MEMORANDUM

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TO: Paul Shriner and Jan Matuszko, EPA
FROM: John Sunda (SAIC) and Kelly Meadows
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SUBJECT: Preliminary Estimate of Costs for Combustion Turbines Installed at Power Plants to Generate Electricity to Replace Closed Cycle Cooling Energy Penalty

This memo presents preliminary cost estimates for combustion turbines installed at power plants. The turbines used in the analysis are sized to replace the power plant energy penalty associated with converting a once-through cooling system to a closed-cycle one.

Table 1 below presents the estimated total energy penalty for different types of power plants. The parasitic energy penalty is based on a condenser ΔT of 15 ^{o}F and uses the parasitic energy factor of 0.0000237 MW/gpm used in EPA cost estimates.

Table 1. Energy Penalty Estimates

Plant Type	Assumed Plant Efficiency	Turbine Efficiency Penalty	gpm/MW at Delta 15	Parasitic Penalty	Total Penalty
Nuclear	33%	2.5%	910	2.2%	4.7%
Non-nuclear (Old & New)	34%	1.5%	680	1.6%	3.1%
Non-Nuclear 39%	39%	1.0%	590	1.4%	2.4%
Non-Nuclear 45%	45%	0.80%	430	1.0%	1.8%
Combined Cycle	57%	0.67%	270	0.6%	1.3%

Table 2 presents performance and costs assumptions for a 160 MW conventional combustion turbine that are used by EIA in their modeling for the 2009 Annual Energy Outlook.

Table 2. EIA Model Technology Performance and Cost Assumptions for Conventional Combustion Turbines

Data Item	Units	Value
Size	MW	160
Total Overnight Cost in 2008	2007 $/Kw	$670
Variable O&M	Million $/Kwh	$3.57
Fixed O&M	$	$12.11
Heat Rate	BTU/Kwh	10,810

Source: EIA 2009

Two other sources cited capital cost values as high as roughly $1,000/Kw for smaller combustion turbines in the 15 to 40 MW range. Dollar per Kw costs decrease with increasing generating unit size and since the units for this analysis will not be as large as the one cited in Table 2, a midpoint value between $670 and $1,000/Kw of $850/Kw was selected for the combustion turbine capital cost estimate.

Capital Costs

Table 3 provides combustion turbine generating capacity and capital costs for an example 1,000 MW plant for each plant type. The capital costs for an "average" difficulty closed cycle cooling retrofit are also shown for comparison.

Table 3. Capital Costs for Energy Penalty Combustion Turbines and Closed Cycle Cooling

Plant Type	Total Penalty	Total Initial Plant Generation (MW)	Combustion Turbine Size (MW)	Combustion Turbine Capital Cost	Circulating Flow (gpm)	"Average" Cooling Tower Retrofit Capital Costs
Nuclear	4.7%	1,000	47	$39,581,950	910,000	$226,590,000
Non-nuclear (Old & New)	3.1%	1,000	31	$26,448,600	680,000	$169,320,000
Non-Nuclear 39%	2.4%	1,000	24	$20,385,550	590,000	$146,910,000
Non-Nuclear 45%	1.8%	1,000	18	$15,462,350	430,000	$107,070,000
Combined Cycle	1.3%	1,000	13	$11,105,817	270,000	$67,230,000
Combustion Turbine Costs:	$850	$$/KW				
Cooling Tower Retrofit Cost:	$249.00	$$/gpm				

O&M Costs and Revenue

O&M costs and revenue of the combustion turbine turbines are provided as a rough measure of the economic viability of this as an option to offset the energy penalty. These costs will be highly dependent on the capacity utilization rate (CUR), the fuel costs, and the wholesale price of electricity sold which are difficult to predict. The costs presented in Table 4 are rough estimates that are based on data shown in Table 2 and the following assumptions:

- CUR is 15%;
- Fuel cost of natural gas is $5.00/1,000 cf based on November 2009 EIA Electric Power Price;

- Heat content of Natural gas is 1,028,000 BTU/cf
- Average peak wholesale power price of $81/MWh

Of particular importance to these costs are the costs of fuel and the wholesale cost of electricity during peak periods. The fuel cost is calculated to be $55.56 /MWh based on the above assumptions. The assumed average peak wholesale price of $81 is a BPJ value based on the 95th percentile value from a table of the EIA 2009 daily "Peak Wholesale Day Ahead Prices for the NEPOOL (New England) Hub. It is not clear how accurate this peaking power price is, so this value may require adjustment to get a more accurate measure. The revenue shown is simply the sales minus the fuel and O&M costs. The relatively high fuel cost is the reason combustion turbines are generally reserved for peak power demand when the wholesale cost of power rises well above the combined fuel and variable O&M cost. In each of these example calculations the combustion turbine capital cost is 51 times as large as estimated annual revenue.

Table 4. O&M and Revenue Estimates for Natural Gas Combustion Turbines

Plant Type	CUR	Annual Power (MWh)	Fuel Cost	Variable O&M	Fixed O&M	Sales	Revenue
Nuclear	15%	61,189	$3,399,871	$218,445	$563,926	$4,956,312	$774,070
Non-nuclear (Old & New)	15%	40,886	$2,271,789	$145,965	$376,815	$3,311,800	$517,232
Non-Nuclear 39%	15%	31,514	$1,751,006	$112,504	$290,434	$2,552,607	$398,663
Non-Nuclear 45%	15%	23,903	$1,328,131	$85,334	$220,293	$1,936,141	$302,384
Combined Cycle	15%	17,168	$953,928	$61,291	$158,225	$1,390,631	$217,187
Fuel Cost	$55.56	$$/MWh					
Variable O&M	$3.57	$$/MWh					
Fixed O&M	$12.11	$$/Kw					
Ave Peak Wholesale Price	$81	$$/MWh					

References

EIA. Energy Information Administration/Assumptions to the Annual Energy Outlook 2009. Table 8.2. Cost and Performance Characteristics of New Central Station Electricity Generating Technologies. from EIA website: http://www.eia.doe.gov/oiaf/aeo/overview/electricity.html