RICE NESHAP Emission Controls Analysis

This analysis first evaluated the capital costs of installing emission controls - diesel oxidation catalyst (DOC) and open crankcase ventilation (OCV) for a range of engine sizes (100-1,500 hp). Next, it evaluated the dispatch costs for the engines including the diesel fuel costs, engine maintenance costs and emission control maintenance costs. Then it evaluated a reasonable range for the capacity revenues that could be earned by these engines based on market data. The analysis is based on two examples of capacity market prices in NYISO and PJM. Lastly it estimated the avoided energy costs and range of energy revenues that could accrue to an engine when dispatched by a particular ISO for 15 and 100 hours per year.

Key Takeaways

- The capital cost for diesel oxidation catalyst (DOC) and open crankcase ventilation (OCV) for a 500 hp engine is approximately $14,000. This includes the costs of equipment and installation.
- In the PJM RTO, annual capacity market revenue available for a 500 hp engine from 2013-2015 would likely total over $60,000 in the PJM MAAC region and $30,000 in lower priced areas of the PJM RTO.
- In NYISO, the capacity revenue available for a 500 hp engine would be in the range of $20,000 per year in the New York City area.
- We estimate that the all-in dispatch cost for a 500 hp engine is $0.28/kWh ($280/MWh).
- In PJM, emergency energy prices paid to emergency DR resources have historically been in the $1,000/MWh range. Using this assumption, a 500 hp engine operating for 15 hours annually would earn approximately $3,600 in net energy revenue and an engine dispatched for the proposed 100 hour maximum would earn more than $24,000 in net energy revenue.
- In NYISO, energy prices paid to emergency DR resources typically average $500/MWh. A 500 hp engine dispatched for 15 hours per year would earn approximately $1,100 in net energy revenue and an engine dispatched for the full 100 hours annually would earn more than $7,000 in net energy revenue.
- In both ISOs, the capacity and energy revenues would pay for the costs of emission controls in approximately one year, even if the engines were dispatched for only 15 hours.
- However, this analysis assumes that all of the capacity and energy revenue would accrue to the owner of the engine enrolled in the demand response program. This may not necessarily be the case as curtailment service providers that aggregate these engines may receive a significant portion of these revenues which would prolong the return on investment for the installation of emissions controls.

Emission Control Cost

The emission control costs for RICE engines include 1) the capital and installation costs of the emission controls, and 2) the annual maintenance costs of the emission controls. The capital costs of the emission controls are a one-time expense while the maintenance costs are a reoccurring cost based on operating hours.

Capital and Annual Costs

To determine the capital costs of the emission controls, the analysis utilized EPA's capital cost numbers outlined in the RIA, as depicted in Table 1 below.[1] As noted in the RIA, EPA developed linear regression equations for capital and annual costs using CARB capital cost data and engine size in hp. The formulas in the table reflect the regression results, with cost as a function of engine size (horsepower) and a constant term. EPA's capital cost numbers as conservative; others estimate the cost of DOC+OCV could be as low as $15/hp.

Table 1: CI RICE Control Technologies and Costs

Technology	Capital Cost ($2008)	Annual Cost ($2008)
Diesel Oxidation Catalyst (DOC)	$27.4 x hp -$939	$4.99 x hp + $480
Open Crankcase Ventilation (OCV)	$0.26 x hp +997	$0.065 x hp + $254

Based on the EPA RIA control cost assumptions, this analysis calculated the capital costs for DOC and OCV on engines ranging from 100 to 1,500 hp as summarized in Table 2 below. For a 500 hp engine we estimate that the capital costs of emission controls are approximately $14,000.

Table 2: Control Technology Cost Estimates by Engine Size

Engine Size (hp)	Capital Cost of Emission Controls ($/engine)
100	$2,824
200	$5,590
300	$8,356
400	$11,122
500	$13,888
1,000	$27,718
1,500	$41,548

Emission Control Maintenance Costs

The analysis developed emission control maintenance cost assumptions based on market experience, estimating that periodic cleaning of the DOC substrate costs $3/hp and is performed every 500 hours of operation. Further, we estimate that the replacement of the oil filter in the OCV costs $100 and is changed every 250 hours of operation.

Dispatch Costs

The emission control maintenance costs are included in the engine dispatch cost estimates along with diesel fuel costs and engine maintenance costs. We use a fuel cost of $3.234 per gallon of

[1] U.S. EPA, *Regulatory Impact Analysis (RIA) for Proposed Reconsideration of Existing Stationary Compression Ignition (CI) Engines NESHAP, Final Report*, May 2012, Table 4-1. Available at http://www.epa.gov/ttnecas1/regdata/RIAs/RIC_Compression_Ignition_Engines_5-22-12.pdf

diesel fuel.[2] Engine maintenance costs include scheduled maintenance and periodic overhaul costs. Based on these assumptions, the dispatch costs for a range of engine sizes are provided below. The fuel cost is the dominant cost that drives the dispatch price for diesel engines. The engine dispatch cost for a 500 hp engine is approximately $0.28/kWh ($280/MWh). Table 3 provides the dispatch costs for the range of engine sizes.

Table 3: Dispatch Costs by Engine Size

Engine Size (hp)	Fuel Cost ($/hr)	Engine Maintenance ($/hr)	Controls Maintenance ($/hr)	Total Dispatch Cost	
				[$/hr]	[$/kWh]
100	$26.20	$0.67	$1.00	$19.14	$0.285
200	$34.94	$1.33	$1.59	$37.86	$0.282
300	$52.41	$2.00	$2.18	$56.58	$0.281
400	$69.87	$2.67	$2.76	$75.30	$0.281
500	$87.34	$3.33	$3.35	$94.03	$0.280
1,000	$174.68	$6.67	$6.29	$187.64	$0.280
1,500	$262.03	$10.00	$9.23	$281.25	$0.279

Capacity and Energy Revenue Analysis

In this section we provide an analysis of the estimated annual capacity revenues and energy revenues for events and tests that an engine could earn in PJM and NYISO.

Capacity revenue comes in the form of a fixed payment for each unit of capacity on a monthly basis. Capacity revenues are paid to committed resources whether or not energy is produced by that resource. The capacity prices are also location specific and program specific. Energy revenues are paid to resources during emergency events and testing.

PJM Capacity Revenue

In PJM, capacity prices are set by auction for a period three years into the future. Therefore, engine owners know the capacity prices through mid-2016. Capacity prices in PJM differ depending upon the location of the unit and demand response product type, with capacity prices in the congested Mid-Atlantic region (MAAC) often much higher than less congested areas of western PJM or the RTO clearing price on a whole as illustrated in Table 4.

Table 4: PJM Capacity Prices for the Whole RTO and MAAC Area ($/MW-day)

PJM Area	2011/2012	2012/2013	2013/2014	2014/2015	2015/2016
RTO	$110.00	$16.46	$27.73	$125.99	$136.00
MAAC	$110.00	$133.37	$226.15	$136.50	$167.46

For this analysis, we assume that the engines participate in the full emergency option, and are therefore eligible to receive capacity and emergency energy payments when dispatched by the ISO.

Using the MAAC capacity prices, we estimate that a 500 hp engine enrolled in DR programs would earn over $60,000 from 2013-2015. Table 5 provides the estimated capacity revenue for a range of engine sizes.

[2] Energy Information Administration, Weekly Retail Gasoline and Diesel Prices, U.S. Average, Onroad Ultra-Low Sulfur Diesel, 7/23/12 less $0.546 per gallon, average federal and state road taxes.

Table 5: Estimated Capacity Revenue for a Range of Engine Sizes (PJM - MAAC)

Engine Size (hp)	2013 Revenue	2014 Revenue	2015 Revenue
100	$4,592	$4,245	$3,782
200	$9,199	$8,505	$7,577
300	$13,799	$12,757	$11,365
400	$18,398	$17,009	$15,154
500	$22,998	$21,261	$18,942
1,000	$45,996	$42,523	$37,884
1,500	$68,994	$63,784	$56,826

Using the RTO capacity prices, we estimate that a 500 hp engine enrolled in DR programs would earn approximately $30,000 from 2013-2015. Table 6 provides the estimated capacity revenue for a range of engine sizes.

Table 6: Estimated Capacity Revenue for a Range of Engine Sizes (PJM - RTO)

Engine Size (hp)	2013 Revenue	2014 Revenue	2015 Revenue
100	$564	$2,087	$3,225
200	$1,130	$4,181	$6,460
300	$1,695	$6,271	$9,690
400	$2,260	$8,362	$12,920
500	$2,825	$10,452	$16,150
1,000	$5,651	$20,905	$32,300
1,500	$8,476	$31,358	$48,450

PJM Energy Revenue

During an emergency event, participants registered in PJM's Full Emergency option are paid the higher of the submitted minimum strike price or the zonal real-time locational marginal price (LMP) for emergency reductions. Given the current program rules, market participants have an incentive to submit a minimum dispatch price at the maximum threshold for energy bids of $1,000/ MWh. For the 2011/2012 delivery year, approximately 73 percent of registered sites representing 64 percent of registered MW in the Emergency Full Capacity option submitted a minimum dispatch price of either $999 or $1,000 per MWh.[3]

Using $1,000/MWh ($1.00/kWh), we estimate that a 500 hp engine dispatched by PJM for 15 hours annually would earn over $3,600 in net energy revenues and an engine dispatched for 100 hours would earn over $24,000. Table 7 provides the estimated net energy revenues for a 500 hp engine.

Table 7: Estimated Net Energy Revenue for a 500 hp Engine (PJM)

Annual Operation (hours)	Generation (kWh)	Engine Dispatch Cost ($)	PJM Energy Cost	Net Energy Revenue ($)

[3] Monitoring Analytics, LLC, *2011 State of the Market Report for PJM*, 2012.

15	5,033	$1,410	$5,033	$3,623
100	33,557	$9,403	$33,557	$24,154

NYISO Capacity Revenue

In NYISO, Special Case Resources (SCR) receive capacity payments, typically on a monthly basis, to ensure availability to curtail power usage upon request by NYISO. In addition, SCR resources receive energy payments when called for events and tests.[4]

The NYISO capacity auctions determine clearing prices for three distinct locations: New York City, Long Island, and New York Control Area (NYCA). In New York City, the spot price averaged $8.36/kW-month in the summer 2011. In NYCA, the spot price averaged $0.29/kW-month in the same time period.[5] The Long Island price was set by the NYCA price for all months except for September.[6,7] This analysis used 2011 historic capacity prices as follows: $8.36/kW-month (January-April), $4.50/kW-month (May-October), and $2.50/kW-month (November-December).

We estimate that a 500 hp engine enrolled in DR programs would earn approximately $22,000 annually. Table 8 provides the estimated capacity revenues for a range of engine sizes.

[4] *NYISO, Annual Report to the Federal Energy Regulatory Commission on the NYISO's Demand Side Management Programs, January 17, 2012.*

[5] Potomac Economics. *2011 State of the Market Report for the New York ISO Markets.* April 2012.

[6] NYISO. *Annual Report to the Federal Energy Regulatory Commission on the NYISO's Installed Capacity ("ICAP") Demand Curves and New Generation Projects in the New York Control Area*, December 20, 2011.

[7] ICAP prices for Summer 2012 are based on a new demand curve. Data for 2012 will be available on the NYISO website at http://www.nyiso.com/public/markets_operations/market_data/icap/index.jsp.

Table 8: Estimated Capacity Revenue for a Range of Engine Sizes (NYISO)

Engine Size (hp)	January-April	May-October	November-December	Total
100	$ 2,240	$1,809	$335	$4,384
200	$4,489	$3,624	$671	$8,784
300	$6,733	$5,436	$1,007	$13,176
400	$8,977	$7,248	$1,342	$17,567
500	$11,221	$9,060	$1,678	$21,959
1,000	$22,443	$18,121	$3,356	$43,919
1,500	$33,664	$27,181	$5,033	$65,878

NYISO Energy Revenue

According to NYISO, the average energy payment during DR events in 2011 was $500/MWh ($0.50/kWh). Using this price level, we estimate that a 500 hp engine dispatched by NYISO for 15 hours annually would earn over $1,100 in net energy revenues and an engine dispatched for 100 hours would earn over $7,000. Table 9 provides the estimated net energy revenues for a 500 hp engine.

Table 9: Estimated Net Energy Revenue for a 500 hp Engine (NYISO)

Annual Operation (hours)	Generation (kWh)	Engine Dispatch Cost ($)	NYISO Energy Cost	Net Energy Revenue ($)
15	5,033	$1,410	$2,517	$1,106
100	33,557	$9,403	$16,778	$7,376

Conclusion

In both PJM and NYISO, the capacity and energy revenues would pay for the costs of emission controls in approximately one year for an engine dispatched for only 15 hours. Table 10 summarizes the annual capacity revenue, energy revenue and payback period for a range of engine sizes. However, this analysis assumes that all of the capacity and energy revenue would accrue to the owner of the engine enrolled in the demand response program. This may not necessarily be the case as curtailment service providers that aggregate these engines may receive a significant portion of these revenues which would prolong the return on investment for the installation of emissions controls.

Table 10: Summary of Emission Control Costs and Annual Engine Revenues

Engine Size (hp)	Emission Controls Capital Cost	Annual Capacity Revenue		Annual Energy Revenue (15 hours)		Annual Revenue		Payback Period (years)	
		NYISO	PJM[1]	NYISO[2]	PJM[3]	NYISO	PJM	NYISO	PJM
100	$2,824	$4,384	$2,087	$216	$718	$4,600	$2,805	0.61	1.01
200	$5,590	$8,784	$4,181	$439	$1,446	$9,223	$5,627	0.61	0.99
300	$8,356	$13,176	$6,272	$661	$2,171	$13,837	$8,443	0.60	0.99
400	$11,122	$17,567	$8,362	$884	$2,897	$18,451	$11,259	0.60	0.99
500	$13,888	$21,959	$10,453	$1,106	$3,623	$23,066	$14,076	0.60	0.99
1,000	$27,718	$43,919	$20,905	$2,219	$7,252	$46,138	$28,157	0.60	0.98
1,500	$41,548	$65,878	$31,358	$3,331	$10,882	$69,210	$42,239	0.60	0.98

1. PJM-RTO capacity values used to estimate 2014 capacity revenue.
2. $500/MWh and 15 hours of operation annually.
3. $1,000/MWh and 15 hours of operation annually.