous emissions, such as SO<sub>2</sub> and NO<sub>x</sub> (NJ DEP, 2001) [27]. Particulate matter (PM) is categorized by its size. PM<sub>10</sub> refers to particulate smaller than 10 microns [28]. Particulates larger than this size are typically trapped in the respiratory tract prior to reaching the lungs. Fine particulate matter, PM<sub>2.5</sub>, pose significant health impacts in New Jersey because these particulates can reach deep into the lungs (NJ DEP, 2004). Sources of fine particulates in New Jersey are diesel-powered engines and upwind power plants, whose gases are converted to PM as they travel downwind to New Jersey (NJ DEP, 2004). According to the NJ DEP, exposure to fine particulate levels above the federal health standards results in an estimated 350 to 1,200 deaths, 6,000 emergency room

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[24] An RPS with RECs (renewable environmental credits) is conceptually the same type of policy as an emission allowance trading policy, except that the emissions are a negative externality and renewables are a positive externality.

[25] NJ DEP, 2004, p. 4.

[26] NJ DEP, 2004, p. 4.

[27] The most recent publicly available air quality report from the NJ DEP on particulates is 2001.

[28] One micron is one millionth of one meter, also called micrometer, denoted by  $\mu\text{m}$ .

visits, and 68,000 asthma attacks per year (NJ DEP, 2004).

## *Sulfur Dioxide (SO<sub>2</sub>)*

Sulfur dioxide is emitted as part of the combustion process involving fuels containing sulfur such as coal and oil. It, along with NO<sub>x</sub>, has adverse impacts on terrestrial and aquatic ecosystems and damages buildings and other structures through the deposition of acid [29]. SO<sub>2</sub> can also lead to reduced visibility and cause irritation of the mucous membranes (NJ DEP, 2002). Sulfur dioxide can be transported long distances, such as from the Midwest to the Northeast before its deposition. Similar to NO<sub>x</sub>, SO<sub>2</sub> is regulated under a cap-and-trade emission allowance program administered by the U.S. Environmental Protection Agency (Ellerman et al and Tietenberg). The net effect in the reduction of NO<sub>x</sub> and SO<sub>2</sub> emissions between a RPS and emission allowance program are discussed below.

## **Interaction between Emission Allowance Programs and a Renewable Portfolio Standard**

SO<sub>2</sub> and NO<sub>x</sub> emissions are capped, and emitters must have sufficient allowances, which can be bought and sold in associated emission markets, to cover their actual emissions. Reductions in these emissions from a RPS frees up allowances that would have been used but for the RPS. These allowances then can be sold to entities that can use the allowance to emit the associated pollutant. If there were sufficient demand for allowances beyond the reduction due to the RPS, then a RPS would not lower the emission of SO<sub>2</sub> and NO<sub>x</sub> but only the price of the allowances.

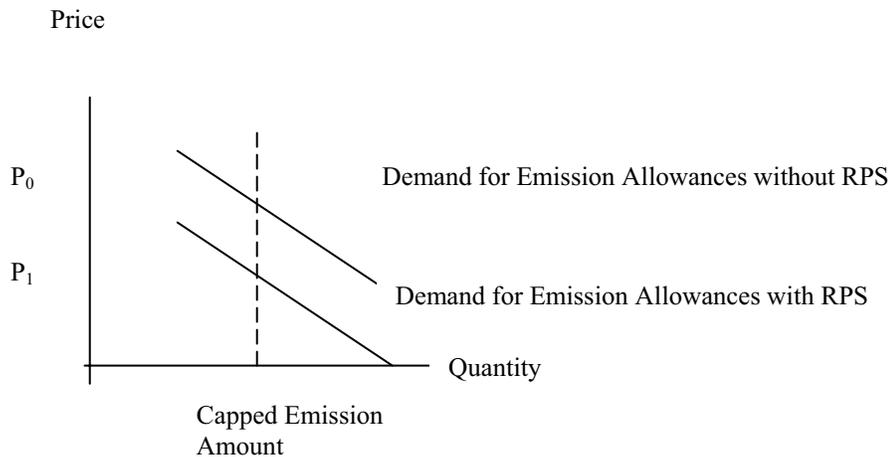
Figure 3.3 illustrates this situation in which an emission cap combined with a RPS does not result in a net reduction of emissions. It shows a vertical supply curve for the emissions because the emission

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[29] Acid deposition can take two forms: wet deposition and dry deposition. Wet deposition occurs when sulfur dioxide and nitrogen oxides in the atmosphere react with water and return to the earth's surface as acidic water, commonly referred to as acid rain. During dry deposition sulfur dioxide and nitrogen oxides settle out of the atmosphere as particles or gases.

is capped and two downward sloping demand curves. The higher curve is the demand curve for emission allowances without a RPS, and the lower curve reflects the reduction in demand for allowances due to the RPS. As Figure 3 indicates, the price for the allowance decreases from  $P_0$  to  $P_1$  but the quantity of the emissions does not change.

**Figure 3.3 Net Effects of Emission Caps and a Renewable Portfolio Standard**



Because of the effect just described, the U.S. Energy Information Agency concluded that a national RPS is projected to have little impact on  $\text{SO}_2$  and  $\text{NO}_x$  emission levels but would result in a significant reduction in  $\text{SO}_2$  allowance prices (EIA, 2003) [30]. Of course, the reduction in allowance prices due to a RPS is a benefit of the policy, but this is an economic benefit not a health or environmental benefit due to reduced concentration. The impact, and therefore environmental benefit, can be captured if the RPS results in a reduction of the cap. While the  $\text{NO}_x$  cap is periodically reduced, it is not clear what precise role that the RPS policies have in that calculation. Accordingly, one recommendation of

[30] The EIA also found that there would be little reduction in  $\text{NO}_x$  allowance prices because the RPS that it analyzed permitted co-firing. Primarily a generation unit's boiler type and emission control type, rather than its fuel drives  $\text{NO}_x$  emissions. The Minnesota Public Utilities Commission made a similar finding with respect to  $\text{SO}_2$ : "Regarding post-2000 issue, the Commission finds that the  $\text{SO}_2$  damages will be internalized after 2000 and, therefore, applying externality costs would be unwarranted (MN PUC)." Minnesota is not part of a  $\text{NO}_x$  cap-and-trade allowance program.

this study, discussed more in Chapter 4, is that New Jersey aggressively seek and lead a coalition of states to obtain specific reductions in established caps to capture all of these environmental benefits.

## Externality Adders

### *Review of Externality Adders*

An extensive literature exists that attempts to quantify the environmental externalities from generating electricity. The goal of this literature is to provide externality adders, which vary by the type of fuel used, to reflect the health and environmental cost of generation beyond the cost of producing that electricity. Policymakers can then use these adders to calculate the environmental benefit of various policies. Adders are commonly reported in units of cents per kilowatt-hour (kWh) of electricity.

This section summarizes the results of this literature based on a recent comprehensive, international, and scholarly review (Sundqvist) [31]. The literature provides a wide range of methodologies and approaches to this problem, and the result is a broad array of estimates for externality adders.

[31] See also Office of Technology Assessment, NREL, and EIA 1995.

Table 3.1 presents these results. Note the wide range of estimates for natural gas externality adders. The maximum (13.22 cents/kWh) is approximately 400 times larger than the minimum estimate (0.003 cents/kWh); the mean and median differ by almost by a factor of two. Natural gas is highlighted because as discussed below, it is the marginal fuel for electricity generation, and it is the fuel that will be displaced by renewable resources.

As Section III reveals, externality adders depend upon numerous assumptions, the results of scientific studies that contain ranges of estimates for a particular parameter, and must account for many specific conditions that may not be transferable between the situation the policymaker is addressing and the availability of scientific evidence. For instance, air concentrations of a pollutant may be different in rural than in urban areas.

Table 3.2 lists the results of U.S. studies and has similar ranges of estimates as Table 3.1. Again note the wide range in the estimates for the natural gas externality adder. The minimum value reported in this table is 0.003 cents/kWh and the maximum is 7.98 cents/kWh, a range that spans three orders of magnitude.

States have taken a wide range of approaches in valuing externalities (EIA, 1995). Typically, values are used that are specific to emissions, e.g., \$/ton of SO<sub>2</sub> or

\$/ton of CO. Although dated, the Energy Information Agency provides a state-by-state summary of public utility commissions' (PUC) activities regarding externalities (EIA, 1995, Appendix). According to this state-by-state summary, Pennsylvania did not require the consideration of externalities and New Jersey gave a 2 cents/kWh (1991 \$) credit to demand-side management projects. Delaware required qualitative but not quantitative consideration of externalities. Maryland did not have an order that mandates the use of externalities but does consider externalities qualitatively and quantitatively. Table 3.3 compares New York and Massachusetts externality adders. States have not been active in this area for several years due to the transition to restructured wholesale electricity markets. It is also important to note that states typically determine externality adders as part of a negotiation process.

Minnesota provides a more recent example of a state's externality values than New York and Massachusetts. They are listed in Table 3.4.

### Illustrative Calculation of the Environmental Benefits of the Proposed 20% RPS

To illustrate how to quantify the health and environmental benefits due to a 20% RPS, various estimates of environmental adders are applied.

**Table 3.1 Summary of Externality Adders from Power Generation Externality Studies**

Cents/kWh (1998 \$)	Coal	Oil	Gas	Nuclear	Hydro	Wind	Solar	Biomass
Minimum	0.004	0.03	0.003	0.0003	0	0	0	0
Maximum	67.72	39.93	13.22	64.45	26.26	0.88	2.2	22.09
% Difference	16930%	1331%	44100 %	214833%	--	--	--	--
Mean	14.01	12.32	4.61	7.12	3.36	0.31	0.84	4.95
Median	6.38	9.11	2.62	0.81	0.32	0.32	0.76	2.68
Standard Deviation	15.99	12.45	4.58	16.96	7.59	0.24	0.74	5.57
Number of Studies	36	20	31	21	16	18	11	22

Source: Sundqvist, Table 3

**Table 3.2 Summary of Externality Adders from Power Generation Externality Studies Conducted in the United States**

Cents/kWh (1998 \$)	Coal	Oil	Gas	Nuclear	Hydro	Wind	Solar	Biomass
Schuman & Cavanagh (1992)	0.06-44.07	--	--	0.11-64.45	--	0.025	0-0.25	--
Chernick & Cavehill (1989)	4.37-7.74	4.87-7.86	1.75-2.62	--	--	--	--	--
Bemow & Marron (1990); Bemow et al. (1991)	5.57-12.45	4.40-12.89	2.10-7.98	--	--	--	--	--
Hall (1990)	--	--	--	2.37-3.37	--	--	--	--
Ottinger et al. (1991)	3.62-8.86	3.87-10.36	1.00-1.62	3.81	1.43-1.62	0-0.12	0-0.5	0-0.87
Putta (1991)	1.75	--	--	--	--	--	--	--
Cifuentes & Lave; Parfomak (1997)	2.17-20.67	--	0.03-0.04	--	--	--	--	--
ORNL & RfF (1994-1998)	0.11-0.48	0.04-0.32	0.01-0.03	0.02-0.12	0.02	--	--	--
RER (1994)	--	0.03-5.81	0.003-0.48	--	--	--	--	--
Row et al. (1995)	0.31	0.73	0.22	0.01	--	0.001	--	--

**Table 3.3 Comparison of New York and Massachusetts Externality Adders**

Pollutant	Massachusetts Externality Adders (2003 \$ per ton)	New York Externality Adders (2003 \$ per ton)
NO <sub>x</sub>	\$9,620/ton	\$8,546/ton
SO <sub>2</sub>	\$2,220/ton	\$1,791/ton
VOC	\$7,844/ton	\$5,764/ton
Total Suspended Particulates	\$5,920/ton	no value assigned
CO	\$1,288/ton	\$1,130/ton
CO <sub>2</sub>	\$33/ton	\$554/ton
CH <sub>4</sub> (methane)	\$326/ton	no value assigned
N <sub>2</sub> O	\$5,861/ton	no value assigned
CFCs	no value assigned	no value assigned
Air Toxics	no value assigned	\$214,840/ton
Water use, land use, ash disposal	no value assigned	no value assigned

Note: Values were calculated using CPI data from the Bureau of Labor Statistics

Source: (EIA, 1995, pp. 34 and 86)

**Table 3.4 Final Environmental Cost Table for the State of Minnesota (ME3)**

Emission (2002 \$/ton)	Urban	Metropolitan Fringe	Rural	Within 200 Miles of Minnesota
SO <sub>2</sub> (after year 2000 - \$/ton)*	0	0	0	0
PM10(\$/ton)	5,060 - 7,284	2,253 - 3,273	637 - 970	637 - 970
CO(\$/ton)	1.20 - 2.57	0.86 - 1.52	0.24 - 0.46	0.24 - 0.46
NO <sub>x</sub> (\$/ton)	421 - 1,109	159 - 302	20 - 116	20 - 116
Pb(\$/ton)	3,551 - 4,394	1,873- 2,262	456 - 508	456 - 508
CO2(\$/ton)	.34 - 3.52	.34 - 3.52	.34 - 3.52	0

\* The zero values for SO<sub>2</sub> are explained in the discussion on the interaction between an RPS and cap-and-trade emission allowance program.

The marginal fuel in the PJM market, as well as throughout the United States, is natural gas. In 2005, the percentage of megaWatt-hours fueled by natural gas in PJM is expected to be 38.7% and decrease slightly to 34% in 2020 [EIA, 2004 Supplemental, Table 62]. According to a list of proposed new generation power plants in PJM covering the next five years, the majority of new power plants in the region and in New Jersey are fired by natural gas. More important than the current and future percentage of natural gas in the electricity fuel mix is the relative variable cost of producing electricity from natural gas compared to other traditional technologies. Once a power plant is built, its variable costs determine how often a unit is dispatched. Nuclear and coal power plants have very low variable costs compared to natural gas-fired plants. For instance, the variable costs of an advanced coal plant are about a third of those of an advanced combined cycle, and even less for a gas-fired turbine (EIA Outlook 2004). Renewable resources will displace high variable cost power plants, that is, ones fueled by natural gas [32].

Table 3.5 calculates the incremental environmental benefits of avoiding generating natural gas due of the proposed 20% RPS. It uses the externality adder of \$0.0216/kWh (in 2004\$), which is the difference between the median externality adder of natural gas fired generation and the median externality adder for PV presented previously. (The difference between the natural gas and wind externality adders

[32] The fact that natural gas-fired units are operating in substantial amounts for most hours of the year was confirmed by running a unit commitment and dispatch model of PJM in selected years between 2010 and 2020.

is \$0.0267/kWh (in 2004\$), which is even larger.) By using the median externality values and the higher PV value, the estimated benefits are conservative values. Table 3.5 does, however, assume that the incremental reductions in SO<sub>2</sub> and NO<sub>x</sub> due to the proposed 20% RPS are captured by New Jersey.

**Table 3.5 Illustration of Incremental Environmental Benefits of a 20% RPS (in 2004 million \$)**

	2010	2015	2020
Environmental Benefit	\$ 12	\$ 110	\$ 330

The above calculations are based on non-state specific estimates of the benefits of avoiding natural gas fired generation not on a specific New Jersey analysis. The next section reviews in detail the health and environmental effects of air emissions and the methodology to quantify in dollars their impact. Section III provides a template for determining New Jersey specific externality adders.

### III. Detailed Review of Health and Environmental Effects of Air Emissions

In this section, a detailed literature review is discussed. The major findings of this section is that New Jersey specific health and environmental benefits of reducing air emissions from a RPS could be determined using a benefit transfer approach in conjunction with modeling the New Jersey atmosphere (air shed modeling). In addition, existing concentration levels of the pollutants of interest across New Jersey spatially and temporally are needed along with the number and duration of exposure. Applying

any existing air shed modeling or conducting it is, however, beyond the scope of this report. In Chapter 4, we discuss whether such an effort should be undertaken for New Jersey. This literature review also demonstrates the types of assumptions necessary for these types of calculations and provides some insight into why there are substantial ranges for the health and environmental impact of air emissions.

### **Benefit Transfer Approach**

Local conditions affect the impact of emissions, such as the existing concentration of the emission, susceptibility of the population and environment to the type of damage caused by the emission, etc. Since conducting detailed and high quality studies for each emission and type of damage is expensive and time consuming for every possible local condition, researchers have developed an alternative, known as a benefit transfer approach.

In a benefit transfer approach, the results of other studies conducted in other regions of the country are reviewed to determine their applicability to the region of interest. Ideally, primary research based on the characteristics of New Jersey is preferred to a benefit transfer approach to developing the dose-response curve, but the types of benefits are too numerous and their phenomenon too complex to pursue this approach given the constraints of this specific project. The validity of this benefit transfer approach depends on how closely the other studies resemble the situation in New Jersey based on timeliness, methodology, and other factors. In addition, as part of the process of evaluating the evidence presented by this body of literature, each study must be evaluated as to the soundness of the data and the analysis techniques and the conclusions drawn by the authors.

A benefit transfer approach is applicable when existing studies value similar effects, when the context of the existing studies is highly similar, and when the existing studies are of high quality. Benefit transfer may increase the inherent uncertainty surrounding environmental benefits estimates, but for practical reasons (e.g. cost and time), benefit transfer is a necessary component of policy analysis. In most situations, the question is not whether to conduct benefit transfer, but how to improve benefit transfer to

make it more reliable.

There are no universally accepted criteria for benefit transfer, but in most cases the defensibility of the benefit estimates depends on the quality of the existing study. We use the following two criteria. First, we selected studies that were published in peer-reviewed journals and cited in the academic literature. In addition, the sources of variation have to be considered between the original study location/situation and the one to which the benefits estimates are transferred. We focus on studies conducted in North America. We used the 1999 U.S. Environmental Protection Agency report (US EPA, 1999) as a baseline and conducted a thorough literature review of studies completed after that report. We cite all studies that met our criteria either below or in our technical Appendix.

### **Direct Benefits to Humans – Health Benefits**

#### *Identifying Health Benefits*

Over the last 15 years, a large body of epidemiological literature has been devoted to the study of adverse health effects occurring at moderate and low pollutant concentrations. There is now sufficient evidence to support the hypothesis that both chronic and acute health effects can occur at ambient pollution levels. Current research focuses on the consequences of acute and chronic air pollution exposure for excess cardiovascular and respiratory morbidity and mortality. (Appendix, Section 4.)

Health benefits resulting from reduced air pollution can be grouped into two broad categories: mortality benefits and morbidity benefits. Mortality benefits are avoided deaths from diseases caused by air pollution. Morbidity benefits refer to avoided cases of non-fatal health effects. Air pollutants that have been linked to adverse health effects include particulate matter (PM), ozone (O<sub>3</sub>), carbon monoxide (CO), sulfur dioxide (SO<sub>2</sub>), and nitrogen dioxide (NO<sub>2</sub>). Until the mid-1980's it was believed that ambient pollutant concentrations did not have adverse health effects [33].

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[33] Katsouyanni (2003)

## *Types of Health Studies*

There are two main types of methods to establish a dose-response relationship for a health effect: epidemiological studies and toxicological studies. Our literature review surveys both types.

Epidemiological studies attempt to establish a quantitative relationship between health effect and air pollution using a cross-sectional sample drawn from a large population. The four most commonly used types of epidemiological studies are cohort studies, case control studies, occupational epidemiology studies, and cross-sectional studies.

In toxicology, mechanistic studies examine how and why various disease processes occur in response to toxicant exposures, and help establish a relationship between dose or exposure and response at the molecular level. For example, an animal study provides direct information about the subject's adverse response to a substance and its level. One of the advantages of animal studies is the researcher's ability to extrapolate from the high doses in animal studies down to the low doses often experienced in human exposure scenarios. Finally, human studies can be used to extrapolate the response of humans at low doses to higher doses.

## *Health Benefits Due To Particulate Matter (PM) Reductions*

Adverse health effects of exposure to particles have been described in numerous epidemiological studies. Health impacts that are measurable and experienced by humans are referred to as *health endpoints* and include all-cause and cause-specific mortality and morbidity. Studies conducted in the United States and in other countries have reported associations between changes in PM and changes in mortality and morbidity, particularly among subgroups of people with respiratory or cardiovascular diseases. However, the exact mechanisms by which PM influences human health are not well understood. Earlier literature focused on PM greater than 10 microns in diameter, while in the last decade the attention of researchers turned to fine particles such as PM<sub>2.5</sub>. Recent research indicates that ultrafine particles (UF) less than 0.1 micron in diameter may play an important role in the induction of toxic effects.

Currently, however, data on UF exposure and health effects are still limited.

Although the importance of long-term exposure to PM has been emphasized, most of the attention in the literature has been devoted to short-term health effects. Two prominent prospective-cohort studies of mortality effects of PM are Dockery et al. (1993) and Pope et al. (1995). Unlike earlier studies, Dockery et al. (1993) estimate the effect of air pollution on mortality, while controlling for individual risk factors. Pope et al. (1995) study the association between air pollution and mortality using data from a large cohort drawn from many study areas. Pope et al. (2002) is a continuation of the Pope et al. (1995), while the HEI (2000) study is a reanalysis of the original Pope et al. (1995) data. Fine particle and sulfur oxide pollution were associated with all-cause death, lung cancer and cardiopulmonary mortality. Each 10 $\mu\text{g}/\text{m}^3$  increase in fine PM pollution was associated with approximately 4%, 6%, and 8% increase in the risk of all-cause death, cardiopulmonary mortality, and lung cancer mortality, respectively (Pope et al, 2002). Information on data, methodology, and the results of these four studies are summarized in Appendix B.

Short-term or acute effects of PM are well established for morbidity endpoints such as, hospital admissions for respiratory and cardiovascular conditions. There is also evidence of acute effects on respiratory function, lower respiratory symptoms, and increased medication use by asthmatics [34]. There are fewer studies available on the long-term, or chronic, health effects of PM pollution. A few studies have linked an increase in chronic bronchitis occurrence to an increase in ambient PM concentration [35]. The studies reviewed find a positive association between the health effect and PM air pollution. Appendix, Section 4.2 summarizes the available studies that assessed morbidity effects resulting in chronic and minor illness, as well as hospital admissions.

## *Health Benefits Due To Ozone Reductions*

Ozone is formed by a chemical reaction from its precursor pollutants (volatile organic compounds

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[34] For additional references, see Katsouyanni (2003)

[35] Abbey et al. (1993), Schwartz (1993), Abbey et al. (1995)

(VOCs) and nitrogen oxides (NO, NO<sub>2</sub>), and nitrous oxide (N<sub>2</sub>O)) in the presence of heat and sunlight. Ozone concentration is the highest in the summer when the weather is hot and sunny with relatively light winds.

Health problems are caused by tropospheric, or ground-level, ozone. Ozone is associated with a variety of adverse health effects ranging from minor symptoms to hospital admissions and chronic illness. Some studies have found a link between ozone and mortality, however there is significant uncertainty about the relationship between mortality and high ozone concentrations, partly because of the possible confounding effect of other pollutants such as particulate matter [36]. Table 3.6 below summarizes the most common adverse health effects associated with ozone.

Mechanistic studies of ozone yield a sufficient evidence for a biologic plausibility of respiratory-

related morbidity and mortality [37]. There is evidence from human and animal exposure studied that long-term exposure to ozone may cause a sustained decrement in lung function. There are well-documented molecular mechanisms for acute respiratory effects of ozone, but the evidence for chronic respiratory effects is limited. There is, however, increasing evidence that high levels of ozone can result in the development of chronic diseases. For example, McConnell (2002) provided the first evidence suggesting that tropospheric ozone causes the development of childhood asthma. In high ozone-concentration cities, children who played outdoor sports were 3 to 4 times more likely to develop chronic asthma than children who did not play sports. In low ozone-concentration cities, children playing sports were no more likely to develop asthma than children who did not play sports.

Because indoor ozone concentrations are generally lower than ambient concentrations, personal exposure may not be directly related to ambient

**Table 3.6 Likely Ozone-related Adverse Health Effects**

Adverse Health Effect	Comment
Respiratory Hospital Admissions	Numerous studies have linked ozone to hospital admissions for pneumonia, chronic obstructive pulmonary disease (COPD), asthma and other respiratory ailments.
Cardiovascular Hospital Admissions	There is a link between high ozone and dysrhythmias (abnormal heartbeat patterns).
Total Respiratory ER Visits	Studies have also found a link between high ozone and emergency room visits which do not result in actual hospital admissions.
Minor Symptoms	Short-term exposure to ozone has been linked to a variety of symptoms, including cough, sore throat and head cold.
Asthma Attacks	Ozone has specifically been linked to incidence of asthma attacks and may be linked to the development of chronic asthma.
Shortness of breath	Ozone associated with shortness of breath in asthmatics and non-asthmatics.

Source: Abt Associates, Adverse Health Effects Associated with Ozone in the Eastern United States (Washington, D.C: Clean Air Task Force, October 1999).

[36] See for, example, Kinney et al. (1995), and Ito and Thurston (1996)

[37] For a review see of mechanistic studies of ozone, see Levy et al. (2001)

concentration. Personal exposures to ozone are influenced by air conditioning or averting behavior, such as, more time spent indoors. When applying concentration-response functions, the relationship between ambient ozone concentrations and personal exposures must be determined. An understanding of any systemic differences between the study and policy region is crucial. For example, if there are differences between indoor air quality or the type of averting behavior in New Jersey from that of studies conducted in other parts of the country used to estimate the health effects of outdoor ozone exposure, then the results may not be transferable. This example illustrates a limitation of the benefit transfer approach.

#### *Health Benefits Due To Carbon Monoxide Reductions*

Carbon monoxide (CO) is a colorless and odorless gas produced through incomplete combustion of carbon-based fuels. Carbon monoxide enters the bloodstream through the lungs and reduces the delivery of oxygen to the body's organs and tissues. The most vulnerable to CO are those who suffer from cardiovascular disease, particularly those with angina or peripheral vascular disease. Fetuses and young infants, children, pregnant women, individuals with obstructive pulmonary disease, such as bronchitis and emphysema, smokers, and individuals spending a lot of time on the street working or doing exercise are also more susceptible to CO exposure. In health studies, high CO concentrations have been linked to hospital admissions for asthma, chronic obstructive pulmonary disease (COPD), dysrhythmias, ischemic heart disease, and congestive heart failure (CHF) [38].

#### *Health Benefits Due To Sulfur Dioxide Reductions*

Sulfur dioxide is formed when fuel, containing sulfur, such as coal and oil, is burned. The main health effects associated with exposure to high SO<sub>2</sub> concentrations include effects on breathing, respiratory illness, changes in pulmonary defenses, and aggravation of cardiovascular disease. The most susceptible groups are children, the elderly, asthmatics,

and people with cardiovascular and chronic lung disease (such as bronchitis and emphysema). High SO<sub>2</sub> levels have been linked to the following endpoints: hospital admissions for pneumonia, ischemic heart disease, and respiratory conditions, chest tightness, shortness of breath, and wheeze [39].

#### *Health Benefits Due To Nitrogen Dioxide Reductions*

NO<sub>2</sub> is a suffocating, brownish gas that is formed when fuel is burned at high temperatures. Primary sources of NO<sub>2</sub> are motor vehicles, electric utilities and industrial boilers. Nitrogen dioxide can irritate the lungs and lower resistance to respiratory infections such as influenza. There is no clear evidence on the effect of short-term exposure to NO<sub>2</sub> on health, but frequent exposure may cause an increased incidence of acute respiratory illness, especially in children. NO<sub>2</sub> has been linked to hospital admissions for respiratory conditions, pneumonia, congestive heart failure, and ischemic heart disease. Epidemiological studies found that NO<sub>2</sub> has a modifying effect on PM: the increase in mortality due to PM was found to be higher in cities where long-term NO<sub>2</sub> concentrations were higher. In addition NO<sub>2</sub> may have other indirect adverse effects, as it contributes to ozone formation. Therefore the importance of NO<sub>2</sub> for health comes from its role as an O<sub>3</sub> precursor and a contributor to the formation of secondary particles [40].

### **Quantifying Health Benefits**

Health benefits are typically estimated using the damage-function (DF) method that consists of the following:

1. Determining the dose-response relationship for each health effect
2. Determining baseline exposure
3. Determining the number of baseline cases for each quantifiable health effect  
Number exposed × Baseline exposure × Dose response relationship.
4. Determining exposure after the regulation (for each regulatory option)

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[38] Burnett et al. (1999), Koken et al. (2003), Linn et al. (2000), Lin et al. (2003), Moolgavkar (1997), Sheppard (1999), Schwartz (1999), Schwartz (1999), Schwartz and Morris (1995)

[39] See Burnet et al, 1997b, Moolgvaka, 1997, and Lim et al., 1990.

[40] See Burnett et al, 1999, Burnett et al 1997b, Moolgvakar, 1997, and Katsiouyanni, 2003.

5. Determining the number of cases for each quantifiable effect with the regulation
6. Determining the number of cases avoided as a result of each regulatory option

The purpose of quantification is to determine the change in the occurrence of a health effect as a result of a change in pollutant concentrations between the baseline and the control scenario. Such a relationship between, say particulate matter (PM) concentration, and the change in the health effect is described by dose-response or concentration-response (CR) functions. Dose-response or concentration-response (CR) functions estimate the risk (of the occurrence of a health effect) per unit of exposure to a pollutant.

Relative risk (RR) is a measure that denotes the seriousness of exposure to a known risk factor. It is defined as the risk for those exposed relative to those who are not exposed. Exposure increases the risk because in a sufficiently large population, some people develop a disease that can be attributed to air pollution regardless of whether they are exposed or not. For example, if the risk of developing a disease in the exposed population is 5% while in the non-exposed population it is 1%, the relative risk is 5. A high relative risk indicates strong evidence between exposure to a pollutant and the health effect.

Typically, dose-response functions that have been estimated for health effects describe a linear no-threshold relationship. This means that every unit of exposure contributes equally to aggregate risk in a large population of people. For example, a linear no-threshold dose-response function treats the case of one person being exposed to one hundred units of the pollutant, and ten people subjected to ten units of pollution equally (simply, as 100 units of human exposure). Thresholds may be incorporated into the analysis even when one uses CR-functions that were derived under the no-threshold assumptions. While the possible existence of a threshold in concentration-response relationship is an important scientific question, there is currently no scientific basis for selecting appropriate threshold levels. A more detailed discussion of this issue is located in Appendix, Section 4.2.

The threshold versus no-threshold issue has an important policy implication for New Jersey. In 2002 all New Jersey air emission levels except for ozone were below the health standard (NJDEP, 2002). If there was a threshold, reductions in emission concentrations beneath that threshold, assuming that the safety standard is the threshold, would not provide any public health benefits whereas if there is not a threshold, even reductions beneath the safety standard would provide health benefits.

There are some important limitations in quantifying health effects of emissions. To determine the number of baseline cases, the following must be identified: the segment of population that is exposed, the number of people exposed within each segment, and the level, duration and frequency of exposure. In order to obtain accurate estimates, averting behavior (that is, people with known risk may act to avoid exposure) must be controlled.

#### *Quantifying Mortality Benefits*

In valuation studies, mortality benefits linked to particulate matter (PM) tend to dominate total monetized benefits of air pollution abatement [41]. The relationship between mortality and ambient PM concentration is well established, while this is not the case for other pollutants [42]. There is some evidence that there are synergistic effects between PM and other pollutants (e.g. ozone). For example, reduction of PM concentration may reduce the health impacts of exposure to other types of emissions such as ozone. Studies that control for these synergistic effects are preferable to ones that do not, and the studies that we reviewed typically accounted for these effects.

#### *Quantifying Mortality due to Particulate Matter*

In epidemiological studies of PM, typical measurable health endpoints include all-cause and cause specific mortality, as well as hospital admissions and emergency room visits. The Pope et al. (2002) study estimates relative risk associated with a 10  $\mu\text{g}/\text{m}^3$  increase in  $\text{PM}_{2.5}$  (particulates less than 2.5  $\mu\text{m}$  in diameter), while the HEI (Health Effects Institute) (2000) study consider a 25  $\mu\text{g}/\text{m}^3$  change. In the

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[41] See for example, Stieb et al. (2002)

[42] USEPA (1999)

Pope et al. study, the relative risk from all causes of mortality from a 10  $\mu\text{g}/\text{m}^3$  increase in  $\text{PM}_{2.5}$  from the years 1999-2000 is 1.06. In Appendix B, Tables 3.13-3.45, we list dose-response functions from available studies.

#### *Quantifying Mortality due to Ozone*

There is considerable epidemiological evidence concerning the relationship between ambient ozone concentrations and human mortality risks. Because ozone contributes to acute (short-term) health effects, the association between daily ozone concentrations and daily mortality is of primary interest to researchers. These studies show mixed findings as to whether there is a statistically significant association between daily ozone concentrations and daily mortality in each of the study areas. Depending on the study, the relative risk for a 25 ppb increase in ozone ranges from 1.00 to 1.06. See the Appendix for further details.

#### *Quantifying Mortality due to Carbon Monoxide*

A number of studies examined the relationship between daily mortality and concentrations of CO. Cardiovascular mortality was found strongly associated with CO concentrations. The Appendix summarizes the results and characteristics of the studies identified in our literature search. The relative risk for a 10 ppm increase in CO reported in the literature we reviewed ranges from 1.06 to 2.44.

#### *Quantifying Morbidity Benefits due to Carbon Monoxide*

Quantifying morbidity benefits is more difficult for chronic (long-term) conditions than for acute (short-term) health effects, because it requires data on exposure over a long period of time. The most frequently used endpoints in the epidemiological literature are hospital admissions for various respiratory and cardiovascular illnesses, emergency department visits, chronic diseases (e.g. chronic bronchitis), and minor health effects, such as upper respiratory symptoms (URS), lower respiratory symptoms (LRS), asthma attacks, shortness of breath, work loss days, minor restricted activity days, etc. In the Appendix, Section 4.2, additional studies are referenced regarding minor illness hospital admissions for respiratory and cardiovascular causes.

## **Valuation of Health Benefits**

### *Monetizing Mortality Benefits*

Environmental economics developed a number of methods for estimating health benefits from avoided air pollution. The most popular primary methods are described below:

- Contingent valuation method (*CVM*) is a survey-based method to determine willingness-to-pay (WTP) for a hypothetical change in environmental effects.
- Averting behavior is a method to infer WTP from the costs and effectiveness of actions taken to avoid a negative environmental effect.
- Cost-of-illness (COI) or damage costs methods involve estimating direct costs (such as, medical expenses) and indirect costs (for example, forgone earnings) of an environmental effect.
- Hedonic methods estimate WTP for an environmental amenity by inferring its value from the market price of another (but in some sense related) good. For example, the *hedonic property values* method estimates a marginal WTP based on an estimated relationship between housing prices and housing attributes (that include environmental amenities, such as good visibility or air quality). In contrast, the *hedonic wages* method estimates the value of environmental amenities from a worker's willingness-to-avoid (WTA) a higher salary to compensate for exposure to higher levels of risk on the job.

Mortality benefits are most often monetized using a Value of Statistical Life (VSL) estimate. VSL is a measure of the WTP for reductions in the risk of premature death aggregated over the population experiencing the potential risk reduction. For example, if each person out of one million people is willing to pay five dollars for a 1:1,000,000 reduction in mortality risk and on average one life is saved, then the value of VSL is \$5,000,000. (EPA relies on a composite VSL estimate based on 26 VSL studies – 21 of which use the hedonic wage method, and 5 use

CVM, EPA's current guidelines advise analysts to use a VSL estimate of \$6.2 million in 2002 dollars).

Despite its widespread use, the VSL concept has been subject to criticism. One shortcoming of the VSL is highlighted when considering the difference between mortality due to acute (short-term) and mortality due to chronic (long-term) exposure. One of the basic assumptions underlying the VSL approach is that that equal increments in fatality risk are valued equally irrespective of the initial risk. This assumption is defensible only if the prior risk is small. Some experts have suggested that it is not appropriate to estimate mortality that is the result of acute exposure, because people affected usually have a pre-existing disease and a relatively high prior risk of mortality [43]. The primary approach of estimating VSL has been the use of hedonic wage and hedonic price models that examine the equilibrium risk choices. The observed market decisions (measured by wages and prices) reflect the joint influence of supply and demand in the market. Most of the empirical literature has concentrated on valuing mortality risk by estimating compensating differentials for on-the-job risk exposure in labor markets. Viscusi and Aldy (2003) provide an analysis of the extensive literature of VSL based on estimates using U.S. labor market data from the last three decades.

Half of the studies reviewed in Viscusi and Aldy (2003) provide estimates that range from \$5 million to \$12 million (in 2000 dollars). Estimates below \$5 million usually are reported by studies that use the Society of Actuaries data, which contains data on workers that self-selected themselves to jobs that are much riskier than the average job. On the other hand, studies that report estimates above \$12 million tend to estimate the wage-risk relationship indirectly. Viscusi and Aldy (2003) regard the median estimate of

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[43] Alternative measures to VSL include the Value of Statistical Life Years (VSLY) lost or saved. For example, if pollution abatement saves one person with average life expectancy of fifty more years, then we say that the policy results in fifty life years extended. VSLY can be interpreted as an age-specific VSL. Another alternative to VSL is the Quality Adjusted Life Years (QALY) measure. QALY adjusts life-years extended for the quality of life during those years. To estimate QALY, information is needed about the path and duration of health states and weights for the different health states must be chosen. See US EPA 1999.

\$7 million from the above table as the most reliable. These values of VSL using hedonic wage methods are similar to those generated by U.S. product market and housing market studies [44].

To transfer the estimates of VSL to non-labor market contexts, the preferences of the study population and the populations in the policy context must be similar. Other factors that may influence the transfer of VSL estimates are the age and income distribution of the study population. In addition to finding a positive association between income and VSL, Viscusi and Aldy (2003) also found a statistically significant relationship between union-status of workers and VSL. In the case of RPS, non-labor populations are impacted by the policy and may have a different VSL from that of the labor market.

### *Valuation of Morbidity Benefits*

There are a number of health endpoints that can be quantified, but difficult to value in monetary terms [45]. Reduced lung function is an example. Currently, there are no studies available on the economic valuation of changes in lung function. One reason is that in many cases there is no clear connection between lung function and the economic well-being of an individual. Reduced lung function is typically associated with other symptoms, such as cough or asthma attacks, and it is unclear whether a temporary decrease in lung function would go unnoticed without the related symptoms, and hence it may have no economic value.

Several endpoints reported in the literature overlap with each other. For example, the various measures of restricted activity, or their definitions are not unique. Therefore, one must be careful not to include a combination of endpoints that could lead to double counting of benefits.

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[44] For example, Jenkins, Owens, and Wiggins (2001), Gayer, Hamilton, and Viscusi (2000), Dreyfus and Viscusi (1995), Carlin and Sandy (1991).

[45] Source: USEPA, "Review of the National Ambient Air Quality Standards for Ozone: Assessment of Scientific and Technical Information, Staff Paper, Office of Air Quality Planning and Standards, 1989. Quoting Avol et al. (1984), Kulle et al. (1985), McDonnell et al. (1983)

In a number of studies, it has been found that the different methods, mentioned in the previous sections, generate systematically different estimates for morbidity effects. For each effect, both estimates are from the same source. These results indicate that people's willingness to pay to avoid certain symptoms usually exceeds the cost of that symptom by an order of a magnitude. For instance, researchers have found that the willingness to pay to avoid nausea is \$72.30 whereas the individual cost of illness is \$3.78 (both in 1996 \$) [46]. The Appendix contains estimates of willingness to pay and cost-of-illness for various health effects.

*Valuation of hospital admissions avoided*

The typical approach for valuing the avoided incidence of hospital admissions is through the use of cost of illness (COI) method [47]. Well-developed and detailed estimates of hospitalization of the health effects are readily available [48]. In a complete cost-benefit analysis, COI estimates should be obtained for each health effects for which dose-response functions are available. Valuation estimates typically have two

components: cost of hospital stay, and lost earnings due to hospitalization. As mentioned above, COI method underestimates WTP, but there are currently no studies available that would estimate WTP directly.

**Indirect Benefits to Humans through Ecosystems**

Air pollution causes ecological effects, and Table 3.7 identifies the most important direct and indirect effects of air pollution.

The first step in valuing ecosystem benefits of reduced air pollution is to identify measurable effects. Freeman (1997) identified the following categories of ecosystem services to humankind:

1. Material inputs into economic activity (fossil fuels, minerals, animals)
2. Life-support services (breathable air, livable climate)
3. Environmental amenities used for recreation
4. Processing of waste products discharged into the environment

**Table 3.7 Ecological Effects of Air Pollution**

<b>Pollutant Class</b>	<b>Major Pollutants and Precursors</b>	<b>Short-term effects</b>	<b>Long-term effects</b>
Acidic Deposition	Sulfuric acid, nitric acid Precursors: SO <sub>2</sub> , NO <sub>x</sub>	Direct toxic effect to plant leaves and aquatic organisms	Progressive deterioration of soil quality and acidification of surface waters
Nitrogen Deposition			Saturation of terrestrial ecosystems with nitrogen. Progressive nitrogen enrichment of coastal estuaries.
Hazardous Air Pollutants (HAPs)	Mercury and dioxins	Direct toxic effects to animals.	Accumulation of mercury and dioxin in the food chain.
Ozone		Direct toxic effects to plant leaves.	Alteration of ecosystem-wide energy flow and nutrient cycling.

Source: USEPA (1999)

[46] Chestnut et al. (1998, 1996)

[47] See for example, US EPA (1999)

[48] For example, the Cost of Illness Handbook by EPA.

Economic analyses of air pollution control have paid less attention to ecological benefits than direct benefits to human health. There is a complex and nonlinear relationship between ecosystems and air pollution, and many impacts are difficult to measure. In addition, available valuation methods can measure only some of these benefits: material inputs and the value of environmental amenities used for active recreation.

The most important ecological benefits of air pollution abatement include:

- Eutrophication [49] of estuaries associated with atmospheric nitrogen deposition
- Reduced tree growth associated with ozone exposure
- Acidification of freshwater bodies associated with atmospheric nitrogen and sulfur deposition
- Accumulation of toxics in freshwater bodies associated with atmospheric toxics deposition
- Aesthetic damages to forests associated with ozone and airborne toxics

**Table 3.8 Service Flows for Quantitative Assessment**

<b>Ecological Effect</b>	<b>Endpoint</b>	<b>Dose-Response Functions</b>	<b>Economic Model</b>
Acidification	1. Forest Aesthetics	1. Not required	1. Site-specific
	2. Recreational Fishing	2. Multiple available	2. Site-specific
	3. Existence Value of Biodiversity	3. Multiple Available	3. Site-specific
Eutrophication	1. Recreational Fishing		1. Site-specific
	2. Existence Value of Biodiversity		2. None available
Toxics Deposition	1. Forest Aesthetics	1. Multiple available	1. Site-specific
	2. Recreational Fishing	2. Multiple available	2. Site-specific
	3. Existence Value of Biodiversity	3. Multiple available	3. None available
	4. Hunting and Wildlife Aesthetics	4. Multiple Available	4. Site-specific
Multiple Pollutant Stress	1. Ecosystem aesthetics and ecosystem existence value	1. None available	1. None available

[49] Eutrophication is a condition in an aquatic ecosystem where high nutrient concentrations stimulate blooms of algae. Increased eutrophication from nutrient enrichment due to human activities is one of the leading problems facing some estuaries in the Mid-Atlantic region.

Since not all ecological benefits are quantifiable or can be monetized, in valuation studies attention is often restricted to ecological impacts associated with benefits to humans, called service flows, rather than broad structural changes to ecosystems. The main criteria for including service flows in valuation studies are that they must be identifiable, quantifiable and monetizable. Table 3.8 summarizes service flows to humans that satisfy these criteria based on the literature cited in the Appendix.

There are four primary methods to monetize non-health-related benefits: hedonic property value models (similar in approach to hedonic methods applied to mortality benefits described previously), travel cost models (TCM), contingent valuation, and market models. TCM exploits observed differences between travel distance and environmental quality of recreation site to estimate the monetary value of each site characteristic. If people are willing to pay more in travel costs to enjoy an environmentally more pristine recreation site than a less pristine one, then the additional travel costs reflect the minimum value that person places on the more pristine site. Market Models study the impact of changes in ecological services on both producers and consumers of market goods that rely on these services, for example the impact on recreational fishing of decreasing toxic discharges in a lake. Contingent valuation methods ask people to express their monetary preferences for hypothetical changes in the environment, for example through the use of surveys asking consumers the additional costs they would be willing to pay to for improved visibility at a state park.

### *Agricultural Productivity Benefits*

Air pollution has a negative impact on agricultural productivity. Research in the area has focused primarily on the economic impacts of tropospheric ozone, acidic deposition, and global climate change on commercial crops [50]. Economic assessments of the impact of air pollution on crop losses are sometimes associated with forestry impacts. However, as Spash (1997) points out, forestry is a multi-product system, in which the economic valuation of the impacts pertains to a much wider

set of issues, including biodiversity changes, reduced aesthetics and recreation services. Some of these impacts do not have commercial value, and therefore forestry damages are poorly represented in market-related production models that are commonly used to estimate agricultural productivity damages. Therefore, what follows is a review only of the methodology commonly used to estimate agricultural crop losses due to air pollution.

Pollutants that have been found to have a negative impact on crop yields are ozone ( $O_3$ ) and its precursor pollutants (mostly  $NO_x$ ), and sulfur dioxide ( $SO_2$ ). Of all the pollutants, the most extensive research has been conducted on tropospheric ozone. Ashmore (1991) concludes that although gaseous pollutants other than ozone (namely  $SO_2$  and  $NO_2$ ) may be locally important at high concentrations, they have little economic impact on a national scale. Only minor damage to plants had been attributed to gaseous pollutants other than ozone and to sulfate and acid deposition. The National Crop Loss Assessment Network (NCLAN) program found a statistically significant response to  $SO_2$  only in soybeans and tomatoes. Herrick and Kulp (1987) report a negligible impact of  $SO_2$  and  $NO_2$  within the National Acid Precipitation Assessment Program (NAPAP). Ashmore (1991) finds that barley, clover, and lucerne are especially sensitive to  $SO_2$ , but these are minor crops associated with small potential economic benefits of pollution control.

Corn and soybean appear to be the most sensitive crops to acidic deposition. In addition, the available research seems to suggest that most commercial crop yields are relatively insensitive to acidic deposition on its own [51]. Spash (1997) concludes that crop damages from  $SO_2$ ,  $NO_2$  and acid deposition combined are 5-10% of the crop damages of ozone pollution.

Segerson (1987) has identified a number of factors that distinguish the effects of acidic deposition from those of ozone [52].

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[50] USEPA (1999)

[51] Segerson (1991) pp. 352

[52] This is the most recent research that is available.

- Acidic deposition affects a wide range of non-market goods while ozone affects mostly commercial crops
- Acidic deposition is a dynamic pollutant that accumulates over time, while ozone is periodic. Therefore an economic analysis of ozone exposure may be based on short-term studies, while acidic deposition should be based upon assessing accumulated impacts over time.
- The impacts of acidic deposition are surrounded by a greater degree of uncertainty than those of ozone.
- Ozone pollution is a more localized problem than acidic deposition.

Ozone has been observed to cause significant damages in terms of crop yield losses at current ambient levels. Furthermore, the increased frequency and duration of hot dry weather implied by global warming will increase the concentration of tropospheric ozone from available precursors. Table 3.9 below illustrates the damages to crops from ozone exposure.

The majority of economic assessments of ozone damage to crops have been at the regional level. Published studies have concentrated on two main regions of the U.S., namely, the Corn Belt (Illinois, Indiana, Iowa, Ohio and Missouri) and California.

To quantify agricultural productivity benefits, dose-response functions that describe the relationship between ambient ozone concentrations and changes in crop yields are used. Estimated minimum and maximum dose-response function for six major crops are described in Appendix, Section 5.1.

#### *Valuation of Agricultural Productivity Benefits*

The traditional approach of valuing crop losses due to air pollution was to calculate monetary equivalents of the approximated losses by multiplying decreased yields by the current market price to give a producer loss estimate equal to total revenue. This method is likely to overestimate the gain to producers from ozone reductions because it ignores farmers' reactions in terms of changing the input mix and cross-crop substitution [53].

**Table 3.9 Processes and Characteristics of Crop Plants That May Be Affected by Ozone**

Growth	Development	Yield	Quality
Rate	Fruit set & development	Number	Appearance: size, shape, and color
Pattern	Branching	Mass	Storage life
	Flowering		Texture/cooking quality, Nutrient content, Viability of seeds

Source: Jacobson (1982) p. 296, Table 14.1.

Although ozone-induced quality degradation may be a significant part of total economic damages, research has almost exclusively focused on estimating changes in output resulting from air pollution. There is currently insufficient information available as to the importance of crop quality response (Spash, 1997).

In more recent empirical work agricultural production models have been used to estimate the economic costs associated with yield losses due to air pollution. These models estimate the social benefit from reduced ozone damages.

Various agricultural production models have been used in economic assessments of ozone damage.

[53] Spash (1997)

Recreational and commercial fishing benefits form a subgroup of ecological benefits of air pollution. The theoretical basis for valuing ecological benefits in general and recreational and commercial fishing benefits in particular, is that the natural environment provides us with services that we value [54]. There are no suitable methods to comprehensively value many of these service flows (e.g. breathable air, livable climate). Therefore in valuation studies, we are limited to valuing services flows that are either material inputs into our economy, or provide amenities associated with marketed services (e.g. recreation).

Three types of pollution are associated with commercial and recreational fishing: acidification, nitrogen eutrophication, and toxics deposition. Acidification, or acid deposition, is probably the best-studied effect of air pollution on ecosystems. The main cause of acidification is acidic precipitation in the form of sulfuric acid ( $H_2SO_4$ ) and nitric acid ( $HNO_3$ ). These acids are formed from sulfur dioxide ( $SO_2$ ) and nitrogen oxides ( $NO_x$ ) found in the atmosphere. Electric power plants are among the primary point sources of  $SO_2$ . On the other hand, a large share of  $NO_x$  is from non-point sources (transportation), and therefore anthropogenic  $NO_x$  is more dispersed in the atmosphere compared with anthropogenic  $SO_2$ .

Deposition occurs via three main pathways: (1) wet deposition, where the pollutant is dissolved in precipitation, (2) dry deposition, which is a direct form of deposition of gases and particles to any surface, and (3) cloud-water deposition, when cloud or water droplets are intercepted by vegetation. Since most of the precipitation falls on the terrestrial part of the catchments, soil properties are generally strongly associated with water quality. Consequently, acidification resulting from acid deposition usually occurs in areas with acidic soils. Throughout the world freshwater acidification is the most serious in eastern parts of the United States. Reductions of anthropogenic  $SO_2$  and  $NO_x$  emissions in Europe in recent years have resulted in an improvement in acidified water bodies, however, the same trend has not been observed in the United States [55]. It is

believed that it may take ecosystems several decades to recover from the impact of acidification even after emissions have been cut.

Eutrophication is the result nitrogen deposition leading to excessive nitrogen enrichment of aquatic ecosystems, and it may adversely affect the biogeochemical cycles of watersheds. Atmospheric nitrogen is deposited into water bodies through dry and wet deposition. Excessive eutrophication can lead, for example, to massive algae booms, which in turn reduces the oxygen levels and leads to habitat loss. It is estimated that 86% of the East Coast Estuaries are susceptible to eutrophication [56].

Toxics deposition involves hazardous air pollutants (HAPs), as defined by the Clean Air Act: mercury, polychlorinated biphenyls (PCBs), chlordane, dioxins, and dichlorodiphenyltrichloroethane (DDT). When considering air pollution from power plants, the most important of these pollutants is mercury. Much of mercury found in ecosystems comes from natural sources. Mercury accumulates in fish, birds, and mammals, and it may be dangerous to humans when the concentration exceeds a critical level. Mercury-based statewide fish consumption advisories are fairly common in the United States.

Table 3.10 below summarizes the main recreational and commercial fishing impacts associated with acidification, eutrophication, and toxics deposition.

Following emissions modeling, and transport and deposition modeling, the next step in the process of quantifying the benefits to recreational fisheries is the use of an exposure model. Unfortunately, comprehensive models to quantify the impacts of acidification, eutrophication, and toxics deposition are currently not available.

To quantify the impact of acid deposition on fisheries, US EPA (1999) uses a region-specific model to quantify the effects of acidification on freshwater fish populations: Model of Acidification

[54] Freeman (1997)

[55] Stoddard et al. (1999)

[56] US EPA (1997)

**Table 3.10 Recreational and Commercial Fishing Can Be Associated With the Following Ecological Impacts of Air Pollution**

Pollutant Class	Ecosystem Effect	Service Flow
Acidification (H <sub>2</sub> SO <sub>4</sub> , HNO <sub>3</sub> )	Freshwater acidification resulting in fish (and other aquatic organism) decline	Recreational Fishing
Nitrogen Eutrophication (NO <sub>x</sub> )	Freshwater acidification resulting in fish (and other aquatic organism) decline	Recreational Fishing
Toxics Deposition (Mercury, Dioxin)	Aquatic bioaccumulation of mercury and dioxin	Recreational and Commercial Fishing

Source: US EPA (1999)

of Groundwater Catchments (MAGIC) [57]. MAGIC is calibrated to the watershed of an individual lake or stream and then used to simulate the response of that system to changes in atmospheric deposition. The model simulates the effects of acid deposition on both soils and surface waters. The simulation typically involves seasonal or annual time steps and is implemented on decadal or centennial time scales.

#### *Quantifying Eutrophication*

When atmospheric nitrogen is deposited in estuaries, it can lead to eutrophication. Estimation of a dose-response relationship between nitrogen loading and water quality changes is complicated because of the dynamic nature of ecosystems. Most likely, these dose-response functions are nonlinear with a threshold. Unfortunately, universally transferable dose-response functions for quantifying the effects of eutrophication have not yet been developed. USEPA (1999) study quantified deposition-related nitrogen loadings for three estuaries (Chesapeake Bay, Long Island Sound, Tampa Bay) using GIS-related methods. Data on nitrogen deposition, together with information on abatement options to reduce excess nutrient loads, was used for valuation purposes. In addition, USEPA (1999) used specific biophysical indicators of estuarine health to quantify the benefits. This approach is useful when there is a direct link between the biophysical indicator and the ecological service flows. USEPA (1999) used the properties of the seagrass bed, which provides habitat for variety organisms, and have been shown to decline with increased nitrogen deposition, as an indicator.

[57] Cosby et al., (1985a,b)

#### *Quantifying Toxics Deposition*

Most damages to ecosystems are caused by five hazardous air pollutants (HAP): mercury, PCBs, dioxins, DDT, and chlordane. The mechanism of ecosystem responses to toxic contamination is poorly understood. Furthermore, service flow impacts of ecosystem damages are difficult to observe because HAPs persist in aquatic ecosystems for a long time. A comprehensive quantitative analysis with the available models and data is currently not possible.

#### *Valuation of Recreational and Commercial Fishing Benefits*

Unlike commercial fishing, recreational fishing is to a large part a non-market activity. Although most states charge a license fee for recreational fishing, the license fee itself is believed not to reflect the true willingness-to-pay (WTP) for recreational fishing. Marginal WTP for recreational fishing is a function of catch attributes (e.g. number and the average size of fish caught) and other determinants. Environmental factors indirectly affect WTP for recreational fishing by affecting the catch attributes. The total value of recreational fishing to the angler can be measured by the consumer surplus, which is the difference between WTP and the actual amount they pay or the cost they incur for the recreational fishing day. Consumer surplus is measured by the area below the demand curve and above the price or the cost of a recreational fishing day.

There is an extensive literature on valuation of fishing opportunities by anglers. In the valuation

literature, two primary methods have been used most often to deduce the value of recreational fishing: travel cost method (TCM), and contingent valuation method (CVM). TCM uses observed travel costs to visit a fishing site and per-capita visitation rates to deduce the demand for recreational fishing. On the other hand, CVM is questionnaire-based method, where anglers are asked hypothetical question about how much they would be willing to pay for a day of fishing.

TCM cannot be used to measure willingness-to-accept (WTA) some degradation in an environmental amenity (i.e. compensation demanded for an environmental damage). Hence, TCM cannot be used to estimate the value of loss of fishing opportunity due to air pollution. Furthermore, the use of CVM in general has generated controversy in the valuation literature. CVM is subject to an inherent bias due to its hypothetical nature. Study participants are often subjected to an unfamiliar market context, or they may not be fully aware of the characteristics of the good in question, or their own budget constraints. Some critics of CVM have pointed out that estimates of WTP obtained using CVM may not reflect the true WTP for the non-market good, but they rather reflect the WTP for moral satisfaction. The answers from CVM studies may be biased because of passive-use motives, such as the “warm glow” effect [58]. Individuals’ responses to WTP questions serve the same function as charitable contributions, and people are assumed to get a “warm glow” from giving. Some economists do not fully recognize “warm glow” as an economic value. Snyder et al. (2003) obtain estimates of the value of a recreational fishing day for 48 U.S. states. In the Appendix, summarizes the results for Mid-Atlantic states that are most likely to be affected by the New Jersey RPS are summarized.

A comparison of Snyder et al. (2003) estimates with the values from other studies reveals that there is a considerable geographic variation in the estimated value of recreational fishing. Moreover, the estimates are significantly lower than those reported in other studies employing TCM or CVM. The differences could be due to methodological differences, as well as, to the elimination of the biases in TCM and CVM. Ranges vary from a few dollars a day to almost twenty.

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[58] Andreoni (1989)

Another limitation of many early studies is that they do not include a direct measure of water quality. A notable exception is Montgomery and Needelman (1997) that consider the special case of toxic contamination of fisheries. Toxic contamination is a special case of pollution, because contaminants in fish become dangerous to humans eating fish before they result in a decline in fish population. In addition, through health advisories the public is better informed about incidences of toxic contamination than other forms of pollution (e.g. acidification or eutrophication).

### *Biodiversity Benefits*

Biodiversity is a valuable environmental benefit. A number of human actions, including anthropogenic air pollution, have led to a dramatic decline in biodiversity across the globe (Pimm et al., 2001). Biodiversity refers not just to an accumulation of species in a given area, but it also incorporates the ecological and evolutionary interactions among them (Armsworth et al., 2004).

The first step in estimating biodiversity benefits is defining biodiversity. Biodiversity encompasses four levels, which are summarized in Table 3.11.

Genetic biodiversity is the most basic level, and it refers to the information represented in the DNA of living organisms. Species-level biodiversity refers to the variety of species in a given area. Because only a small fraction of the estimated 5-30 million species currently living on the earth (Wilson, 1988) have been identified and described, empirical estimates of the species-level biodiversity are often surrounded by a great degree of uncertainty. Community-level biodiversity is important, because it is believed that species-level diversity enhances the productivity and stability of ecosystems (Nunes and van den Bergh., 2001, Odum, 1950). However, recent studies suggest that no pattern or determinate relationship may exist between species-level diversity and stability of ecosystems (Nunes and van den Bergh. 2001, Johnson et al. 1996). Functional diversity, or the ecosystem’s functional robustness, refers to the ability of the ecosystem to absorb external shocks. Unfortunately, the ecosystem’s functional diversity is still poorly understood (Nunes and van den Bergh, 2001).

**Table 3.11 Four Levels of Biodiversity**

Type of Biodiversity	Physical Expression
Genetic	Genes, nucleotides, chromosomes, individuals
Species	Kingdom, phyla, families, genera, subspecies, populations
Ecosystem	Bioregions, landscapes, habitats
Functional	Ecosystem, functional, robustness ecosystem resilience services goods

Source: Turner et al. (1999)

Human threats to biodiversity include activities causing habitat loss (conversion, degradation or fragmentation) and climate change, harvesting, as well as the introduction of exotic species that by becoming dominant competitors or effective predators may drive many native species to extinction.

Empirical estimates of Morse et al. (1995) and Field et al. (1999) of the impact of climate change on biodiversity illustrate the magnitude of threats to biodiversity: 4 °F average temperature increase can reduce the number of all species in California by 5%-10%.

A traditional approach to measuring biodiversity has focused on species-level biodiversity, which can be measured in two ways [59]: richness – number of species in a given area – and evenness – how well distributed abundance or biomass is among species within a community. Evenness is the greatest when species are equally abundant. For example an area that has a total population of 100 of 10 different species, each comprising of 10 individuals, is more diverse than a community of 1 species with 91 individuals and 9 other species with one individual each. To quantify diversity, a diversity index may be used that combines aspects of richness and evenness.

The monetization of biodiversity benefits requires assessing what it is about biodiversity that consumers’ value. In general, consumers’ benefit can be divided into *use value* (direct such as tourism or indirect such as pollination) or *non-use value* (intrinsic

or existence value). Direct benefits to consumers arise in two important ways:

- **Service flows** – Ecosystems provide valuable services to society, such as water purification in natural watersheds, prevention of soil erosion and carbon sequestration by standing forests, and recreational services such as ecotourism and birdwatching. The service flow approach to valuation is predicated upon investments in preserving or restoring biodiversity needed to deliver a competitive return relative to other investment opportunities within the economy otherwise capital would be put to other uses, and hence it does not necessarily maximize some types of diversity (Armsworth, 2004).
- **Bet hedging** – Conserving biodiversity provides society with a hedge against unforeseen circumstances. For example, if society were overly reliant on monocultured ecosystems, it would be vulnerable to catastrophic losses due to disease outbreaks.
- **Nonuse or existence value** – Consumers derive utility from knowing that certain species (still) exist.

Nunes and van den Bergh (2001) critically evaluate a number of biodiversity valuation studies at each level of biodiversity value. The authors conclude that available economic valuation estimates should be regarded as providing an incomplete perspective on the value of biodiversity changes, and they provide at best the lower bounds on that value. The main shortcoming of these single-species valuation studies is that they do not account for species substitution and complementary effects. Multiple-species valuation

[59] Much of the following discussion is based on Armsworth et al. (2004).

studies account for all related species, and the resulting estimates are in general higher than those of single-species studies. There are also studies that link the value of biodiversity to the value of natural areas with high tourism and outdoor recreation demand. Studies reviewed by Nunes and van den Bergh (2001) report a wide range of estimates for the various levels of biodiversity valued from hundreds of thousands of dollars to hundreds of millions depending on the biodiversity level.

Appendix B presents tables that summarize the results from the valuation studies that have been performed in North America.

### *Forestry Benefits*

Air pollution has been recognized as a potential problem for forests for a long time. Sulfur dioxide, fluorides, heavy metals and ozone pose the greatest threat to forest ecosystems. In the past, sulfur emissions, that cause acid rain, were the primary concern, but in recent decades massive efforts to reduce this pollutant have been largely successful. Today, in terms forestry impacts, ozone may be the pollutant associated with the greatest potential benefits.

Scientific evidence suggests that elevated tropospheric ozone levels disrupt vegetation growth, and interfere with the respiratory function of plants carried out by photosynthesis even at concentrations below current air quality standards [60]. Sometimes ozone injury to plants has observable effects such as yellowing or stippling of leaves, but negative impacts of ozone often occur without accompanying visible symptoms.

Ambient ozone enters the plant through pores in the leaf or needle called stomata, where most of the plant's metabolic and respiratory activity occurs. Once ozone enters these stomata, it initiates a chain reaction that destroys or damages plant proteins and enzymes, as well as the fatty chemicals that help form cell membranes. Plants continue to suffer damage long after the ozone exposure episode is over. Furthermore,

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[60] See for example, Wang et al. (1986) and Reich and Amudson (1985)

some researchers have suggested that there are synergies between ozone and acid deposition [61].

Ozone damage to forests is a common problem in many parts of the eastern U.S. Particularly sensitive species to ozone are the poplars (*Populus* spp.), white pine (*Pinus strobus*), and the oak family (*Quercus* spp.).

Another serious threat to forest ecosystems is acid deposition in the form of nitrogen acids due to nitrogen oxides emissions. Aluminum is naturally present in forest soils in the form of chemical compounds that are harmless to living organisms. Nitrogen acids cause ions of aluminum to become mobile in soil, and in its toxic form, aluminum is taken up into the tree's roots. This may result in reduced root growth, which reduces the tree's ability to take up water and withstand drought. Excess nitrogen is also absorbed directly from the air through the leaves during fog and low clouds. If ozone is present in sufficient concentrations, exposure to this oxidant can damage the leaves, damaging respiration processes of the organism.

Given the evidence on damage to forests and the size of the forest cover, forestry benefits seem to play an important role in total benefits due to reduced air pollution in the northeastern United States. According to Mid-Atlantic Integrated Assessment (MAIA) – the multi-agency effort headed by the USEPA to assess the health and sustainability of ecosystems – forests cover 61% of the total land area in the MAIA region [62]. Ninety-five percent of the region's forests are classified as timberland. The vast majority (79%) of timberland is owned by nonindustrial private landowners, while the forest industry owns approximately 7%. Hardwood forests dominate the MAIA region. For the region as a whole, oak/hickory is the predominant forest type. Other dominant forest types in the region are northern hardwoods, loblolly/shortleaf pine, and oak/pine.

Due to the different life cycles involved, the assessment of forest damage is substantially more

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[61] Hewitt (1990)

[62] The MAIA study region includes Delaware, Maryland, Pennsylvania, Virginia, and West Virginia, and parts of New Jersey, New York, and North Carolina.

difficult than that of agricultural crop damage. On one hand trees live for a long time, which makes the study of pollution impacts much more difficult. On the other hand, unlike agricultural soils, which are effectively managed through annual cycles, forest soils are much less disturbed which leads to an accumulation of acidification impacts.

USEPA (1999) uses the PnET-II model to estimate the impacts of tropospheric ozone on commercial timber growth. The PnET model simulates the cycles of carbon, water, and nitrogen through forest ecosystems. Model inputs of monthly weather data and nitrogen inputs are used to predict photosynthesis, evapotranspiration, and nitrogen cycling on a monthly time-step for several forest types.

### *Valuation of Forestry Benefits*

The valuation techniques of forestry benefits can be grouped into three categories: 1. direct market prices, 2. indirect market prices, 3. hypothetical values. Methods using direct market prices are based on actual prices, and consequently they do not reflect some benefits (e.g. preservation of biodiversity) that the market participants did not take into account in their decision-making. Methods utilizing indirect market prices include hedonic property values, the travel costs, opportunity costs, surrogate prices and replacement costs [63]. The opportunity cost method uses the market price of the best alternative forgone to provide a lower bound on forestry benefits. Surrogate prices methods use the market price of a close substitute as a proxy for the benefits. A surrogate market approach is used by methods using hypothetical values. Two methods that belong to this category are the contingent valuation method, and conjoint analysis. As described in the previous sections, contingent valuation method uses surveys that ask hypothetical questions to estimate economic values. Conjoint analysis estimates values by asking people by asking people questions across a range of features or attributes of a forest [64].

Forestry benefits may be grouped into three categories for valuation purposes: on-site private

benefits, on-site public benefits, and global benefits. On-site private benefits include timber productions, agricultural and other agroforestry products, and non-timber forest products (e.g. mushrooms, medicinal plants, honey, fruits, nuts, etc.), and recreation and tourism. On-site public benefits include watershed protection, agricultural productivity enhancement, nutrient cycling, microclimate regulation, and aesthetic, cultural, and spiritual values. Global benefits include carbon sequestration, and biodiversity conservation. Values derived for some of these benefits are not transferable, and therefore most valuation studies restrict attention to on-site benefits such as timber production. These benefits are usually estimated using market models. For example, USEPA (1999) used the USDA Forest Service Timber Assessment Market Model to estimate market changes that result from reduced timber growth.

### **Indirect Benefits to Humans through Nonliving Systems**

There are two types of indirect benefits through nonliving systems that were studied the most: avoided materials damages, and improved visibility. The steps of estimating these benefits are summarized in the sections that follow.

#### *Avoided Materials Damages*

Anthropogenic sulfur and nitrogen pollutants are believed to have caused vast damage to buildings, structures, as well as the cultural heritage in the past century. Much of the damage has occurred in Europe and North America, but with growing car traffic, and very high concentrations of sulfur dioxide in many cities of China, India, and Latin America material damages due to air pollution continue to remain a significant problem.

Objects most susceptible to air pollution are the ones with long lives, particularly buildings. Other objects, such as cars, may be damaged by air pollution, but these damages tend to be less important, because they are usually replaced before the damage could become significant.

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[63] Cavatassi (2004)

[64] Cavatassi (2004)

Pollutants that contribute to degradation of buildings are particles (particularly soot) causing soiling, and sulfur dioxide (SO<sub>2</sub>) contributing to corrosion and erosion caused by acid rain. Principal effects associated with air pollution are loss of mechanical strength, leakage, failure of protective coatings, loss of details in carvings, and pipe corrosion.

SO<sub>2</sub> has a strong accelerating effect on the degradation of certain materials by contributing to corrosion by acidic deposition. Atmospheric corrosion is influenced by climatic patterns such as relative humidity, temperature and precipitation, and it tends to be a local problem, because the damage often occurs near the source of emission. On the other hand, indirect effects of SO<sub>2</sub> emissions caused the acidification of soil and water bodies tend to be a regional problem due to the long-range transport of air pollutants.

Air pollution damages materials such as zinc, copper, stone, as well as organic materials. In case of zinc and copper, the dissolution of protective corrosion products leads to increased deterioration rates. Calcareous stones, such as limestone or marble, are very susceptible to acid deposition by sulfur dioxide through transformation of the original calcium carbonate to gypsum and calcium sulfate. Degradation of organic materials, such as rubber tires and paints, are usually associated with ozone in conjunction with temperature and solar radiation.

The ideal approach to quantifying materials damages is analogous to the approach used to quantify health endpoints. One would start by estimating the change in pollutant concentrations caused by a policy-induced reduction in emissions. The second step would involve the use of dose-response or concentration-response (CR) functions that relate the physical damage to ambient pollutant concentrations. And the last step involves attaching monetary values to damages.

A valid CR function provides a mathematical relationship between properties of the environment and some index of materials, such as loss of stock thickness. Some early attempts aimed at deriving such CR functions focused on the relationship between

ambient pollutant concentrations and corrosion rates. As Lipfert (1996) points out, this approach neglects the important variable of delivery of the reactant to the surface. A full understanding of the process requires a separation of pollutant delivery process from the subsequent chemical reactions. The appropriate technique to estimate a CR function is that of a multiple regression, in which some index of corrosion is the dependent variable and the various environmental factors are the independent variables.

Perhaps the most difficult element of economic assessment of materials damages (or benefits from reduced air pollution) is the problem of estimating stocks of buildings at risk [65]. One problem is that there is considerable heterogeneity in the use of housing materials across country. While residential housing materials tend to follow regional patterns, commercial and industrial buildings tend to be more uniform. Another important problem since atmospheric corrosion has been present in many parts of the country for a long time people may have substituted away from the more sensitive building materials toward less sensitive ones. The greatest difficulty lies in distinguishing chemical characteristics of exposed surfaces within each building type and category. Lipfert (1996) suggests that there is a need for a probabilistic, as opposed to deterministic, approach to assessment. There are many relevant but disparate databases on building stocks, but no effort has been made yet to synthesize that information [66].

As an alternative to the above bottom-up approach, Rabl (1999) estimates damages to buildings in France by working with aggregate data on observed frequencies of cleaning and repair activities. The result is a “combined concentration-response function”. The main variables in the CR function are income and the ambient concentration of particulate matter.

Rabl (1999) considers two types of damage caused by air pollution: corrosion or erosion of coatings and construction materials and soiling. Corrosion and erosion are primarily due to acid deposition. A large number of studies analyzed the effects of air pollution, corrosion, and erosion. Dose-response functions have

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[65] Lipfert and Daum (1992)

[66] Lipfert (1996)

been estimated for several building materials [67]. There are relatively few studies on soiling due to air pollution, and consequently few dose-response functions are available [68].

Using a bottom-up approach, the following are the steps in valuations:

- Division into pollution strata
- Materials inventory and inspection of physical damage
- Damage functions
- Estimated change in service life
- Maintenance/ Replacement cost
- Estimated economic damage

The main drawback of the bottom-approach is the need for very detailed data on building inventories. Neither approach to valuation may be used to assess damages to the cultural heritage. Cultural heritage encompasses both outdoor buildings and sculptures and treasured objects kept indoors, stored in museums and archives. The most appropriate valuation method for assessment is contingent valuation. These valuation studies tend to be case specific and generally not transferable.

### *Visibility Benefits*

Reduced visibility due to anthropogenic air pollution affects some of the country's most scenic areas. US EPA estimates that in national parks in the eastern United States, average visual range has decreased from 90 miles to 15-25 miles. In the West, visual range has decreased from 140 miles to 35-90 miles. The main cause of visibility impairment is haze. Under stagnant air mass conditions, aerosols can be trapped and produce a visibility condition usually referred to as layered haze. Some light is absorbed by particles while other light may be scattered away before it reaches the observer. The introduction of particulate matter and certain gases into the atmosphere therefore reduces visibility.

From a technical point of view, visibility is a complex and difficult concept to define. Visibility

includes psychophysical processes and concurrent value judgments of visual impacts, as well as the physical interaction of light with particles in the atmosphere. Therefore it is important to understand the psychological process involved in viewing a scenic resource, and to be able to establish a link between the physical and psychological processes.

Quantifying visibility requires developing links between visibility and particles that scatter and absorb light. Visibility, in the most general sense, reduces to understanding the effect that various types of aerosol and lighting conditions have on the appearance of landscape features. Measuring visibility by a single index, however, is not possible because visibility cannot be defined by a single parameter [69]. Many visibility indices have been proposed, however, the most simple and direct way of communicating reduced visibility is through a photograph. In fact, many contingent valuation (CV) studies of visibility present the subjects with photographs of scenic areas with varying levels of visibility. The reason photographs communicate visibility-changes so well is that the human eye works much like a camera. The human eye detects relative differences in brightness rather than the overall brightness level, that is to say, the eye measures contrast between adjacent objects.

Because the human eye functions like a camera, a photograph captures visibility changes, as humans perceive it. However, it is difficult to extract quantitative information from photographs, and therefore direct measures of fundamental optical measures of the atmosphere have been developed. The most common measures are atmospheric extinction and scattering.

The scattering coefficient is a measure of the ability of particles to scatter photons out of a beam of light, while the absorption coefficient is a measure of how many photons are absorbed. Both coefficients are expressed as a number proportional to the amount of photons scattered or absorbed per distance. The sum of scattering and absorption is referred to as extinction or attenuation.

The most commonly used methods for visibility valuation are hedonic property values and contingent

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[67] See, for example, Kucera (1990), Haneef et al. (1992), Butlin et al. (1992), and Lipfert (1987)

[68] See Hamilton and Masnfield (1992)

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[69] Malm (1999)

valuation. Hedonic methods are based on revealed preference of consumers, because they link nonmarket valuation to a traded commodity. Hedonic property value studies estimate the marginal WTP function on the basis of an estimated relationship between housing prices and housing attributes (including air quality).

There are several factors that affect the relationship between property values and air quality. These include adverse health effects, reduced visibility or soiling due to air pollution. Hedonic methods cannot be used to estimate individual effects separately. Disaggregation of overall impacts requires making subjective judgments by the researcher. Nevertheless, the results of hedonic property value studies confirm the hypothesis that air quality has a significant impact on property prices. Kenneth and Greenstone (1998) estimate that the Clean Air Act induced nationwide monetized benefits were \$80 billion (in 1982-84 dollars) in the 1970's, and \$50 billion during the 1980s. Delucchi, Murphy and McCubbin (2002) estimate monetized costs of total suspended particle pollution in 1990 at \$52-\$88 billion in (1990 dollars). Some studies [70] attempted to disaggregate property value impacts into health, visibility, soiling, and other impacts. They find that visibility impacts are the second most important, after health effects, representing 19-34% of total monetized benefits.

Burtraw et al. (1997) present the results of an integrated assessment of the benefits and costs of the Title IV of the 1990 Clean Air Act Amendments initiated reductions in emissions of sulfur dioxide and nitrogen oxides. They use the Tracking and Analysis Framework (TAF) developed for the National Acid Precipitation Assessment Program (NAPAP). Although uncertainties surround their estimates, the findings suggest that the benefits of the program substantially outweigh its costs. Two types of visibility effects are examined: recreational visibility at two national parks

(Grand Canyon and Shenandoah), and residential visibility in five metropolitan areas (Albany, NY, Atlantic City, NJ, Charlottesville, VA, Knoxville, TN, and Washington, DC). The results, summarized in Table 3.12, are most usefully considered on a per capita basis.

**Table 3.12 Per Capita Benefits in 2010 for Affected Population**

<b>Effect</b>	<b>Benefits per Capita (1990\$)</b>
Morbidity	3.50
Mortality	59.29
Aquatic	0.62
Recreational Visibility	3.34
Residential Visibility	5.81
Costs	5.30

Source: Burtraw et al. (1997), Table 2, pp. 13

These visibility estimates illustrate their potential magnitude, but it should be noted that they are based on the relatively small number of studies available in the literature, and also the geographical scope of the project is limited. Burtraw et al. (1997) explain the relatively large magnitude of visibility benefits compared to other types of benefits, namely aquatics, by claiming that willingness to pay depends on the availability of substitutes, and visibility, along with health, has no close substitutes.

Smith and Osborne (1996) perform a meta-analysis of visibility valuation studies to test whether CV estimates of WTP are responsive to the amount, or scope, of the environmental amenity being offered. They consider an internal consistency test for CV-based WTP. Internal consistency tests assess the reliability and validity of CV surveys. One way to evaluate the CV method is to compare WTP functions estimated with CV surveys with the specific, observable properties that economic theory implies WTP should follow. Smith and Osborne (1996) selected five of CV studies that used comparable methods for the meta-analysis. These studies focused on air quality as a key element. Furthermore, in each study air quality is presented in a way that permits computation of the change in visible range. The five selected studies are summarized in Table 3.13.

[70] For example, see Brookshire et al. (1979; 1982), Loehman et al. (1994), and McClelland et al. (1991)

**Table 3.13 Summary of CV studies for visibility at national parks analyzed by Smith and Osborne (1996)**

<b>Authors</b>	<b>Mean and inter-quartile range of WTP (per month in 1990 \$)</b>	<b>Mean change in visibility</b>	<b>Location</b>	<b>Type of survey</b>
Rowe et al. (1980)	\$9.27 (\$6.83, \$10.82)	0.50	Navaho Recreation Area	In-person interviews administered to to households in area
MacFarland et al	\$2.75 (\$1.69, \$3.73)	1.18	Grand Canyon and Mesa Verde National Parks	In-person interviews administered to visitors to the area
Schulze et al.	\$8.50 (\$4.42, \$11.67)	0.79	Grand Canyon, Mesa Verde, and Zion National Parks	In-person interviews administered to households in Albuquerque, Los Angeles, Denver, and Chicago
Chestnut and Rowe	\$4.35 (\$3.15, \$5.48)	0.62	Grand Canyon, Yosemite, and Shenandoah National Parks	Mail with telephone households in Arizona, Virginia, California, New York, and Missouri
Balson et al.	\$0.46 (\$0.007, \$0.97)	0.955	Grand Canyon National Park	In-person interviews conducted in St. Louis and San Diego Counties

Source: Smith and Osborne (1996), pp. 291, Table 1

The findings of Smith and Osborne (1996) support a positive, statistically significant and robust relationship between the WTP estimates and the percentage improvement in visible range. These results suggest that it may be possible to transfer results from a meta-analysis of past CV studies. The crucial issue in benefit transfer is to find a common metric to measure the environmental amenity.

#### **IV. Conclusion**

The proposed New Jersey RPS will reduce emissions generated by power plants that adversely affect the health and welfare of its population. Translating reduced emissions into reduction of emission concentrations, then into reduced health effects, and finally into a monetary value requires extensive New Jersey specific data, modeling, and analysis. Policy makers, however, must make decisions before such a research effort can be completed and should not ignore environmental externalities because

of the difficulty in quantifying them. One option is to apply environmental externality adders, which other policymakers have done, to the New Jersey proposed RPS. The illustrative calculations in this Chapter indicate that the environmental benefits of a

20% RPS are in the range of several hundred million dollars. Chapter 4 then discusses the associated policy implications of the proposed RPS.

# Chapter 4: Summary of Findings and Discussion of Policy Recommendations

Assuming cost reductions in renewables occur as expected, the impact of the establishment of a 20% RPS in 2020 on the New Jersey economy is negligible. The impact may be positive under scenarios of higher fuel prices. Moreover, there are other benefits of the proposed 20% RPS that can be realized if the state takes action to implement a variety of policy initiatives. After summarizing the findings of the economic assessment of the proposed New Jersey 20% RPS, this chapter discusses initiatives and policy recommendations that should be considered by state officials in order to capture fully the benefits of increasing the RPS.

## I. Summary of Findings

The major findings regarding the economic impact of the proposed 20% RPS compared to the existing RPS are the following:

1. Under the Expected Case assumptions, the proposed 20% RPS compared to the existing RPS would raise electricity prices approximately 3.7% in the year 2020 and have negligible impact on the growth of New Jersey's economy;
2. If natural gas prices rise to levels assumed in the High Energy Price scenario, the proposed 20% RPS has a positive economic impact on the New Jersey economy because electricity prices would be lower than under the existing RPS scenario;
3. Under the proposed 20% RPS, the location in New Jersey of all of the manufacturing, operations, and maintenance facilities and employees needed to support the PV and off shore wind infrastructure in New Jersey would be adding approximately 11,700 jobs and attenuate economic benefits to the New Jersey economy in the year 2020. In addition, the number of jobs could grow as demand for goods and services extends throughout the region;
4. The health and environmental benefits from a RPS result from and depend on the reduction in the atmospheric concentration of emissions, which are (with the exception of carbon dioxide) geographic specific, and other policymakers use a wide range of externality values that may have limited application to New Jersey but these values are used in this report for illustrative purposes;
5. Illustrative calculations using generic environmental externality adders indicate that in the year 2020 several hundred million dollars in environmental damage may be avoided by implementing a 20% RPS;
6. The proposed 20% RPS would lower natural gas prices for consumers in New Jersey and nationwide by reducing the burning of this fuel in power generation;
7. The proposed 20% RPS would increase reliability by providing electricity when grid power is not available and may reduce expenditures on T&D within the state;
8. The economic and electricity price impacts of the proposed 20% RPS depend substantially on whether expected cost reductions occur that reduce the cost of PVs and wind power; and

- Existing cap-and-trade emission allowance policies for sulfur dioxide and nitrogen oxide act in combination with a RPS so that the RPS may not alone result in reduced levels of these emissions but will lower the price of emission allowances.

The proposed 20% RPS has many important policy implications, and New Jersey's ability to obtain the full benefits of the proposed 20% RPS depend on future actions. Recommendations are divided into two major categories – those that New Jersey can act upon unilaterally and those that require New Jersey to coordinate with other states. These recommendations are also discussed in the context of making connections between them and other policies and discussing those that improve knowledge by which to better inform policy.

## II. Recommendations that New Jersey Can Implement Unilaterally

- Monitor future cost reductions in renewable technologies particularly wind and PVs.** The economic and electricity price impacts of the proposed 20% RPS depend substantially on whether expected technological improvements and other factors occur that reduce the cost of PVs and wind power. The costs of these technologies are the key driver of the effects on electricity prices and economic growth under the proposed 20% RPS. The BPU should track and reevaluate the costs of wind, PVs, and other renewables to ensure that policies are being pursued to lower the cost of these renewable technologies and adjusted to their changing cost structure. If costs reductions occur slower than anticipated, consideration should be given to adjusting downward the level of renewables required. Similarly, if cost reductions occur more rapidly, thought should be given to accelerating the proposed 20% RPS. This cost monitoring should occur in tandem with setting the alternative compliance payment (ACP), the payment that suppliers must pay if they do not have sufficient renewables in their portfolio. The ACP performs both the role as an incentive to have suppliers procure required quantities of renewables but also acts to mitigate market power

in the REC market by, in effect, capping the price of RECs. Accordingly, the BPU should require the committee that advises it as to the setting of ACP to include a specific report on actual and projected cost of renewables.

- Evaluate the appropriateness of off-shore wind in New Jersey as an electricity generation resource.** New Jersey policymakers should give serious attention to determining policies addressing the appropriateness of developing, permitting, and siting of offshore wind, a potentially large Class 1 resource in terms of a resource and economic development. While there are numerous competing arguments to encourage or discourage the development of off-shore wind, it is important that state policy address these issues on a timely basis. A timely determination may be particularly important if New Jersey decides to adopt policies to attract off-shore wind and the supporting labor force, whose economic benefits may be substantial. If New Jersey determines to encourage the development of this resource, the State's economic development policies should be integrated with its wind policies.
- Coordinate and integrate various policies to maximize their impact.** The BPU should take specific efforts to ensure that New Jersey's policies on PVs, critical infrastructure, distributed generation, and siting are aligned. For example, if New Jersey policy seeks to maximize the reliability value of the state's investment in PVs, they should be located on the transmission and distribution system (T&D) in load pockets to reduce these costs. Similarly, PVs should be design to function safely and reliability when grid power is not available and if possible, be located at critical facilities.
- Strengthen the link between New Jersey's renewable energy and economic development programs by proactive initiatives to attract the location of manufacturing and maintenance facilities within the state.** The transformation of the existing electric power system requires new technologies and manufacturing and maintenance facilities, which provides an opportunity for New Jersey to attract new and expanding businesses. New Jersey is in competition with other states

for these facilities and therefore should launch proactive initiatives to realize the potential benefits to the state's economy. The BPU's efforts should be coordinated with the state's Economic Development Authority.

- **Assess whether New Jersey should develop the research and modeling capability to quantify the state specific health and environmental benefits of its renewable energy policies and to provide insights into its effectiveness.** Illustrative calculations using generic environmental externality adders indicate that in the year 2020 several hundred million dollars in environmental damage may be avoided by implementing a 20% RPS. The New Jersey BPU should lead an interagency group that includes the Department of Environmental Protection and the Department of Health to make this assessment.

### III. Recommendations that Require New Jersey to Coordinate with Others

Since New Jersey is part of regional, national, and international markets for electricity, emissions, and fuels, the effectiveness of its RPS policies also depends upon the policies of other states and the federal government. To obtain the full benefits from its RPS policy, New Jersey needs to actively participate and lead a coalition of states to ensure the following:

- **Monitor the adoption of RPS policies by other states in the region, especially regarding the cost and availability of renewable resources.** Although this report assumes a static REC market in the mid-Atlantic and Northeast regions, adoption of RPS by other states will unquestionably affect the availability and costs of renewables.
- **Establish the link between reductions in emissions due to the RPS and corresponding changes in environmental policies to capture those reductions.** Existing cap-and-trade emission allowance policies for sulfur dioxide and nitrogen oxide act in combination with a RPS so that the RPS may not alone result in reduced levels of these emissions but will lower the price of emission allowances. In the case of SO<sub>x</sub> and NO<sub>x</sub>, obtain specific reductions in the caps on these emissions due to its RPS. If regional or national emission caps on CO<sub>2</sub>, CO, and particulates (PM) are established, then lower their caps over time to reflect the reductions of these emissions due to the RPS. Establishing these links should also accelerate having renewables replace existing oil and coal facilities that have worse emission rates than natural gas facilities.
- **Continue New Jersey's leadership role to facilitate trading the essential elements of RECs in the mid-Atlantic and Northeast regions to enhance liquidity in order to finance renewable projects within these regions.** RPS definitions do and are likely to continue to differ across state boundaries, which result in different types of RECs. Policies that account for these differences and permit trading the common elements of RECs across states are needed to finance renewable development.
- **Work with PJM to ensure that the wholesale market and reliability rules applicable to renewables reflect the value these resources provide.** For example, the determination of capacity contribution of PV and wind technologies is an important issue. In addition, as the percentage of renewables increase within PJM, this may raise some important reliability, transmission planning, and market issues.

Increasing the percentage of renewable resources that generate electricity for electricity consumption by New Jersey consumers reduces environmental emissions, aids in the state's economic development, provides some downward pressure on natural gas prices, and allows customers with PVs to have access to electricity when the grid is unavailable. These benefits come at a cost of a small increase in the price of electricity but have only a negligible impact to the New Jersey economy.

How to implement the proposed 20% RPS is as important as whether to do so, and there are many steps, some requiring coordination with other states and the federal government, that New Jersey policymakers should consider in order to maximize the value of the proposed 20% RPS, if they were to adopt such a policy.

# References

## Chapter 1

Binz, Ronald J. 2004. *The Impact of the Renewable Energy Standard in Amendment 37 on Electric Rates in Colorado*. Denver: Public Policy Consulting.

Chen, Cliff, David White, Tim Woolf, and Lucy Johnson. 2003. *The Maryland Portfolio Standard: An Assessment of Potential Cost Impacts*. Report prepared for the Maryland Public Interest Research Group. Cambridge, MA: Synapse Energy Economics, Inc.

GDS Associates, Inc. 2001. *Analysis of Renewable Portfolio Standard Options for Hawaii*. Report submitted to the State of Hawaii, Department of Business, Economic Development, & Tourism. Marietta, GA: GDS Associates.

Keith, Geoff, Bruce Beiwald, David White, Anna Sommer, and Cliff Chen. 2003. *Cleaner Air, Fuel Diversity, and Quality Jobs: Reviewing Selected Potential Benefits of an RPS in New York State*. Report prepared for the Renewable Energy Technology and Environment Coalition. Cambridge, MA: Synapse Energy Economics, Inc.

Masters, Gilbert M. 2004. *Renewable and Efficient Electric Power Systems*. New York: Wiley-Interscience.

Pletka, Ryan, John Wynne, Jason, Abiecunas, Sam Scupham, Ryan Jaconson, and Bill Stevens. 2004. *Economic Impact of Renewable Energy in Pennsylvania*. Report for the Community Foundation for the Alleghenies. Overland Park, KS: Black & Veatch Corporation.

Smith, Douglas C., Karlynn S. Cory, Robert C. Grace, and Ryan Wisner. 2000. *Massachusetts Renewable Portfolio Standard: Cost Analysis Report*. Report for the Massachusetts Division of Energy Resources. Boston: LaCapra Associates.

Woolf, Tim, David White, Cliff Chen, and Anna Sommer. 2003. *Potential Cost Impacts of a Vermont Renewable Portfolio Standard*. Report for the Vermont Public Service Board. Cambridge, MA: Synapse Energy Economics, Inc.

## Chapter 2

Comparative Collection Summary, State of New Jersey Division of Taxation, Processing and Administration, monthly data sheets from 1998 to present.

Energy Information Administration, *Annual Energy Outlook, 2004*.

National Petroleum Council, *Balancing Natural Gas Policy*, September 2003.

Navigant Consulting Inc., Sustainable Energy Advantage LLC, and Boreal Renewable Energy Development, 2004. *New Jersey Renewable Energy Market Assessment: Final Report to Rutgers University Center for energy, Economic and Environmental Policy*, August 2, 2004, available at <http://www.policy.rutgers.edu/cecep/events.html> as of October 17, 2004.

North American Industry Classification System, 1998. US Office of Management and Budget.

Pace University Center for Environmental Legal Studies, Richard L. Ottinger, David R. Wooley, Nicholas A. Robinson, David R. Hodas, Susan E. Babb, Shepard C. Buchanan, Paul L. Chernick, Emily Caverhill, Alan Krupnick, Winston Harrington, Seri Radin, Uwe Fritsche, 1990. *Environmental Costs of Electricity*, Oceana Publications, Inc., New York.

Parsons, Brian, Michael Milligan, Bob Zavadil, Daniel Brooks, Brendan Kirby, Ken Dragoon, and Jim Caldwell, 2003. *Grid Impacts of Wind Power: A Summary of Recent Studies in the United States*, European Wind Energy Conference, Madrid, Spain, June 2003.

Wiser, Ryan, Mark Bolinger, and Matthew St. Clair, 2004. *Putting Downward Pressure on Natural Gas Prices: the Impact of Renewable Energy and Energy Efficiency*, Lawrence Berkeley National Laboratory, May 20, 2004.

## Chapter 3

Abbey DE, Petersen FF, Mills PK, Beeson WL, 1993. *Long-term ambient concentrations of total suspended particulates, ozone, and sulfur dioxide and respiratory*

- symptoms in a non-smoking population. *Arch of Environ Health* 48(1); 33-46.
- Abbey DE, Ostro B, Petersen F, Burchette RJ., 1995. Chronic respiratory symptoms associated with estimated long-term ambient concentrations of fine particulates less than 2.5 Microns in diameter (PM2.5) and other air pollutants. *JEAE* 5(2): 137-159.
- Abdalla, C.W., Roach, B.A., Epp, D.J., 1992. Valuing environmental quality changes using averting expenditure: an application to groundwater contamination. *Land Economics* 38 (2), 163–169.
- Adams, R. M., Hamilton, S. A. and McCarl, B. A. 1986. The benefits of pollution control: the case of ozone and US agriculture. *American Journal of Agricultural Economics* 68, 886–889.
- Ahn, Soeun; de Steiguer, Joseph E.; Palmquist, Raymond B.; Holmes, Thomas P., 2000 Economic Analysis of the Potential Impact of Climate Change on Recreational Trout Fishing in the Southern Appalachian Mountains: An Application of a Nested Multinomial Logit Model *Climatic Change* 45: 493-509.
- Andreoni, James, 1989. Giving with Impure Altruism: Applications to Charity and Ricardian Equivalence, *Journal of Political Economy*, Vol. 97 (6) pp. 1447-58. University of Chicago Press.
- Arnould, R.J. and L.M. Nichols, 1983. Wage-Risk Premiums and Workers' Compensation: A Refinement of Estimates of Compensating Wage Differential, *Journal of Political Economy* 91(2), 332-340.
- Armsworth, Paul R., Kendall, Bruce E., Davis, Frank W., 2004. "An Introduction to biodiversity concepts for environmental economists" *Resource and Energy Economics*, 26, pp. 115-136
- Ashmore, M. R., 1991. Air Pollution and Agriculture. *Outlook on Agriculture* 20, 139–144.
- Balson, W. E., Carson, R. T., Conaway, M. B., Fischhoff, B., Hanemann, W. M., Hulse, A., Kopp, R. J., Martin, K. M., Mitchell, R. C., Molenar, J., Presser, S., and Ruud, P. A., 1990. Development and Design of a Contingent Valuation Survey for Measuring the Public's Value for Visibility Improvements at the Grand Canyon National Park, draft report, Decision Focus, Inc., Los Altos, CA.
- Boyle, K.J., 1990. Dichotomous choice, contingent valuation questions: functional form is important. *Northeastern Journal of Agriculture and Resource Economics* 19 (2), 125–131.
- Boyle, K.J., Bishop, R.C., 1987. Valuing wildlife in benefit cost analysis: a case study involving endangered species. *Water Resources Research* 23, 943–950.
- Brookshire, D.S., Eubanks, L.S., Randall, A., 1983. Estimating option prices and existence values for wildlife resources. *Land Economics* 59, 1–15.
- Brown, C. 1980. Equalizing Differences in the Labor Market, *Quarterly Journal of Economics* 94(1), 113-134.
- Brown, William G. and Faisal M. Shalloof, 1984. Recommended Values for Columbia River Salmon and Steelhead for Current Fishery Management Decisions. Oregon State University.
- Brookshire, D.S., Eubanks, L.S., Randall, A., 1983. Estimating option prices and existence values for wildlife resources. *Land Economics* 59, 1–15.
- Burtraw, Dallas, Alan Krupnick, Erin Mansur, David Austin, and Deirdre Farrell, 1997. The costs and benefits of reducing acid rain, Discussion Paper 97-31- REV, Resources for the Future, Washington, DC.
- Burnett R, Cakmak S, Raizenne M, Stieb D, Vincent R, Krewski D, Brook J, Philips O and Ozkanyak H., 1998. The Association between Ambient Carbon Monoxide Levels and Daily Mortality in Toronto, Canada. *Journal of the Air & Waste Management Association*, 48, 689-700.
- Butler, R.J., 1983. "Wage and Injury Rate Responses to Shifting Levels of Workers' Compensation." In J.D. Worrall (ed.), *Safety and the Workforce: Incentives and Disincentives in Workers' Compensation*. Ithaca, NY: ILR Press, pp. 61-86.
- Bower, J.M., Stoll, J.R., 1988. Use of dichotomous choice nonmarket methods to value the whooping crane resource. *American Journal of Agricultural Economics* 70, 327–381.
- Butlin, RN et al., 1993. Preliminary results from the analysis of stone tablets from the National Materials Exposure Program (NMEP), *Atmospheric Environment*, vol. 26B, number 2, pp. 189-198.
- Carlin, P., Sandy, R., 1991. Estimating the Implicit Value of a Young Child's Life, *Southern Economic Journal*, Vol. 58, No. 1, 291-310.
- Cavatassi, R., 2004. Valuation Methods for Environmental Benefits in Forestry and Watershed Investment Projects, The Food and Agriculture Organization of the United Nations, ESA Working Paper No. 04-01.
- Chapman RS, Calafiore CC, Hasselblad V., 1985. Prevalence of persistent cough and phlegm in young adults in relation to long-term ambient sulfur oxide exposure. *Am Rev Respir Dis*; 132: 261-67.
- Chestnut, L.G., L.R. Keller, W.E. Lanbert, and R.D. Rowe. 1996. Measuring Heart Patients' Willingness to Pay for Changes in Angina Symptoms. *Medical Decision Making* 16: 65-77.

- Chestnut, L. G. and Rowe, R. D., 1990. Preservation Value for Visibility Protection at the National Parks, Draft final report to U.S. Environmental Protection Agency, RCGrHagler Bailey
- Cosby, B.J., Hornberger, G.M., Galloway, J.N., Wright, R.F., 1985a. Modelling the effects of acid deposition: assessment of a lumped-parameter model of soil water and streamwater chemistry. *Water Resour. Res.*, 21,51.
- Cosby, B.J., Wright, R.F., Hornberger, G.M., Galloway, J.N., 1985b. Modelling the effects of acid deposition: estimation of long-term water quality responses in a small forested catchment. *Water Resour. Res.*, 21, 1591.
- Delucchi, Mark, James Murphy, Donald McCubbin, 2002. The Health and Visibility Cost of Air Pollution: A Comparison of Estimation Methods, *Journal of Environmental Management* 64, 139–152
- Desvousges, W.H., Johnson, F.R., Dunford, R.W., Boyle, K.J., Hudson, S.P., Wilson, K.N., 1993. Measuring natural resource damages with contingent valuation: tests of validity and reliability, In: Hausman, J.A. (ed.), *Contingent valuation: a critical assessment, contributions to economic analysis*, Chapter III, North-Holland, New York, US.
- Diamond, P.A., Hausman, J.A., Leonard, G.L., Denning, M.A., 1993. Does contingent valuation measure preferences? experimental evidence, In: Hausman, J.A. (ed.), *Contingent valuation: a critical assessment, contributions to economic analysis*, Chapter II, North-Holland, New York, US.
- Dickie, M. and S. Gerking, 1991b. Willingness to Pay for Ozone Control: Inferences from the Demand for Medical Care. *Journal of Environmental Economics and Management* 21(1): 1-16.
- Dillingham, A.E. and R.S. Smith., 1984. Union Effects on the Valuation of Fatal Risk. In Dennis, B.O. (ed.), *Proceedings of the Industrial Relations Research Association 36th Annual Meeting*, San Francisco, CA, December 28 – 30, 1983. Madison, WI: Industrial Relations Research Association, pp. 270-277.
- Dillingham, A.E., 1985. The Influence of Risk Variable Definition on Value-of-Life Estimates, *Economic Inquiry* 23(2), 277-294.
- Dockins, C., Maguire, K., Simon, N., Sullivan, M., 2004. Value of Statistical Life Analysis and Environmental Policy: A White Paper, U.S. Environmental Protection Agency National Center for Environmental Economics.
- Dockery DW, Pope CA 3<sup>rd</sup>, Xu X, Spengler JD, Ware JH, Fay ME, Ferris BG Jr, Speizer FE., 1993. An association between air pollution and mortality in six U.S. cities., *N Engl J Med.* 9; 329(24):1753-9.
- Dockery DW, Cunningham J, Damokosh AI, Neas LM, Spengler JD, Koutrakis P, Ware JH, Raizenne M, Speizer FE., 1996. Health effects of acid aerosols on North American children: Respiratory symptoms. *Environ Health Perspect*; 104(5): 500-505.
- Dorsey S. and N. Walzer, 1983. “Workers’ Compensation, Job Hazards, and Wages,” *Industrial and Labor Relations Review* 36(4), 642-654.
- Dreyfus, M. K., Viscusi, W. K., 1995. Rates of Time Preference and Consumer Valuations of Automobile Safety and Fuel Efficiency, *Journal of Law and Economics*, Vol. 38, Issue 1, pp. 79-105.
- Duffield, J.W., Patterson, D.A., 1992. Field testing existence values: an instream flow trust fund for Montana rivers, paper presented at the Allied Social Science Association Annual Meeting, New Orleans, Louisiana.
- Dutta, Nilima 1984. The Value of Recreational Boating and Fishing in the Central Basin of Ohio’s Portion of Lake Erie. Ohio State University, Sea Grant Program.
- Ellerman, D., P. L. Joskow, R. Schmalensee, J.P. Montero, E. M. Bailey, 2000. *Markets for Clean Air: The U.S. Acid Rain Program*, Cambridge University Press.
- Energy Central, 2004. New Jersey Governor Takes First Step in Limiting Greenhouse Emissions, September 20, 2004.
- Energy Information Agency, U.S. Department of Energy, Analysis of a 10-percent Renewable Portfolio Standard, SR/OIA/2003-01, May 2003.
- Energy Information Agency, U.S. Department of Energy, Electricity Generation and Environmental Externalities: Case Studies, DOE/EIA-0598, September 1995.
- Gayer, T., Hamilton J.T., Viscusi, W.K., 2000. Private Values of Risk Tradeoffs at Superfund Sites: Housing Market Evidence on Learning about Risk, *The Review of Economics and Statistics*, Vol. 82, Issue 3.
- Goulder, L.H., Kennedy, D., 1997. Valuing ecosystem services: philosophical bases and empirical methods. In: Daily, G.C. (Ed.), *Nature’s Services: Societal Dependence on Natural Ecosystems*. Island Press, Washington, DC, pp. 23–47.
- Greene, Gretchen; Moss, Charles B., and Spreen, Thomas H.; 1997. Demand for Recreational Fishing in Tampa Bay, Florida: a Random Utility Approach . *Marine Resource Economics.* 12: 293-305.
- Haas, Mark A. and Stephen A. Weithman 1982. Socioeconomic Value of the Trout Fishery in Lake Teneycomo, Missouri., *Transactions of the American Fisheries Society* 111, pp.223-230.

- Hageman, R., 1985. Valuing marine mammal populations: benefits valuations in multispecies ecosystems, In: Administrative Report, Southwest Fisheries, values cited in Eagle, J., Betters, D., 1998. The Endangered Species Act and Economic Values: a Comparison of Fines and Contingent Valuation Studies, *Ecological Economics* 26, 165– 171.
- Halstead, J.M., Luloff, A.E., Stevens, T.H., 1992. Protest bidders in contingent valuation. *Northeastern Journal of Agricultural and Resource Economics* 21 (2), 247–361.
- Haneef, SJ, Johnson, JB, Dickinson, C, Thompson, GE, Wood, GC, 1992. Effect of Dry Deposition of NO<sub>x</sub> and SO<sub>2</sub> gaseous pollutants on the degradation of calcareous building stones, *Atmospheric Environment*, vol. 26A, number 16, pp. 2963-2974.
- HEI (2000): Krewski, D., R. Burnett, M. Goldberg, K. Hoover, J. Siemiatycki, M. Jerrett, M. Abrahamowicz and M. White. 2000. Reanalysis of the Harvard Six Cities Study and the American Cancer Society Study of Particulate Air Pollution and Mortality. Health Effects Institute. Cambridge. July.
- Herrick, C. N. and Kulp, J. L., 1987. Interim Assessment: The Causes and Effects of Acidic Deposition. Volume 1, Executive Summary. Washington, DC: National Acid Precipitation Assessment Program, Office for the Director of Research.
- Hoehn, J. P.; Tomasi, Theodore; Lupi, Frank, and Chen, Heng Z., 1996. An Economic Model for Valuing Recreational Angling Resources in Michigan. Michigan State University, Report to the Michigan Department of Environmental Quality.
- Hoehn, J.P., Loomis, J.B., 1993. Substitution effects in the valuation of multiple environmental programs. *Journal of Environmental Economics and Management* 25 (1), 56–75.
- Holland, M., Mills, G., Hayes, F., Buse, A., Emberson, L., Cambridge, H., Cinderby, H., Terry, A. and Ashmore, M., 2002. Economic Assessment of Crop Yield Losses from Ozone Exposure. Part of the UNECE International Cooperative Programme on Vegetation. Progress Report (April 2001 – March 2002). Contract EPG 1/3/170 . CEH Project No: C01643.
- Holmes, T.P., 1988. The offsite impact of soil erosion on the water treatment industry. *Land Economics* 64 (4), 356–366.
- Hong, Y.-C., Lee J.-T., Kim, H., Ha, E.-H., Schwartz, J., and Christiani, D.C., 2002a. Effects of Air Pollutants on Acute Stroke Mortality. *Environ. Health Perspec.* Vol. 110, pp. 187-191, 2002. *Environmental Health Perspectives*
- Hong, Y.-C., Lee, J.-T., Kim, H., Kwon, H.-J., 2002b. Air Pollution: A New Risk Factor in Ischemic Stroke Mortality, *Stroke*, Vol. 33, No. 9, pp. 2165.
- Howitt, R. E., Gossard, T. W. and Adams, R. M., 1984. Effects of alternative ozone concentrations and response data on economic assessments: the case of California crops. *Journal of the Air Pollution Control Association* 34, 1122–1127.
- Huszar, P.C., 1989. Economics of reducing off-site costs of wind erosion. *Land Economics* 65 (4), 333–340.
- Ito, K. and Thurston, G., 1996. Daily PM10/mortality associations: An investigation of at-risk subpopulations. *J. Expos. Anal. Environ. Epidemiol.* 6:79-95.
- Jacobson, J. S., 1982. Ozone and the growth and productivity of agricultural crops. In M. H. Unsworth and D. P. Ormond (eds.), *Effects of Gaseous Air Pollutants in Agriculture and Horticulture*, London: Butterworths.
- Jakus, Paul M.; Dadakas, Dimitrios, and Fly, J. Mark; 1998. Fish Consumption Advisories: Incorporating Angler-Specific Knowledge, Habits, and Catch Rates in a Site Choice Model. *American Journal of Agricultural Economics*. 80(5):1019-1024.
- Jenkins, R. R., Owens, N., Wiggins, L.B., 2001. Valuing Reduced Risk to Children: The Case of Bicycle Safety Helmets, *Contemporary Economic Policy*, Vol. 19, No.4, pp. 397-408
- Kealy, Mary Jo and Richard C. Bishop, 1986. Theoretical and Empirical Specifications Issues in Travel Cost Demand Studies. *American Journal of Agricultural Economics* 68, pp.660-667.
- Kealy, M.J., Turner, R.W., 1993. A test of the equality of the closed-ended and the open-ended contingent valuations. *American Journal of Agriculture Economics* 75 (2), 311–331.
- Kenneth Y. Chay, Michael Greenstone, 1998. Does Air Quality Matter? Evidence from the Housing Market, NBER Working Paper No. w6826.
- King, David A. and John G. Hof, 1985. Experimental Commodity Definition in Recreation Travel Cost Methods. *Forest Science* 31, pp. 519-529.
- Kucera, V., 1990. External Building Materials – Quantities and Degradation, The National Swedish Institute for Building Research, Gaole, Sweden, Research Report TN:19.
- Laughland, A.S., Musser, W.N., Shortle, J.S., Musser, L.M., 1996. Construct validity of averting cost measures of environmental benefits. *Land Economics* 72 (1), 100–112.
- Lee, EH, WE Hogsett., 1996. Methodology for calculating inputs for ozone secondary standard benefits analysis: Part II. Prepared for the US EPA, OAQPS.
- Leigh, J.P. and R.N. Folsom, 1984. Estimates of the Value of Accident Avoidance at the Job Depend on the Concavity of the

- Equalizing Differences Curve, *Quarterly Review of Economics and Business* 24(1), 56-66.
- Leigh, J.P., 1987. Gender, Firm Size, Industry, and Estimates of the Value of Life, *Journal of Health Economics* 1, 331-344.
- Leung, S. K., Reed, W. and Geng, S., 1982. Estimation of ozone damage to selected crops grown in Southern California. *Journal of Air Pollution Control Association*, 32, pp. 160-164.
- Lipfert F. W. Estimating the effects of air pollution on buildings and structures: the U.S. experience since 1985 and some lessons for the future, Brookhaven National Laboratory
- Loomis, John B. and Cindy F. Sorg, 1986. Economic Value of Idaho Sport Fisheries With an Update on Valuation Techniques., *North American Journal of Fisheries Management* 6, pp.494-503.
- Low, S.A. and L.R. McPheters., 1983. Wage Differentials and the Risk of Death: An Empirical Analysis, *Economic Inquiry* 21, 271-280.
- Loomis, J.B., 1989. Test-retest reliability of the contingent valuation method: a comparison of general population and visitor responses. *American Journal of Agriculture Economics* 71 (1), 76–84.
- Loomis, J.B., Helfand, G., 1993. A tale of two owls and lessons for the reauthorization of the endangered species act, *Choices*, 21–25.
- Loomis, J.B., Larson, D.M., 1994. Total economic value of increasing Gray Whale populations: results from a contingent valuation survey of visitors and households. *Marine Resource Economics* 9, 275–286.
- Lupi, Frank and Hoehn, John P.; 1998. The Effect of Trip Lengths on Travel Cost Parameters in Recreation Demand. Michigan State University.
- Kengen, S. 1997, Funding sustainable forestry: Linking forest valuation and financing. *Unasylva*, 48(1), Issue no. 188.
- Kinney, P.L., Ito, K., Thurston, G.D., 1995. A sensitivity analysis of mortality/PM10 association in Los Angeles, *Inhalation Toxicol.* 7, 59-69.
- MacFarland, K., W. Malm, and Molenaar, J., 1983. An examination of methodologies for assessing the value of visibility, in “Managing Air Quality and Scenic Resources at National Parks and Wilderness Areas” R. Rowe and L. Chestnut, Eds. , Westview Press, Boulder, CO.
- Mar TF, Norris GA, Koenig JQ, Larson TV., 2000. Associations between air pollution and mortality inPhoenix, 1995-1997. *Environ Health Perspect.*; 108(4):347-53.
- McClelland, G.H., Schulze, W.D, Lazo, J.K., Waldman, D.M., Doyle, J.K., Elliot, S.R. and J.R. Irwin, 1992. Methods for measuring the non-use values: a contingent valuation study of the groundwater cleanup, draft report to USEPA, Center for Economic Analysis, University of Colorado, Boulder, Colorado.
- McConnell, R., et al., 2002. Asthma in exercising children exposed to ozone: A cohort study, *Lancet*, 359:386–391.
- McConnell, K. E. and Strand, I. E.; 1994. The Economic Value of Mid and South Atlantic Sportfishing. University of Maryland, Report to the USEPA and NOAA.
- McDonnell WF, Abbey DE, Nishino N, Lebowitz MD., 1999. Long-term ambient ozone concentration and the incidence of asthma in nonsmoking adults: the AHSMOG Study. *Environ Research*; 80:110-121
- ME3, Minnesotans for an Energy –Efficient Economy, [www.me3.org/](http://www.me3.org/), last checked September 26, 2004.
- Minnesota Public Utilities Commission, In the Matter of the Quantification of Environmental Costs Pursuant to Laws of Minnesota, Docket No. E-999/CI-93-583, December 16, 1996.
- Mitchell, R.C., Carson, R.T., 1984. Willingness to pay for national freshwater improvements, draft report to USEPA, Resources for the Future, Washington, DC.
- Moolgavkar, S.H., Luebeck, E.G., Hall, T.A. and Anderson, E.L., 1995. Air pollution and daily mortality in Philadelphia. *Epidemiology* 6, 476-484.
- Moore, M.J. and W.K. Viscusi, 1988a. Doubling the Estimated Value of Life: Results Using New Occupational Fatality Data, *Journal of Policy Analysis and Management* 7(3), 476-490.
- Murphy, J.J, Delucchi M.A., McCubbin D.R., Kim,H.J. 1999. The Cost of Crop Damage Caused by Ozone Air Pollution From Motor Vehicles, *Journal of Environmental Management*, vol. 55, pp. 273-289
- Miller, John R. and Michael J. Hay 1980. Estimating Substate Values of Fishing and Hunting. *Transactions of the North American Wilderness and Natural Resources Conference* 49, pp.345-355.
- Montgomery, Mark and Needelman, Michael; 1997. The Welfare Effects of Toxic Contamination in Freshwater Fish. *Land Economics*. 73:211-273.
- Morey, Edward R., Breffle, William S., and Greene, Pamela A., 2001. Two Nested Constant-Elasticity-of-Substitution Models of Recreational Participation and Site Choice: An “Alternatives” Model and an “Expenditures” Model, *American Journal of Agricultural Economics*. Vol 83, Issue 2, pp 414-427.
- National Renewable Energy Laboratory, U.S. Department of Energy, Issues and Methods in Incorporating Environmental Externalities into the Integrated Resource Planning Process,

- Task No. AS115445, November 1994.
- New Jersey Department of Environmental Protection, In Pursuit of Clean Air: A Review of State and Federal Policies Affecting New Jersey's Air Quality, April 2004.
- New Jersey Department of Environmental Protection, 2002 Air Quality Report, Carbon Monoxide section, 2002.
- Office of Technology Assessment, Congress of the United States, 1994. Studies of the Environmental Costs of Electricity, OTA-BP-ETI-134.
- Olson, C.A., 1981. An Analysis of Wage Differentials Received by Workers on Dangerous Jobs, *Journal of Human Resources* 16(2), 167-185.
- Parsons, George R. and Hauber, A. Brett; 1998. Spatial Boundaries and Choice Set Definition in a Random Utility Model of Recreation Demand. *Land Economics*. 74(1):32-48.
- Pendleton, Linwood H. and Mendelsohn, Robert; 1998. Estimating the Economic Impact of Climate Change on the Freshwater Sportsfisheries of the Northeastern U.S. *Land Economics*. 74(4):483-96.
- Pimm, S.L., et al., 2001. Can we defy Nature's end? *Science* 293, 2207-2208.
- Pope CA 3<sup>rd</sup>, Thun MJ, Namboodiri MM, Dockery DW, Evans JS, Speizer FE, Heath CW Jr., 1995. Particulate air pollution as a predictor of mortality in a prospective study of U.S. adults. *American Journal of Respir Crit Care Med.*, 151 (3 Pt 1):669-74.
- Pope, C.A., 3<sup>rd</sup>, R.T. Burnett, M.J. Thun, E.E. Calle, D. Krewski, K. Ito and G.D. Thurston. 2002. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. *Jama*. Vol. 287(9): 1132-41.
- Portney, PR, and J. Mullahy. 1990. Urban Air Quality and Chronic Respiratory Disease. *Regional Science and Urban Economics* 20:407-418.
- Rabl, A., 1999. Air Pollution and Buildings: An Estimation of Damage Costs in France, *Environmental Impact Assessment Review*, vol. 19 (4), pp. 361-385
- Ribaudo, M.O., 1989a. Water quality benefits from the conservation reserve program, agricultural economics report, Economic Research Service, Washington.
- Ribaudo, M.O., 1989b. Targeting the conservation reserve program to maximize water quality benefits. *Land Economics* 65 (4), 320-332.
- Richer, J., 1995. Willingness to pay for desert protection. *Contemporary Economic Policy* XIII, 93-104.
- Rowe, R.D. and L.G. Chestnut, 1986. Valuing Changes in Morbidity: WTP Versus COI Measures. Boulder, CO: Resources for the Future. Paper presented at the American Economic Association annual meeting, Dallas, Texas. Energy and Resource Consultants, Inc., Boulder, CO.
- Roughgarden, J., 1993. Production functions from ecological populations: a survey with emphasis on spatially explicit models. In: Tilman, D. and P. Kareiva, (eds.) *Spatial Ecology: The Role of Space in rough Population Dynamics and Interspecific Interactions*, Princeton University Press, pp. 296-317.
- Rowe, R. D. and Chestnut, L. G., 1985. Economic assessment of the effects of air pollution on agricultural crops in the San Joaquin Valley. *Journal of Air Pollution Control Association*, 35, 728-734.
- Rowe, R. D., d'Arge, R., and Brookshire, D., 1980. An experiment on the economic value of visibility, *Journal of Environmental Economics and Management*, Vol. 7, pp. 1-19
- Saldiva PHN, Dockery DW, Pope CA, et al., 1995. Air pollution and mortality in elderly people: a time-series study in Sao Paulo, Brazil. *Arch Environ Health*; 50:159-63.
- Samet, J.M., Zeger, S.L., Kelsall, J.E., Xu, J. and Kalkstein, L.S., 1997. Air pollution, weather and mortality in Philadelphia, 1973-1988. Particulate Air Pollution and Daily Mortality: Analyses of the Effects of Weather and Multiple Air Pollutants. The Phase IB Report of the Particle Epidemiology Evaluation Project. Health Effects Institute, Cambridge, MA, pp. 1-29.
- Samples, K., Hollyer, J., 1989. Contingent valuation of wildlife resources in the presence of substitutes and complements, In: Johnson, R., Johnson, G. (Eds.). *Economic Valuation of Natural Resources: Issues, Theory and Application*, Boulder.
- Samples, K., Hollyer, J., 1989. Contingent valuation of wildlife resources in the presence of substitutes and complements, In: Johnson, R., Johnson, G. (Eds.). *Economic Valuation of Natural Resources: Issues, Theory and Application*, Boulder.
- Schuhmann, Peter William; 1998. Deriving Species-Specific Benefits Measures for Expected Catch Improvements in a Random Utility Framework, *Marine Resource Economics*, Volume 13, No.1, pp. 1-21
- Schluter, D., Ricklefs, R.E., 1993. Species diversity: an introduction to the problem. In: Ricklefs, R.E., Schluter, D. (Eds.), *Species Diversity in Ecological Communities*. University of Chicago Press, Chicago, pp. 1-10.
- Schulze, W. D., Brookshire, D., Walther, E. and Kelly, K., 1983. The Benefits of Preserving Visibility in the National Parklands of the Southwest, VIII, draft report prepared for the U.S. Environmental Protection Agency, Washington, D.C.
- Schwartz J. Particulate air pollution and chronic respiratory

- disease. *Environ Res* 1993; 62:7-13.
- Segerson, K., 1987. Economic impacts of ozone and acid rain: discussion. *American Journal of Agricultural Economics*, December, Volume 69, Number 5, pp. 970-971.
- Segerson, K., 1991. Air pollution and agriculture: a review and evaluation of policy interactions. In R. E. Just and N. Bockstael (eds.), *Commodity and Resource Policies in Agricultural Systems*, Berlin: Springer-Verlag pp. 349-367, Chapter 18.
- Silberman, J., Gerlowski, D.A., Williams, N.A., 1992. Estimating existence value for users and nonusers of New Jersey beaches. *Land Economics* 68 (2), 225–236.
- Smith, R.S., 1974. The Feasibility of an 'Injury Tax' Approach to Occupational Safety, *Law and Contemporary Problems* 38(4), 730-744.
- Smith, R.S., 1976. *The Occupational Safety and Health Act: Its Goals and Its Achievements*. Washington, DC: American Enterprise Institute.
- Smith, V.K. and C.C.S. Gilbert, 1984. The Implicit Valuation of Risks to Life: A Comparative Analysis, *Economics Letters* 16, 393-399.
- Smith, V.K. and C.C.S. Gilbert, 1985. The Valuation of Environmental Risks Using Hedonic Wage Models. In M. David and T. Smeeding (eds.), *Horizontal Equity, Uncertainty, and Economic Well-Being*. Chicago: University of Chicago Press. pp. 359-385.
- Smith, V.K., Desvousges, W.H., 1986. *Measuring Water Quality Benefits*. Kluwer Nijhoff Publishing, Dordrecht.
- Snyder, Lori D., Stavins, Robert, N., Wagner, Alexander F., 2003. Private Options to Use Public Goods: Exploiting Revealed Preferences to Estimate Environmental Benefits, *Resource for the Future Discussion Paper* 03-49.
- Spash, C. L., 1997. Assessing the Economic Benefits to Agriculture from Air Pollution Control, *Journal of Economic Surveys*, vol. 11, issue 1, pages 47-70
- Stevens, T.H., DeCoteau, N.E., Willis, C.E., 1997. Sensitivity of contingent valuation to alternative payment schedules. *Land Economics* 73 (1), 140–148.
- Stieb, D.M., De Civita, P, Johnson, F.R., Manary M.P., Anis, A.H., Beveridge, R.C., Judek, S., 2002. Economic evaluation of the benefits of reducing acute cardiorespiratory morbidity associated with air pollution, *Environ Health.*, 1(1):7.
- Stieb DM, Beveridge RC, Brook JR, Smith-Doiron M, Burnett RT, Dales RE, Beaulieu S, Judek S, Mamedov A., 2000. Air pollution, aeroallergens and cardiorespiratory emergency department visits in Saint John, Canada. *J Expo Anal Environ Epidemiol.*;10(5):461-77.
- Stoddard, J.L. et al., 1999. Regional trends in aquatic recovery from acidification in North America and Europe. *Nature*, 401, 575-578.
- Tasdemiroglu, F., 1991. Costs of Material Damage Due to Air Pollution in the United States, *Renewable Energy*, 1, pp. 639-48
- Thaler, R. and S. Rosen, 1975. "The Value of Saving a Life: Evidence from the Labor Market." In N.E. Terleckyj (ed.), *Household Production and Consumption*. New York: Columbia University Press, pp. 265-300.
- Tietenberg, T. H., 1985. *Emission Trading: An Exercise in Reforming Pollution Policy*, Resources for the Future.
- Toulomi G, Samoli E, Katsoyanni K., 1996. Daily mortality and "winter type" air pollution in Athens, Greece – a time series analysis within the APHEA project. *J Epidemiol Comm Health*; 50 (Suppl 1):S47-S51.
- Torell, L.A., Libbin, J.D., Miller, M.D., 1990. The market value of water in the Ogalla Aquifer. *Land Economics* 66 (2), 163–175.
- Train, Kenneth E.; 1998. Recreation Demand Models With Taste Differences Over People. *Land Economics*. 74(2): 230-239.
- Turner R. K., Button, K., Nijkamp, P. (Editors), 1999. *Ecosystems and Nature: Economics, Science and Policy*, Edward Elgar Pub.
- USEPA, 1999. *The Benefits and Costs of the Clean Air Act 1990 to 2010*, EPA Report to Congress, EPA 410-R-99-001, November 1999
- USEPA, 1999. *The Benefits and Costs of the Clean Air Act: 1990 to 2010*. (EPA-410-R-99-001) Office of Policy and Office of Air and Radiation, Washington, DC.
- USEPA, 1997. Issue fact sheet on nutrients Report of Annual Meeting of National Estuary Program Directors, March 1997. National Estuary Program, Washington, D.C.
- van Kooten, G.C., 1993. Bioeconomic evaluation of government agricultural programs on wetland conservation. *Land Economics* 69 (1), 27–38.
- Vedal S., Brauer M., White R., Petkau J., 2002. Air Pollution and daily mortality in a city with low pollution concentrations, *Environmental Health Perspectives*; 111:45-51.
- Viscusi, W.K., 1978a. Labor Market Valuations of Life and Limb: Empirical Evidence and Policy Implications, *Public Policy* 26(3), 359-386.
- Viscusi, W.K., 1979. *Employment Hazards: An Investigation of Market Performance*. Cambridge, MA: Harvard University Press.

- Viscusi, W.K., 1981. Occupational Safety and Health Regulation: Its Impact and Policy Alternatives. In J.P. Creche (ed.), *Research in Public Policy Analysis and Management*. Greenwich, CT: JAI Press, vol. 2, 281-299.
- Viscusi W.K., Aldy J.E., 2003. The Value of a Statistical Life: A Critical Review of Market Estimates Throughout the World, NBER Working Paper #9487.
- Walker, D.J., Young, D.L., 1986. The effect of technical progress erosion damage and economic incentives for soil conservation. *Land Economics* 62 (1), 83-93.
- Walsh, Richard, Ray Ericson, Daniel Arosteguy, and Michael Hansen, 1980. An Empirical Application of a Model for Estimating the Recreation Value of Instream Flow. Colorado Water Resources Research Institute, Colorado State University.
- Walsh, R.O., Loomis, J.B., Gillman, R.A., 1984. Valuing option, existence, and bequest demands for wilderness. *Land Economics* 60, 14-29.
- Whitehead, J.C., 1993. Total economic values for coastal and marine wildlife: specification, validity and valuation issues. *Marine Resource Economics* 8, 119-132.
- Whittaker, R.H., 1972. Evolution and measurement of species diversity. *Taxon* 21, 213-251.
- Xu X, Wang L., 1993. Association of indoor and outdoor particulate level with chronic respiratory illness. *Am Rev Respir Dis*; 148:1516-22.
- Zanobetti A, Schwartz J, Gold D., 2000. Are there sensitive subgroups for the effects of airborne particles? *Environ Health Perspect.*; 108(9):841-5.
- Zemp E, Elsasser S, Schindler C, et al., 1999. Long-term ambient air pollution and respiratory symptoms in adults (SAPALDIA study). The SAPALDIA Team. *Am J Respir Crit Care Med*; 159:1257-66.
- Ziemer, Rod, Wesley Musser, and Carter Hill, 1980. Recreation Demand Equations: Functional Form and Consumer Surplus. *American Journal of Agricultural Economics* 62, pp.136-141.

