Cost Estimates for the Mandatory Closure of Surface Impoundments Used for the Management of Coal Combustion Byproducts at Coal-Fired Electric Utilities

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Cost Estimates for Closure of Ash Ponds at Fossil Fuel Power Generation Facilities

Summary

Environmental groups and others have proposed the elimination of the use of surface impoundments in the management of high volume fossil fuel combustion wastes (FFCW). Eliminating this use of surface impoundments has cost implications well beyond the cost of premature pond closure and the costs of dry waste management. Where ash ponds are present at facilities they are used to provide environmental services beyond the management of FFCW. This paper summarizes an analysis of the cost implications of the phase out of ash management ponds. The analysis shows an estimate of $39B in net present value costs. This estimate does not include any allowance for the potential increased stringency of closure requirements, landfill design or operating standards and potential generation capacity at risk of premature closure.

Methodology

We use individual cost data collected from engineering analyses performed by utilities with facilities affected by this proposal. We then generalize this information to the entire affected industry using data collected by the Energy Information Administration for the year 2005 (the most recent data available).

Cost Elements

The costs associated with phase out of ash ponds consists of the following:

- ***Conversion of boilers to facilitate dry management of bottom ash:*** Ash handling equipment needs to be added to existing units to transport waste to disposal facility.
- ***Conversion to dry collection and management of fly ash:*** Ash handling equipment needs to be added to existing units to transport waste to disposal facility.
- ***Increased operating costs:*** Dry management of wastes is more costly than wet management because it is more equipment intensive and requires additional controls to prevent dust and other spread of wastes.
- ***Premature pond closure:*** Unused capacity in ponds represents a loss of resources that must be replaced.
- ***Additional wastewater capacity:***
    - New surface impoundments will be required to provide stormwater management as well as other water pollution control services currently provided by the ponds.

  - Additional wastewater treatment capacity will be required to meet pollution control requirements currently managed with the assistance of the existing ponds.
- ***Additional Landfill Costs:*** Acquisition of additional land to facilitate installation of new equipment and landfill capacity. This cost was not quantified.
- ***Power Generation Capacity at Risk of Premature Closure:*** At-risk capacity: Some units are likely to be too small or too old to justify major capital expenditure associated with conversion. This cost was not quantified.

Cost Estimates

The following table includes the analysis of these costs. Present value and annualized costs are calculated over 20 years using a three percent discount rate.

Cost Component	**Affected Units**	**Unit Cost**	**Present Value Cost**
Bottom Ash Conversion	397 Generating Units	$30 million per unit	$10 billion
Fly Ash Conversion	15,000,000 Tons	$200 per ton	$2.5 billion
Dry Materials Management	20.6 million Tons	$2 per ton	$400 million
Accelerated Pond Closure	11.6 years of unused capacity foregone	$280 million	$2.5 billion
WWTP Capital Cost	155[1] Facilities	$80 million or $120 million[2]	$14.5 billion
WWTP Operating Costs	155 Facilities	$3 million or $4.5 million[3]	$5.2 billion
WWTP Pond Capacity	155 Facilities	$30 million	$4 billion
Additional Land Acquisition Cost	N.A.		Unquantified
At-Risk Generation Capacity	397 units 27,000 MW		Unquantified
Total NPV Cost			**$39 billion**
Annualized Cost			**$2.5 billion per year**

[1] There were116 units without FGD and 39 units with FGD in 2005.
[2] Cost of constructing wastewater treatment capacity is a function of whether a facility has a scrubber (FGD). If the facility has a scrubber, the new unit must be larger and more complex to manage FGD dewatering wastes.
[3] The same is true of operating costs with the higher number associated with the facilities with FGD.

Sensitivity Analysis

The proposal being evaluated is one that requires immediate cessation of placement of wastes in surface impoundments and closure of all remaining surface impoundments within two years. Actually, we determined that it is physically impossible to meet such a requirement as facilities would have to be converted to dry streams currently managed wet and landfill capacity would have to be permitted and constructed to hold these waste streams. A more realistic time frame would be a ten year phase out, and that is the basis for these numbers. We do a sensitivity run ignoring the real world constraints and assuming a two year phase out of ponds. This estimate includes a net present value cost of $48B or an annualized cost of $3.2B per year.

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INTRODUCTION

The U.S. Environmental Protection Agency ("EPA") currently is evaluating regulatory options for the management of coal combustion byproducts ("CCBs") and plans to propose federal management standards for CCBs by the end of the year. EPA reportedly is considering as part of its proposed CCB regulations the requirement that electric utility coal-fired power plants engage in the mandatory closure of surface impoundments used for the management of CCBs. This Report estimates the potential costs to the electric utility industry of complying with a rule mandating the closure of CCB surface impoundments.

While the beneficial use of CCBs has steadily increased over the past decade to approximately 43% of total annual production, the majority of CCBs produced by electric utilities are managed in either dry form in landfills or in wet form in surface impoundments. Based on data compiled by the Energy Information Administration in 2005 -- the last year for which compiled data is available – coal coal-fired power plants manage approximately 21 million tons of CCBs in surface impoundments annually. A regulatory mandate to close CCB surface impoundments would therefore affect a significant number of electric utility power plants. From an operational perspective, a CCB surface impoundment closure rule would require electric utilities currently using surface impoundments for CCBs to convert from the wet handling to the dry handling of these materials. This Report also assesses the potential wastewater management implications to the electric utility industry of no longer being able to employ CCB surface impoundment for ancillary wastewater management and treatment at the affected facilities.

The cost estimates used in this Report are derived from engineering cost estimates from power plants believed to be representative of the portion of the industry that uses CCB impoundments and the estimated conversion costs that these power plants would incur in converting from the wet to dry handling of CCBs. When developing these high level cost estimates, feasibility and implementation studies were not completed.

As discussed in the body of this Report, a requirement that electric utilities close CCB surface impoundments would result in significant operational costs. Based on representative engineering and cost data, the Report estimates that the present value cost to the electric utility industry of a regulation mandating the closure of CCB surface impoundments would be approximately $39 billion. Annualized over 20 years, this represents a cost of approximately $2.5 billion per year. In some cases, these costs could be sufficiently high to render a facility, or some smaller generating units at facilities, uneconomic and result in facility or generating unit closure. Closure of this generating capacity could potentially affect system reliability as well as energy prices. Assuming that only one-third of this at-risk capacity needed to be replaced, the gross replacement costs could range from $12 to $37 billion. These costs are in addition to the $39 billion in present value costs to the electric utility of complying with a mandatory CCB surface impoundment closure rule.

The above estimated costs are predicated on the current classification of CCBs as a non-hazardous waste. If CCBs were to be regulated as hazardous waste, these estimated costs would be significantly higher.

METHODOLOGY

The Report uses engineering estimates from a sample of facilities believed to be representative of facilities that rely on surface impoundments to manage some or all of their CCBs. The Report used estimated component costs to derive estimates of the overall unit costs involved in a conversion to dry management of waste. For example, the Report uses these estimates to derive a unit cost associated with installation of equipment to allow the dry management of bottom ash at each generating unit requiring conversion.

The Report applied these unit costs to data from the 2005 Energy Information Agency (EIA) Form 767 database. Form 767 is used to collect information on plant design and pollution control equipment and expenses. The EIA has converted to a new form for the collection of this data, so 2005 is the most recent available data. 2008 data will be available later this year, but was not available for use in this analysis.

REGULATORY IMPACT

It should be noted at the outset that the EIA Form 767 database was not designed to provide a complete and comprehensive inventory of all surface impoundments used to manage CCBs. Therefore, use of this database is necessarily under-inclusive with respect to assessing the potential economic impact on the utility industry of complying with a mandatory CCB surface impoundment closure rule. Nonetheless, as noted above, the EIA database is being used in the Report because it contains the best data available at this time.

The EIA Form 767 database includes information on 3854 combustion-based generating units at 1370 facilities. Of these facilities 122 report managing fly ash in surface impoundments, 128 report managing bottom ash in surface impoundments, and four report managing gypsum (FGD waste) in surface impoundments. Net generation of electricity from all sources in 2005 was approximately 3.9 trillion kilowatt hours (kWh). 51 percent of this electricity (approximately 2 billion kWh) was generated through the combustion of coal. The generation associated with the units directly affected by the closure of CCB surface impoundments represents approximately half of all coal fired generation, or one billion kWh. This one billion kWh estimate is based on declared primary fuel at affected units, so the actual affected generation could be higher since some units may burn coal as a secondary fuel source. It follows therefore that closure of surface impoundments would have a significant effect on units responsible for 25 percent of all electricity generation in the United States.

REGULATORY TIMING

This Report uses a ten year implementation period for complying with a mandatory CCB surface impoundment closure rule. This time period is based on several factors.

First, there are currently only a few domestic companies that manufacture the equipment necessary to convert wet ash handling systems to dry systems. Supply and demand for these system conversions, including design and supply for equipment, may result in new or expanded company capabilities, but vendor qualification will likely be an issue for adequate manufacturing capacity. Given the limited manufacturing capacity of key conversion equipment, the Report estimates that it would take approximately ten years to manufacture and provide equipment sufficient to convert the affected components of the electric utility industry from wet to dry CCB handling.

A second significant timing factor involves the time necessary for constructing and permitting the dry units necessary to accommodate the CCBs that are diverted from wet to dry handling. As a general rule this will require constructing new landfills (onsite if possible) to replace the lost management capacity from the closed surface impoundments. Importantly, the construction and – more importantly – permitting of a landfill cannot be accomplished in short order. When considering siting studies, land options, land purchase, design, engineering, permitting, construction and quality assurance, it generally takes between five and six years under the best of circumstances. If state regulators are confronted with multiple permit applications associated with a sudden change in regulatory requirements, or there is significant public opposition to the proposed site, this process will slow even further.

For these reasons, it is unreasonable to assume that the mandatory closure of all CCB surface impoundments could occur any faster than within ten years of promulgation of a mandatory closure rule. Therefore, the cost estimates in this Report assume a ten year implementation period. Reducing this implementation period would cause the costs to increase significantly from those estimated here.

COST COMPONENTS

The costs presented in this Report are associated with the following components:

- Capital Costs
    - There are changes in equipment required to shift from wet management of CCBs to dry management of these wastes. These capital costs occur in three areas:
        - Conversion of bottom ash handling systems from wet to dry
        - Conversion of fly ash handling systems from wet to dry

        - Installation of waste water treatment capacity to replace services provided by surface impoundments
- Operating Costs
    - The dry handling of these waste streams is more reliant on mechanical equipment than the wet management of the same waste streams. As a result, the operations and maintenance costs associated with dry management of these streams is higher.
    - Operation and management costs associated with replacement waste water treatment.
- Stranded Capital
    - Capital expenditures on surface impoundments were made with an expectation of a certain useful life.
    - A premature phase-out of the use of surface impoundments requires replacement of that capacity with landfill capacity sufficient to manage the CCBs that would have gone into impoundments. Essentially requiring the same capacity to be built twice.
- Opportunity and Other Costs
    - The fixed costs associated with conversion may be sufficiently high to make some smaller affected units uneconomic – there is simply not enough capacity and useful life remaining in these units to be able to recover the cost of conversion.
    - Closure of these units will reduce revenues to the operators who own them and decrease reserve margins of the regional grids where such facilities are located.
    - In the medium to long term lost generating capacity will have to be replaced. The cost of this new capacity likely exceeds the cost of operating the closed units. This additional cost would be attributed to the regulatory change forcing the closure of these units.
    - Surface impoundments often provide environmental benefits in addition to management of CCB. They may provide storm water runoff surge capacity, other waste water benefits, and they can affect the ability to meet other environmental goals such as mercury control. Loss of the surface impoundments results in a loss of these benefits. Additional costs will be incurred replacing these services.
    - Some facilities may require additional space to facilitate new equipment, landfill space, and waste water treatment surface impoundments.

CAPITAL COSTS

Conversion to Dry Management of Bottom Ash

The EIA Form 767 database indicates that there are 128 facilities that manage some or all of their bottom ash in surface impoundments. There are 397 coal-fired boilers at these facilities. Management of bottom ash in surface impoundments does not necessarily indicate that the boilers at the facility are wet-bottom boilers. Management in surface impoundments may simply be more convenient if there are other significant high-volume

CCBs managed in impoundments at the site. It is also possible that bottom ash streams from different boilers at the same site are managed in different ways.

There are two potential components to the cost of conversion of a boiler to facilitate dry management of bottom ash. One is the conversion of the bottom of the boiler itself to a dry removal system and the other is the conversion of the existing equipment to facilitate the dewatering and transporting of the waste stream to the dry waste management unit (i.e., a landfill). Even if a boiler is set up as a dry bottom boiler the wastes are hydraulically sluiced to a surface impoundment for final disposal. If this is the case, elimination of surface impoundments will not only require additional equipment to collect the bottom ash dry, but also to transport the dry wastes to a landfill for disposal.

Whether or not the boiler itself is a wet or dry bottom boiler, there are significant costs associated with modifying the ash handling system to facilitate dry management. Wet management involves simply hydraulically transporting the ash into a system that uses the water to carry the ash to the surface impoundment. A dry system relies on mechanical systems (such as augers) to move the ash out of the boiler; the ash then has to be conveyed to a centralized location where it can be transported to a landfill.

Based on engineering estimates across a number of affected utilities, capital costs associated with modifying these generating units averages approximately $30 million per unit. The total cost across all electricity generating units is, therefore, estimated at approximately $12 billion over ten years.

Conversion to Dry Management of Fly Ash

Like bottom ash, the cost associated with conversion to dry management of these wastes is associated with the modification of solids collection and handling systems. However, fly ash from multiple boilers may be collected and managed together. As a result, the Report uses information from the engineering cost estimates to derive an average capital cost per ton of fly ash.

Using information developed from these cost estimates, the capital costs associated with conversion of fly ash handling systems are approximately $200 per ton based on average cost estimates and size of the units and the amount of fly ash generated by those units.

According to the data reported in the EIA Form 767 for the year 2005, there is approximately 15 million tons of fly ash disposed of in surface impoundments on an annual basis.

Combining the engineering estimates with the disposal data the Report estimates that conversion of fly ash handling equipment to facilitate dry management will require capital expenditures of approximately $3 billion.

Conversion to Dry Management of FGD

Conversion of FGD solids handling systems to dry management involves the same capital intensive conversion. However, there were only four facilities that managed FGD waste streams in surface impoundments in 2005. As a result, the Report does not attempt to estimate the capital costs of converting these systems. The Report does, however, include the operations and maintenance costs associated with these solids in its O&M calculation.

Another important issue related to FGD operations is the use of surface impoundments to help manage FGD dewatering waste streams. What is not included in this cost estimate is the capital costs associated with the dewatering equipment (belt filters and vacuum/pump equipment packages, conveyors, and construction of stack out areas, etc.). Waters from gypsum dewatering and other processes are treated and augmented by other process water treated in surface impoundments. Closure of surface impoundments will require a significant change in the size and type of wastewater treatment equipment which means a significant increase in capital cost to manage the existing FGD wastewater streams.

Wastewater Treatment

Surface impoundments are an integral part of overall site wastewater compliance for facilities that use surface impoundments. Loss of these impoundments will require additional capital and operating expenses to replace this lost capacity.

This cost is affected by whether or not the facility has an FGD. The costs of managing certain constituents in the FGD dewatering waste significantly increase the cost of the wastewater treatment system required to replace the functionality of the surface impoundments.

Using cost estimates developed from data provided by utilities, the average capital cost for a facility without a FGD is $80 million, and increases to $200 million for a facility with an FGD. The difference in cost is attributable to the fact that new FGD systems remove soluble salts and other constituents that are more expensive to treat prior to discharge.

Based on 2005 EIA Form 767 data, 155 facilities would require new wastewater treatment capacity, and of these 39 were FGD facilities. This translates into additional capital cost requirements of approximately $17 billion.

OPERATING COSTS

Dry Handling

As noted above, wet management involves using gravity and water to move the solids into surface impoundments for management. Dry handling involves the use of mechanical systems such as silo, augers, and conveyors to get the wastes from point A to point B. These mechanical systems are inherently more expensive to operate and maintain.

Based on information received from utilities, the Report estimates that the operating costs associated with dry management are approximately $2.00 per ton higher than the costs associated with wet management.

In 2005 facilities managed 15.3 million tons of fly ash, 4.4 million tons of bottom ash, and 0.9 million tons of gypsum (FGD solids) in surface impoundments. Importantly, though, the amount of FGD solids managed in surface impoundments could be considerably higher than in 2005 due to the increased installation by coal-fired power plants of new pollution control equipment. The annual increase in operating costs associated with managing these wastes dry is, therefore, conservatively estimated to be $41.2 million.

<u>Waste Water Treatment</u>

The additional waste water treatment capacity that would be required to convert to dry handling systems would also result in increased operations and maintenance costs. For facilities without a FGD annual operating expenses are estimated to be approximately $3 million, and for a facility with an FGD this cost estimate increases to $4.5 million annually.

As noted above, the 2005 EIA Form 767 indicates that 155 facilities would require new wastewater treatment capacity, and of these 39 were FGD facilities. The resulting operating costs are roughly $525 million per year.

STRANDED COSTS

<u>Accelerated Closure of Surface Impoundments</u>

The long term management of landfills and surface impoundments are similar. A unit with a given capacity is constructed, CCBs are managed in the unit until the capacity is reached, and the waste unit is then capped and enters long term management and monitoring.

Construction costs for the two types of units are roughly similar. Operation costs for the landfill are slightly higher than for surface impoundments due to the need for dust control, the cost to transport the waste to the landfill as compared to wet sluicing and other issues related to dry wastes, but these costs are accounted for in the $2.00 per ton O&M increase already discussed. Costs of closure of the units are already required whether the surface impoundments are allowed or not in the future.

Therefore, if a facility reached the capacity of its surface impoundments before the surface impoundment was required to be closed, there would be no additional closure costs attributable to the phase out of surface impoundments. However, if the surface impoundments are required to be closed before they reach capacity, the cost of new capacity and accelerated closure costs would be attributable to the change in regulation.

Put another way, any capacity remaining in surface impoundments when they are closed represents a stranded cost equal to the cost of replacing that capacity with landfills.

Looking across a variety of units, the Report estimates that one acre of landfill capacity is required for every 75,000 tons of CCB. As noted previously, about 21 million tons of CCB are currently managed in surface impoundments each year. Therefore, there is an annual requirement for 280 acres of landfill capacity to manage these wastes.

In 2005 DPRA Incorporated conducted an analysis for the EPA evaluating potential costs associated with management of CCBs under the municipal solid waste landfill rules under Part 258 of RCRA. In this analysis, DPRA assumed that surface impoundments had an expected useful life of 40 years. Assuming this to be true, the current fleet has an average remaining life of approximately 20.5 years of capacity. If, as discussed above, the Report further assumes a ten year phase in period, the existing fleet would be expected to have 11.6 years of remaining capacity still in use at the time surface impoundments were closed.

If all existing surface impoundments were closed within ten years, the amount of unused capacity that would be stranded equates to about 3,200 acres of landfill space. At a cost of roughly $1 million per acre, this represents a stranded cost of $3.2 billion in year ten. A more rapid phase in would increase nominal costs by $280 million for each year closure is accelerated. The increase cost noted here is the estimated cost as related to accelerated surface impoundment closure, and does not include the estimated costs related the other associated processes affected by early impoundment closure (e.g., wastewater treatment implications).

TOTAL QUANTIFIED COSTS

For purposes of calculating present value and annualized costs, the Report assumes that the capital costs are incurred evenly over the ten year implementation period, and that surface impoundment closure costs are incurred in year 10. The Report uses a 20 year annualization period and a discount rate of three percent.

The present value cost to the electric utility industry of a mandatory CCB surface impoundment closure rule is $39 billion. If annualized over 20 years, this represents a cost of approximately $2.5 billion per year.

As noted earlier, these estimated costs rise significantly if an accelerated closure schedule is used. For example, certain advocacy groups have argued for a two year closure deadline for CCB surface impoundments. Assuming for purposes of discussion that a two-year compliance period is achievable, the potential compliance costs for the electric utility of a two year CCB surface impoundment closure rule jumps to $48 billion, which represents an annualized cost of $3.2 billion per year. This estimate does not include higher costs associated with rapid deployment of resources and disruption of operations necessary to meet a two year deadline.

It is also worthy to note that the cost estimates were developed in absence of engineering feasibility studies. The cost estimates, however, include contingency factors to reflect the unknown costs and variables associated with any conversion program of this magnitude.

UNQUANTIFIED AND OTHER COSTS

Loss of Additional Environmental Benefit

Existing surface impoundments also provide storm water surge capacity that assists facilities in the management of runoff. If the ash management surface impoundments are closed at these facilities, new surface impoundment or tank capacity will be required to replace lost volume treatment capacity. The size of these replacement surface impoundments will, of course, vary by a number of factors such as facility footprint, rainfall, site topography, existing controls, etc. Facilities that provided information on the amount of necessary replacement capacity stated needs ranging from zero to 70 acres of new surface impoundment capacity. These facilities also estimate a cost of one million dollars per acre for construction and operation of these surface impoundments. This adds an additional $4.5 billion in costs to the phase out of ash management surface impoundments.

Land Acquisition

A significant number of facilities evaluated would have to acquire additional land to facilitate the installation of equipment or the construction of landfill or wastewater surface impoundment capacity. The cost of such land acquisition is, of course, location specific. Some facilities have adequate space at the facility; others are in rural locations where land adjacent to the facility may be available and relatively inexpensive. Facilities in urban areas, on the other hand, may face absolute constraints on growth or very expensive land prices. It must be noted that even if suitable land is currently owned by facility operators, the value of its current use will be lost if converted to landfill space, so its use cannot be considered free. Another key point is that if land use restrictions require new off-site landfill capacity, the associated CCB management costs will be even higher.

In addition, it is not always obvious what portion of these costs would be attributable to a rule requiring phase out of surface impoundments. Facilities that were originally designed with surface impoundment capacity sufficient to accommodate the full useful life of the facility face a real economic cost if a rule would require them to acquire new land to accommodate landfill construction. On the other hand, facilities that would have to acquire additional land to facilitate the next expansion of waste storage capacity (wet or dry) can not legitimately argue that the next purchase is a result of the new rule.

For these reasons, the Report does not attempt to derive a national estimate of the cost of land acquisition associated with the rule, though it is important to note that these acquisition costs for individual facilities could be in the millions of dollars.

The Report did a screening level analysis of potential land acquisition costs by looking at a variety of individual facilities in different circumstances – rural locations, urban locations, sufficient existing space, moderate additional land requirements, significant new land requirements, etc. – and standardized the estimated requirements for these facilities to annual tons of CCB managed in existing surface impoundments (the only variable for which data were available for all facilities). Using this methodology, the Reports estimates total costs to all facilities at roughly $100 million dollars over the ten year implementation period. While this cost does not change the overall estimate of costs, it is not insignificant and tends to be concentrated at a small subset of individual facilities with much higher than average costs.

At-Risk Capacity

For some smaller units and/or units with limited remaining useful life, the fixed costs associated with the conversion to dry management of CCBs may, depending on a range of factors, be too high to allow the facility to recover the conversion costs given the limited capacity of these units. The most cost-effective compliance solution for generators with such units may be to terminate operations and purchase replacement power from elsewhere. Based on discussions with utilities, the Report concludes that units with below 230 MW of generating capacity have the greatest potential risk of ceasing operations if required to undertake the mandatory closure of CCB surface impoundments. This does not mean that such units will close, but rather that units below this MW generating capacity cutoff are at greater risk of no longer being economically viable.

The Report looks at this potential on a per unit basis due to the significant capital cost associated with converting bottom ash handling systems. There are 397 generating units operating at facilities that manage bottom ash in surface impoundments. As much as 20 percent (~35,000 MW) of the generating capacity of at these facilities is below 230 MW and thus face the greatest potential risk of ceasing operations if required to undertake the mandatory closure of CCB surface impoundments.

Units that are at-risk were responsible for the generation of 18 percent of all coal generation in 2005. This represents over four percent of all electricity generated in the United States.

Costs of Replacement Power

Another cost is that of utilities having to purchase replacement power for those plants that would be at risk of ceasing operations due to the economic burdens of complying with a mandatory surface impoundment closure rule. For example, if older plants are retired before they are fully depreciated, regulated utilities will need to request rate increases to recover the un-depreciated portion of the plants, including any uncollected removal costs. The cost of retiring these older, smaller units (<~230 MW) prematurely could be significant. Replacement capacity would have to be built to supply the lost generation and to maintain generating capacity margins required of regulated electric utilities by the state Public Utility Commissions. Those new units would be added to the rate base and would increase the price of electricity to the customer, so the rate payer would be paying twice; once for the remaining, stranded cost of the older unit being retired early and then for construction of the replacement capacity.

New, base-loaded generation to replace the lost units could be added at capital costs ranging between $1,186 per installed kW for natural gas combined cycle to $2,485 per installed kW for supercritical, pulverized coal. Other generating technologies that would be practicable in the 600 MW size units would include nuclear at a capital cost of $3,682 per installed kW and perhaps Integrated Gasification Combined Cycle at $3,359 per installed kW, depending on the timing. *(Congressional Research Service Report for Congress, Power Plants: Characteristics and Costs*, Stan Kaplan, November 13, 2008). Using those government cost figures, the capital cost for a replacement 600 MW unit would be in the $0.7 billion to $2.2 billion range. If only 10,000 MW of the 35,000 MW at-risk capacity needed to be replaced, the gross replacement costs would be in a range of between $12 and $37 billion. These costs are in addition to the $39 billion in quantified costs discussed above.

If the lost generating capacity were replaced with technologies having a lower capacity factor than the 230 MW units they were replacing, then wind (at $1,896 per installed kW), solar thermal (at $2,836 per installed kW) and solar photovoltaic (at $5,782 per installed kW) plants /cells could come into play. However all of these alternatives necessitate increasing costs for customers. (Capacity factor is the ratio of the amount of power generated by a unit for a period of time - typically one year - to the maximum power output of the unit if it were to run all the time and at full power. Capacity factor ranges from about 20% for solar photovoltaic to about 90% for nuclear.)