CENTER FOR ENERGY,
ECONOMIC & ENVIRONMENTAL POLICY

Discussion Paper

Prepared For The New Jersey Clean Energy Council

Impacts of Environmental Externalities Upon Relative Costs of Renewable Technology

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Impact of The Deployment of Renewable Generation On The Market Price of Electricity

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Introduction

As the Clean Energy Council knows, a complete comparison of costs among different generation and conservation technologies requires incorporating all of the social costs associated with each technology. Monetizing externalities, however, is challenging, especially environmental ones. There are many methodologies that researchers use, which lead to different results. Moreover, studies regarding the costs of various environmental externalities depend heavily on layers of assumptions, each of which can dramatically influence the results. Also, many assumptions are context specific and therefore environmental externalities results may not be transferable from one situation to another. In addition to environmental externalities, there may be others, such as reliability, avoided transmission and distribution costs, and improved market efficiencies.

This memorandum attempts to accomplish several goals. First, it discusses some of the important issues that the CEC is confronting in monetizing externalities that are relevant to its decision-making. Second, it employs a simple approach under different environmental externality assumptions to illustrate the comparison of the social costs of renewable technologies. The purpose here is to illustrate these points not to provide New Jersey specific externality adders that should be used in policymaking. Third, it discusses the issue of lower electricity prices due to policies that spur investment in renewables. Again, the point is to inform the discussion as opposed to providing precise values.

Issues in Monetizing Externalities Relevant to New Jersey

Externalities are those benefits or costs that are not internalized in the market. The classic example is air emissions. Generators of electricity, assuming no environmental regulatory policy, do not include in their cost structure the social costs due to their emissions. Environmental externality adders are a means to estimate the additional social cost of additional emissions. In the case of electricity, the sum of all of these costs are estimated either on a dollar per MWh (equivalently cents/kWh) or on a dollar per pound of emission. These estimates vary by technology: the externality adder for coal is different from the natural gas or solar adder.

The top portion of table 1 reports a wide range of externality adders based on a recent review of externality studies conducted over the past thirty years. This social cost can consist of many types of damages, such as increased mortality, morbidity, property damage, environmental harm, among others. The damage is caused by the concentration of the emission in the atmosphere, not the emission itself. Emission concentrations vary by weather conditions, location specific condition, time of year, and non-electric generation sources. These are just some of the factors that result in the wide range of externality adders. The table reports the minimum, the mean, the median, and the maximum externality costs based on its review of the literature.

Table 1: Summary of Environmental Externality Studies for Different Electric Generation Technologies[1]

(Cents/kWh, 2004 $)

Technology	**Minimum**	**Mean**	**Median**	**Maximum**
Coal	0.00	16.25	7.40	78.53
Oil	0.03	14.29	10.56	46.31
Nat. Gas	0.00	5.35	3.04	15.33
Nuclear	0.00	8.26	0.94	74.74
Hydro	0.00	3.90	0.37	30.45
Wind	0.00	0.36	0.37	1.02
Solar	0.00	0.97	0.88	2.55
Biomass	0.00	5.74	6.46	25.62

Another important issue is comparing renewable technologies to the technology that the renewables would replace and not to the existing fuel mix. The comparison must be made with the marginal technology not with the average of existing technologies. Although PJM has a lot of coal and nuclear, the marginal technology, particularly in future years, is dominated by natural gas combined cycle and gas turbines. Table 2, using the values in Table 1, compares natural gas and coal to solar to highlight the importance of the marginal fuel issue.

Table 2: Net Environmental Externality Costs of Natural Gas vs. Solar and Coal vs. Solar

(Cents/kWh, 2004 $)

	Minimum	**Mean**	**Median**	**Maximum**
Natural Gas	0.00	5.35	3.04	15.33
Solar	0.00	0.97	0.88	2.55
Difference	0.00	4.37	2.16	12.78
Coal	0.00	16.25	7.40	78.53
Solar	0.00	0.97	0.88	2.55
Difference	0.00	15.27	6.52	75.98

The CEC may also want to consider the point that just because emissions occur, it does not necessarily mean that an externality adder should be applied. For instance, the emissions of NO_x and SO_x are capped as part of the emission allowance regulatory policy. Decreases in these emissions will not result in fewer total emissions (unless the cap is subsequently lowered or the incremental allowances are retired) but only in a reduction in the price of the associated allowances.[2] Therefore, under a cap-and-trade program, the externality adders for these emissions may have already been internalized and therefore are zero. How to capture these values is an important policy discussion.

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[1] Thomas Sundqvist, *Power Generation Choice in the Presence of Environmental Externalities*, Doctoral Thesis, Lulea University of Technology, 2002, p. 17. (Adjusted to 2004 $.)

[2] The emission allowance rules are complex and the net impact on the total amount of emissions depends on the incentives of these rules.

Table 3, using information primarily from the Navigant Renewable Market Assessment[3], presents the levelized cost of electricity (in constant 2004 $'s) of a variety of renewable technologies along with natural gas for four specific years, 2005, 2008, 2015, and 2020. It contains three sub-tables. Using Table 1's values, the first sub-table has no externality adder to each technology, the second adds the mean externality adder, and the third adds the maximum. Within each sub-table, the technologies are ordered from lowest cost (including the externality adder, if applicable) to highest cost based on year 2005.[4]

Table 3: Cost of Various Electric Generation Technologies With and Without Environmental Externalities

Table 3-1

Levelized Cost, Cents/kWh (2004 $)

Ranked in Ascending 2005 Costs

	No Externality Adder			
Generation Technology	**2005**	**2008**	**2015**	**2020**
Biogas from Wastewater Treatment Municipal Financing	**2.8**	2.7	2.6	2.5
On-shore Class 4 Wind with Municipal Financing 5 MW Size	**3.8**	3.3	2.7	2.2
Landfill Gas IC Engine, Developer Financing, With Gas Collection System	**4.1**	3.9	3.7	3.5
On-shore Class 3 Wind with Municipal Financing 20 MW Size	**4.2**	3.9	3.0	2.5
On-shore Class 3 Wind with Municipal Financing 5 MW Size	**4.5**	4.1	3.1	2.9
Landfill Gas IC Engine, Developer Financing, No Gas Collection System	**5.0**	4.9	4.5	4.3
Combined Cycle	**5.3**	5.3	5.3	5.3
On-shore Class 4 Wind with Developer Financing 5 MW Size	**6.1**	5.5	4.3	3.9
On-shore Class 3 Wind with Developer Financing 20 MW Size	**7.0**	6.1	5.0	4.2
On-shore Class 3 Wind with Developer Financing 5 MW Size	**7.2**	6.5	5.1	4.5
Solid Biomass Direct Combustion ($3.00/MMBtu)	**10.0**	9.7	9.0	8.9
Gas Turbine	**12.1**	12.1	12.1	12.1
Residential PV	**48.0**	40.0	29.0	21.0
Commerical PV	**65.0**	55.0	39.0	30.0
Solid Biomass Gasification Integration Combined Cycle ($3.00/MMBtu)	**n.a.**	8.7	7.6	6.9
Off-shore Class 6 Wind with Developer Financing 20 MW Size	**n.a.**	9.0	7.5	7.0

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[3] Navigant Consulting, *New Jersey Renewable Energy Market Assessment,* August 2, 2004. Levelized cost of electricity values for gas turbines and combined cycle, however, are imputed from the Balck & Veatch Report, *Economic Impact of Renewable Energy in Pennsylvania*, March 2004.

[4] Another approach to calculating the costs of environmental externality is use emission specific adders, such as $100 per ton of carbon dioxide, calculate the amount of avoided emissions for all emissions, and sum the product of the avoided emissions by type with the associated externality adder. This approach requires a lot more assumptions and analysis than just using a technology-wide adder as in Table 1 but can account for specific emission rates within a fuel type or for location specific externality adders. This more detailed approach is not used in this memo only because of space and time limitations.

	Levelized Cost, Cents/kWh (2004 $)			
Table3-2	**Mean Externality Adder**			
On-shore Class 4 Wind with Municipal Financing 5 MW Size	**4.8**	4.2	5.3	2.2
On-shore Class 3 Wind with Municipal Financing 5 MW Size	**4.9**	4.5	4.1	2.9
On-shore Class 4 Wind with Developer Financing 5 MW Size	**6.1**	5.5	4.3	3.9
On-shore Class 3 Wind with Developer Financing 20 MW Size	**7.0**	6.1	5.0	4.2
On-shore Class 3 Wind with Developer Financing 5 MW Size	**7.2**	6.5	5.1	4.5
Biogas from Wastewater Treatment Municipal Financing	**8.5**	8.4	8.3	8.2
Landfill Gas IC Engine, Developer Financing, With Gas Collection System	**9.4**	9.2	9.0	8.8
On-shore Class 3 Wind with Municipal Financing 20 MW Size	**9.9**	10.4	28.6	2.5
Landfill Gas IC Engine, Developer Financing, No Gas Collection System	**10.3**	10.2	9.8	9.6
Combined Cycle	**10.6**	10.6	10.6	10.6
Solid Biomass Direct Combustion ($3.00/MMBtu)	**15.7**	9.7	9.0	8.9
Gas Turbine	**17.4**	17.4	17.4	17.4
Residential PV	**49.0**	41.0	30.0	22.0
Commerical PV	**66.0**	56.0	40.0	31.0
Solid Biomass Gasification Integration Combined Cycle ($3.00/MMBtu)	**n.a.**	8.7	7.6	6.9
Off-shore Class 6 Wind with Developer Financing 20 MW Size	**n.a.**	9.4	7.9	8.0

Table 3-3	**Max. Externality Adder**			
On-shore Class 3 Wind with Municipal Financing 5 MW Size	**5.5**	4.1	3.1	2.9
On-shore Class 4 Wind with Developer Financing 5 MW Size	**6.1**	5.5	4.3	3.9
On-shore Class 4 Wind with Municipal Financing 5 MW Size	**6.4**	3.3	2.7	2.2
On-shore Class 3 Wind with Developer Financing 20 MW Size	**7.0**	6.1	5.0	4.2
On-shore Class 3 Wind with Developer Financing 5 MW Size	**7.2**	6.5	5.1	4.5
Landfill Gas IC Engine, Developer Financing, With Gas Collection System	**19.4**	19.2	19.0	18.8
Landfill Gas IC Engine, Developer Financing, No Gas Collection System	**20.3**	20.2	19.8	19.6
Combined Cycle	**20.6**	20.6	20.6	20.6
Gas Turbine	**27.4**	27.4	27.4	27.4
Biogas from Wastewater Treatment Municipal Financing	**28.4**	28.3	28.2	28.1
On-shore Class 3 Wind with Municipal Financing 20 MW Size	**29.8**	3.9	3.0	2.5
Solid Biomass Direct Combustion ($3.00/MMBtu)	**35.6**	35.3	34.6	34.5
Residential PV	**50.6**	42.6	31.6	23.6
Commerical PV	**67.6**	57.6	41.6	32.6
Off-shore Class 6 Wind with Developer Financing 20 MW Size	**n.a.**	10.0	7.5	7.0
Solid Biomass Gasification Integration Combined Cycle ($3.00/MMBtu)	**n.a.**	34.3	33.2	32.5

Finally, Table 4 compares residential PV to PJM's avoided costs, accounting for the minimum, mean, and maximum environmental externality adders. For instance, to arrive at the 29.9 cents/kWh number (denoted in bold in Table 4), the following equation is used:

Residential PV Cost – PJM Avoided Cost – Max. Environmental Externalty = Net Cost of Residential PV. So, for 2005 the Net Cost of Residential PV = 48.0 – 5.3 – 12.8 = 29.9 cents/kWh

Table 4: Comparison of PV Costs with Externality Adders to PJM Avoided Costs (2004 $)[5]

			Environmental Externality Adder			Net Cost of Residential PV		
Year	**Residential PV Costs (cents/kWh)**	**PJM Avoided Cost**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Min**
2005	48.0	5.3	12.8	4.4	0.0	**29.9**	38.3	42.7
2008	40.0	4.8	12.8	4.4	0.0	22.4	30.8	35.2
2015	29.0	5.3	12.8	4.4	0.0	10.9	19.3	23.7
2020	21.0	5.7	12.8	4.4	0.0	2.5	10.9	15.3

Up until now, all of the analysis has been on a cents/kWh basis. This last part translates the above results to annual dollar values. Table 5 calculates the PJM avoided costs (energy and capacity) plus net environmental benefits compared to natural gas of a 90 MW PV program starting in 2005 through 2008 with 22.5 MW being added each year. At a 9% real discount rate, the present value of these benefits from 2005 through 2020 is $95 million.[6]

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[5] PJM avoided costs from Navigant's Report, cited above.

[6] PJM avoided costs based on Navigant's Report, pp. 95 & 97 and accounts for the fact that PV's earn energy revenues that are on average higher than average annual energy prices. The 9% real discount rate is based on 12% nominal discount rate for PV's (p. 210). T&D losses are assumed to be 7%.

Table 5: Avoided PJM Costs Plus Net Mean Externality Benefits of a 90 MW PV Program Implemented 2005 through 2008

Year	**PV (MW)**	**MWh**	**PJM Avoided Energy (2004 $/MWh)**	**PJM Avoided Capacity (2004 $/kW-Yr)**	**PJM Avoided Energy and Capacity (2004 $)**	**Net Mean Environ. Extern. Benefit (2004 $)**	**TOTAL**
2005	23	27,594	51	8	$1,689,805	$1,290,268	$2,980,072
2006	45	55,188	51	8	$3,371,609	$2,580,536	$5,952,145
2007	68	82,782	52	9	$5,217,990	$3,870,804	$9,088,794
2008	90	110,376	48	9	$6,478,911	$5,161,071	$11,639,983
2009	90	110,376	48	9	$6,478,911	$5,161,071	$11,639,983
2010	90	110,376	48	9	$6,478,911	$5,161,071	$11,639,983
2011	90	110,376	48	9	$6,478,911	$5,161,071	$11,639,983
2012	90	110,376	48	10	$6,568,911	$5,161,071	$11,729,983
2013	90	110,376	49	21	$7,677,014	$5,161,071	$12,838,085
2014	90	110,376	51	41	$9,713,218	$5,161,071	$14,874,290
2015	90	110,376	52	68	$12,261,321	$5,161,071	$17,422,392
2016	90	110,376	53	68	$12,379,423	$5,161,071	$17,540,494
2017	90	110,376	54	68	$12,497,525	$5,161,071	$17,658,597
2018	90	110,376	54	68	$12,497,525	$5,161,071	$17,658,597
2019	90	110,376	55	68	$12,615,628	$5,161,071	$17,776,699
2020	90	110,376	56	68	$12,733,730	$5,161,071	$17,894,801

Improving Market Efficiency

The investment in renewables, or for that matter any generation technology, will reduce the market price for electricity by the increase of supply. Similarly, a decrease in demand will affect the supply/demand relationship to cause a reduction in price.

Figure 1 illustrates a demand side investment, which shifts the original demand curve, D_0, to the left to D_1 and lowers the wholesale price.[7]

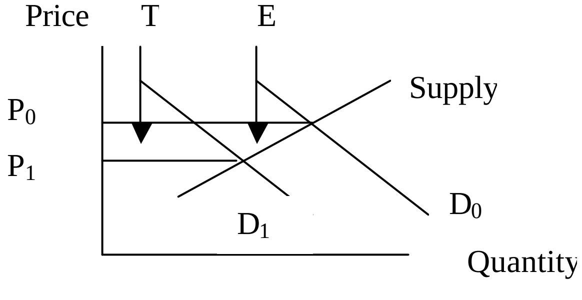

Figure1: Transfer vs. Efficiency

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[7] The JBS Energy Report, *Mid-Atlantic States Cost Curve Analysis*, December 5, 2000, p. 4 has a similar figure.

Economists distinguish between two parts associated with the reduction of price and increase in demand. First, there is an efficiency benefit E, whose area reflects the amount that society (consumers and producers) are collectively better off due to shifting the demand curve.[8] The area T reflects a transfer of resources from producers to consumers and is not an efficiency benefit. It is called a transfer because the amount that society is better off has not increased by T, but only who receives these resources has changed.

Regardless of whether or how T should factor into a policymaker's decision, the comparison is not between shifting the demand curve by investing in PVs or not shifting the demand curve, but between shifting the demand curve by investing in renewables and any shifts in the supply curve to the right that the market would undertake without the investment in PVs. Stated in more practical terms, investment in PVs will accelerate the retirement of existing assets or forgo the investment in new ones. Moreover, this decrease in investment that would have occurred but for the renewable investment and its associated market impact must be reflected in a calculation of value.

Thus, the net transfer and efficiency benefit (or loss) by investing in renewables from shifting the demand curve is not T_R+E_R but $T_R + E_R – (T_M +E_M)$, where the subscript R refers to renewable PVs and the subscript M refers to what the market would do if the renewable investment is not undertaken. This "but-for effect" must be accounted for in any analysis, and the net effect is likely to be small and as likely to be positive as negative. Analyses that state electricity prices will decrease by a certain amount due to renewable policies that do not account for reduction in investment by the market in response to these policies are not likely to see those reductions materialize.

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[8] Of course, producers are worse off with the demand decrease than without it. In addition, the cost of shifting the demand curve would be subtracted from E, to provide a net benefit.