# Quantifying the Costs of Subtitle C Regulation of Coal Combustion Residuals Using Site-Specific Data: Why Limitations in Publicly-Available Data Lead to Estimation Error

**Dawn Santoianni[1], Jennifer Whaley[1], Matthew Bingham[1], Ken Ladwig[2], and James Lingle[2]**

[1]Veritas Economic Consulting, 1851 Evans Road, Cary, NC 27513;
[2] Electric Power Research Institute, 3420 Hillview Avenue, Palo Alto, CA 94304

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ABSTRACT

An analysis quantifying the costs to the coal-fired electric generating industry from EPA's proposed Subtitle C regulation of coal combustion residuals (CCR) was undertaken by the Electric Power Research Institute (EPRI). The analysis utilized data from a survey of owners of coal-fired generating stations to accurately assign compliance costs to individual generating units and plants affected by the regulation. Survey data provided site-specific information on plant configuration and CCR management practices. These survey responses covered 60 percent of the coal-fired capacity in the United States subject to the proposed CCR regulation, providing a level of detail pertinent to compliance costs that cannot be obtained from publicly-available databases. Survey data was used in the assessment of unit- and plant-level compliance costs, as well as to improve projections for non-surveyed plants. Multivariate regressions on survey data were used to identify unit and plant characteristics that influenced CCR disposal decisions. Based on regression coefficients, an estimate of disposal costs was calculated for non-surveyed plants within a Monte Carlo model to account for parameter uncertainty. The analysis showed that cost assumptions based solely on publicly-available data could introduce significant estimation error. Further, the analysis also included the cost implications for Subtitle C regulation "upstream" in the plant, including plant engineering retrofits for tanks, secondary containment, and wastewater treatment. These refinements account for the difference between EPRI's regulatory cost estimate and EPA's cost estimate for the Subtitle C option.

## INTRODUCTION

The regulation of coal combustion residuals (CCRs) under the Resource Recovery and Conservation Act (RCRA) would have significant economic implications for the coal-fired electric generating industry. The U.S. Environmental Protection Agency (EPA) co-

proposed two regulatory options for CCRs on June 21, 2010 – regulation under Subtitle D of RCRA or Subtitle C of RCRA (75 *Fed. Reg*. 35127–35264). While the Subtitle D option would allow the disposal of CCRs in surface impoundments that meet specified design requirements, the Subtitle C option would essentially mandate the phase-out of surface impoundments for the storage and disposal of CCRs, requiring disposal in landfills that meet the new design, monitoring and performance standards. However, the costs of the proposed Subtitle C rule go beyond pond closure, conversion from wet to dry CCR handling, and landfill construction. Coal-fired station owners would also need to meet RCRA C requirements for boilers, tanks, and buildings, which in a typical power plant would require significant upgrades and retrofits. Tank-based wastewater treatment systems would be required to replace impoundment functions. In addition, RCRA administrative costs such as permitting fees, groundwater monitoring, financial assurance, and RCRA facility investigations could be substantial. Evaluation of several of these cost components requires site-specific information not found in publicly-available data.

To quantify the costs of the proposed Subtitle C regulation, EPRI undertook a comprehensive engineering cost analysis. The project included site visits to coal-fired power generating stations to assess the compliance requirements and necessary engineering, and administration of a survey of coal-fired generating plant owners that provided site-specific information on CCR management practices and plant configuration that would affect compliance costs. These site-specific parameters were used in a Monte Carlo statistical model to generate unit- and plant-specific compliance cost estimates for each of the regulated facilities.[1] Using only publicly-available data will underestimate plant-specific compliance costs by a significant amount. A comparison of plant-specific costs estimated from public data with the costs developed from site-specific survey data shows that the compliance costs for some plants could be underestimated by a factor of 10 or greater (i.e. compliance costs would be 10 times the estimate derived from public data). The mean error in cost estimates across all plants using publicly-available data was 125%.

## SITE-SPECIFIC DATA COLLECTION

Site visits were used to develop a range of compliance costs dependent on plant size. The objective of the site visits was to assess the range of CCR management practices, plant configurations, and the retrofits required for Subtitle C compliance “upstream” of disposal units. For example, bottom ash hoppers, hydrobins, and FGD dewatering areas may require secondary containment, and truck loading facilities from silos may require negative pressure enclosures. The scope of the potential modifications necessary within the plant, and the associated engineering cost estimates are detailed in EPRI 2010a. It is important to note that EPA did not include these upstream costs in their Regulatory Impact Analysis (RIA) and specifically requested data on these costs (EPA 2010). Other economic analyses of the proposed CCR rule also did not include these costs (NERC 2010).

[1] The cost analysis included only plants with a generating capacity of 100 MW or greater.

The EPRI survey of coal-fired generating unit owners provided site-specific data necessary for accurate cost assignments. The survey responses covered 561 coal-fired units at 225 plants, representing 60.3 percent o the coal-fired generating capacity in the U.S. subject to the rule, and 60.2 percent of the annual net coal-fired generation. Respondents included large utilities with numerous coal-fired plants, independent power producers, and small, municipal-owned facilities.

Data gathered from the excel-format surveys were compiled using the statistical program STATA, which was used to update the generating unit database. The generating unit database was initially constructed using Energy Information Administration (EIA) Forms 860 and 923 for the year 2008. While the EIA forms are useful for identifying basic plant and unit information, these databases lack the detail necessary to fully understand CCR handling practices and plant configuration. For example, EIA 923 contains plant-level data on CCR final disposition, such as amounts disposed in ponds, landfills, sold, used on-site, or used off-site. However, it does not contain information on temporary storage of CCRs, including the use of stacker pads or semi-enclosed buildings. Further, plants that use impoundments for the settling of solids followed by dredging and reuse would not report final disposition to ponds, and would appear to not use impoundments even if they utilize a sluiced system. This is particularly true for bottom ash handling, where approximately 50 percent of surveyed plants reported sluicing bottom ash to impoundments, whereas EIA data indicated only 30 percent of plants disposing of bottom ash in ponds. Plants that use impoundments as part of the overall wastewater treatment of CCR contact streams would incur costs for replacement tank-based treatment systems. Plant characteristics such as open or closed solids conveyance, building enclosures, and details about wastewater treatment systems all affect costs under Subtitle C. These characteristics are not currently found in the publicly-available databases.

## PLANT RETROFIT REQUIREMENTS

Under Subtitle C regulation, CCRs destined for disposal would be regulated from the “point of generation.” Because plant configurations, operations, and CCR handling practices can vary widely, it is anticipated that point of generation would be subject to interpretation, and could occur as “upstream” in the plant as the boiler itself. Even at a plant where CCRs are normally destined for sale to secondary markets, system disturbances can make CCRs occasionally unmarketable; seasonal or fluctuating market demand can also affect the amount of CCRs beneficially used. In analysis of the point of generation, EPRI applied concepts codified by EPA. Under 40 CFR 260.10, disposal is defined as “the discharge, deposit, injection, dumping, spilling, leaking, or placing of any solid waste or hazardous waste into or on any land or water.” Therefore, disposal may be an active decision (i.e. disposal in a landfill) or passive (discharge, spilling, etc.) If CCRs are spilled, leaked, or discharged, the point of generation occurs at the place of discharge.

The engineering retrofits that would be required to meet Subtitle C requirements and prevent the spillage or discharge of CCRs from process equipment are dependent on the plant-specific configuration and operations, including:

1. Whether ESPs/baghouses are enclosed in a building with an impermeable floor, or are open or without concrete flooring.
2. Closed or open conveyance of CCR solids, particularly FGD solids, from dewatering area to storage.
3. Use of stacker pads or sheds for the temporary storage of CCRs.
4. Type of FGD system (dry, wet gypsum, or sulfite producer) and dewatering equipment used (hydroclones, thickeners, belt or drum dewatering).
5. Wastewater treatment process, including co-mingling of CCR waste streams with non-CCR wastewaters; use of settling ponds or tank-based systems.
6. Use of wet-sluicing as a backup to pneumatic system (during maintenance or forced outages).

The details of how these characteristics affect compliance costs is provided in EPRI 2010a, b. This configuration data is not available in public data, and thus would be difficult to quantify without site-specific information. The EPRI analysis used site-specific data for 60 percent of the plants, and developed a set of cost assignment assumptions for non-surveyed plants based on analysis of site-specific survey data and best professional judgment.

## DISPOSAL DECISION

The decision on where to dispose of CCRs under a Subtitle C regulation would be a function of numerous site-specific parameters. These parameters include whether the plant currently has a landfill on-site (or nearby) with remaining capacity that could meet Subtitle C siting and design criteria, land availability, proximity to commercial hazardous waste landfills, concerns about the permitting and public involvement process, and potential legal or liability issues. Site-specific restrictions may preclude many plants from siting new land disposal units. These restrictions include seismic, fault area, karst topology, floodplain, watershed, and state-level restrictions. Significantly, some states currently have statutes more restrictive than federal Subtitle C rules, such as Florida that prohibits the land disposal of hazardous waste (2010 Florida Statutes, sec. 403.7222, *Prohibition of hazardous waste landfills*; ASTSWMO 2007).

If a plant does not currently have a landfill on-site (or has limited capacity), that facility would be faced with a decision to permit and construct a new landfill on-site, transport CCRs for disposal at an off-site company-owned landfill, or transport CCRs to a commercial hazardous waste landfill for disposal. Lacking site-specific data, disposal choice is difficult to assess and can lead to gross inaccuracies in estimating disposal costs. Current disposal patterns are a poor predictor for future disposal choice under Subtitle C due to the more restrictive requirements of the regulation. In the RIA, EPA

assumes that current disposal practices continue as reported in EIA 767[2] and facilities that currently dispose of CCRs on-site would continue to do so under Subtitle C.[3] The EPRI CCR survey confirms not all facilities would be able to, or would choose to, site a new on-site landfill under the Subtitle C rules. Of the 225 plants with survey data, 104 (46 percent) reported they did not have available land on-site (within 5 miles) for a new landfill. Seismic, fault, floodplain, watershed, or state-level restrictions were identified by 72 plants (32 percent). These numbers likely underestimate the number of plants subject to Subtitle C siting restrictions as many answered "Unknown" to these questions. Companies also cited other reasons why they would not choose to build an on-site landfill. This included liability concerns, legal issues, or anticipation of a lengthy public involvement process; a decision to build a centrally located regional landfill that served several plants; or plants that were too small or had a low capacity factor which did not justify the time and expense of permitting an on-site landfill. Due to these restrictions and other factors, survey responses indicated that 42 percent (95 plants) would choose on-site disposal, 29 percent (66 plants) would choose to transport CCRs off-site to another company-owned landfill, and 28 percent (64 plants) would choose commercial landfill disposal. In terms of percentage of CCRs, 67 percent of CCRs produced by the surveyed plants would be disposed on-site, 21 percent of CCRs would be disposed off-site, and 12 percent of CCRs would be disposed of in commercial hazardous waste landfills.[4]

## MULTINOMIAL REGRESSION ANALYSIS

The surveys provided site-specific disposal data for 225 plants, leaving 152 plants without site-specific information. To develop more accurate estimates of compliance costs for non-surveyed plants, a multinomial regression analysis was used to identify variables that correlated with disposal decision for surveyed plants. The probabilities for on-site, off-site, and commercial disposal were calculated by evaluating the statistical relationship between the characteristics of the surveyed facilities with their disposal decision. It is important to note that the regression could only include variables for which data exists for non-surveyed plants. So although "land availability" was a survey question, those data do not exist for non-surveyed plants. Therefore, other parameters that would serve as a proxy for unknown variables were selected. When two parameters were highly correlated with each other (i.e. annual generation and CCR production), the more accessible, or publicly-available parameter was used.

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[2] The last year for which EIA Form767 data was available was 2005, which was used in the RIA. Form 767 was subsequently combined with other forms and replaced with Form 923 in 2007.

[3] EPA includes an increased cost of $4.1 million for each facility within seismic, fault area, or karst zones, but assumes that a new landfill could be sited. Water table, floodplain, wetlands, and state restrictions were not assessed.

[4] Based on EIA 767 (2005) disposition data, EPA assumed a total of 12 percent of CCRs would be trucked off-site, and made no distinction between commercial and utility-owned landfills.

The parameters in the regression include:

- Annual generation in MWh: the annual generation is a proxy for the capacity factor and ash production at the plant.
- Population density: population density would affect nearby land availability and the possibility for legal hurdles regarding siting landfills.
- Whether the plant currently has ponds or landfills: a plant that currently has ponds or landfills may be more likely to have land availability for new disposal units.
- Distance to nearest commercial hazardous waste landfill: transportation costs are a function of distance to landfill, and thus would influence the disposal decision.

Distance to the nearest commercial landfill was calculated for each plant, using the latitude and longitude coordinates of each plant and each commercial hazardous waste landfill in the U.S. Population density data was obtained based on the zip code where the plant was located. The regression showed a strong positive correlation between annual generation and on-site disposal. In other words, the more electricity a plant produces (in MWh), the more likely the plant was to dispose of CCRs on-site. Plants that produce more electricity are typically larger, have a higher capacity factor, and thus produce more CCRs. Hence, the economical decision would be to build an on-site landfill. In addition, these plants have a larger footprint and are more likely to have land available for landfill siting.

Population density (City-Data 2010) inversely correlated with on-site disposal. The more populous an area, the more likely the plant was to choose off-site or commercial disposal. This is likely due to land availability and potential permitting delays because of the public participation process (i.e. larger number of stakeholders could affect the permitting process).

If the plant currently had a landfill or pond on-site, it was more likely to choose on-site disposal. This variable is a proxy for land availability. Distance to commercial landfill positively correlated with a higher probability for disposal in an on-site or nearby company-owned landfill. The further away a commercial landfill was located from a plant, the more likely the plant was to choose on-site or company-owned off-site disposal.

A statistical model was estimated to predict the probability of each disposal choice for each individual plant. The disposal costs associated with each disposal decision were applied to each plant based on these probabilities. From survey data, the mean distance to a company-owned off-site landfill was 81 miles (130.4 km).[5] This mean value was used as the distance to off-site landfill for non-surveyed plants. If a surveyed plant indicated a specific distance to a company-owned off-site landfill, the specified distance was used. Cost distributions were developed to account for the probability for each disposal decision for non-surveyed plants, including a statistical range in transportation costs (trucking cost per mile per ton), and tipping fees at commercial

[5] EPA assumes a 6-mile (9.7 km) trucking distance to off-site landfills.

landfills. The regression approach allows for development of a range in disposal costs specific to each plant, thus quantifying the uncertainty in disposal decision and allowing development of a cost scenario that is based on a representative sample of the regulated plants. The total 20-year industry disposal cost was estimated as $23.90 billion (discounted by 7%). The disposal costs do not include landfill construction costs, however. The EPRI cost analysis focused on quantifying the incremental costs of Subtitle C regulation, and not a total compliance cost estimate. The assumption was made that over the 20-year study horizon, all plants would have to build or expand a landfill, and thus those construction costs were deemed not incremental due to the rule.

In terms of volume of CCRs, the regression predicted between 14,970,000 and 20,550,000 tons (13,580,556 – 18,642,646 metric tons) of CCRs would be sent to commercial hazardous waste landfills each year. This volume of waste would exceed the entire current capacity of the commercial hazardous waste market, estimated at 34,000,000 tons (30,844,281 metric tons) within two years (ECOS 2010; U.S. EPA 2008).

## KEY SOURCES OF ERROR USING PUBLICLY-AVAILABLE DATA

The use of site-specific data yields much different results than the use of publicly-available information for two main reasons:

1. Lack of data on plant configuration to support estimation of "upstream" Subtitle C costs
2. Current disposal patterns are not indicative of future disposal practices under the rule.

To examine the implications of these limitations, the cost model was modified to make cost assignments based solely on the public data. This is useful for identifying the key drivers of the regulatory cost, and for identifying sources of error in estimates.

**The upstream costs of the Subtitle C regulation** (including wastewater treatment) account for $10.1 billion present value (discounted at 7% over 20 years) total for the coal-fired electric generating industry. This represents 16% of the estimated incremental cost of the Subtitle C rule. These costs were not included in EPA's regulatory cost estimate.

**Estimation error using publicly-available data for disposal practices is significant** as it fails to incorporate restrictions imposed by the proposed rule. This occurs because the disposal choices that would be made by coal-fired station owners under a Subtitle C rule would be different than current disposal patterns. Further, restrictions on beneficial uses under the proposed rule would cause more CCRs to be disposed, as certain unencapsulated uses would be considered disposal.[6] Stigma associated with Subtitle C

[6] In the proposed rulemaking, EPA notes that "unencapsulated uses have raised concerns and merit closer attention" and explicitly considers large-scale unencapsulated uses (filling of

regulation could also negatively affect beneficial use markets. Even plants that currently sell or re-use 100 percent of their CCRs would potentially require land disposal units under the rule.

To evaluate the cost estimation error induced by using public data, the cost model was re-estimated with all site-specific data (and regression analysis) removed. From EIA 923 2008 disposition data, current disposal patterns were assumed to continue. Plants that report on-site disposition were assumed to continue this disposal pattern. Plants that currently dispose of CCRs off-site were assumed to continue to do so under the proposed rule (with off-site being a company-owned land disposal unit). Plants that currently sell or use (on-site or off-site) 100 percent of their generated CCRs were assumed to dispose of a percentage on-site. This percentage equates to the industry average rates of unencapsulated uses specifically construed as disposal by EPA in the proposed rule, and is different for each of the CCR streams (bottom ash, fly ash, boiler slag, and FGD products). With these changes to the cost model, the industry 20-year disposal cost is estimated at $4.14 billion (present value at discount rate of 7%). This is significantly less than the estimated $23.90 billion using site-specific data and regression analysis of survey data to predict disposal cost for non-surveyed plants. It is important to note that neither of these estimates includes landfill construction costs, as these costs were not deemed incremental due to the proposed rule.

## CONCLUSIONS AND FUTURE ANALYSIS

EPRI's cost analysis was undertaken to provide an assessment of the full suite of compliance costs that were incremental due to the Subtitle C rule. Site-specific data on 60 percent of the coal-fired capacity subject to the regulation allowed for the development of more accurate cost estimates, and to quantify uncertainty in those estimates. The total incremental cost to the coal-fired electric generating industry for Subtitle C regulation of CCRs over a 20-year period is estimated between $54.66 billion and $76.84 billion present value (at a discount rate of seven percent). If upstream in-plant Subtitle C compliance costs are not included, and if disposal costs are calculated based on current disposal patterns, the incremental compliance costs would be underestimated by approximately $30 billion. This largely accounts for the difference between EPRI's regulatory cost estimate, and EPA's $20.35 billion estimate for Subtitle C regulation.

The industry cost estimate using site-specific data could be improved by obtaining site-specific data for the remaining 40 percent of the coal-fired generating units subject to the regulation, and a site-specific analysis of impoundment closure costs. While industry-wide impoundment closure costs were estimated, a site-specific analysis was not undertaken due to time constraints. The design, condition, and location of impoundments would affect the cost of closure. This is likely to increase the total cost

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quarries or gravel pits, and regrading of landscapes with CCRs) to be disposal and subject to the management standards in the rule (75 *Fed. Reg.* 35161).

estimate of Subtitle C regulation due to limitations on closing-in-place and Subtitle C requirements for clean-closure of ponds at some facilities.

The economic impact of the regulation is not just felt in the coal-fired electric generating industry, but also across all the beneficial use industries. A thorough economic analysis of the proposed rule should include the costs across all industries.

Finally, compliance decisions (including disposal choice) for each generating unit would be made in context of compliance with other regulations affecting the coal-fired generating industry, including national emission standards for hazardous air pollutants (NESHAP), the Transport Rule, greenhouse gas regulation, and 316(b) regulation of once-through cooling intake structures. The technological requirements to comply with one rule could also affect the compliance strategy and costs for another regulation. A good example of this is the addition of scrubbers for $SO_2$ which would then affect the amount of CCRs generated and overall CCR rule compliance costs. The cumulative economic impacts of multiple regulations, from both an economic standpoint as well as a technological standpoint, will ultimately impact compliance or retirement choices.

## REFERENCES

[1] Association of State and Territorial Solid Waste Management Officials. State RCRA Subtitle C Core Hazardous Waste Management Program Implementation Costs: Final Report, 2007. Available at http://www.astswmo.org/files/publications/hazardouswaste/Final%20Report%20-%20RCRA%20Subtitle%20C%20Core%20Project.pdf. Retrieved on September 14, 2010.

[2] The Environmental Council of States. Letter to Mathy Stanislaus, U.S. Environmental Protection Agency, 2009. Available at http://www.ecos.org/files/3869_file_ECOS_CCW_Consultation_Comments_to_EPA.pdf?PHPSESSID=5a06febfcf09139fbf428ce294e1bc80. Retrieved on September 14, 2010.

[3] City-Data.com. Home page, 2010. Available at http://www.city-data.com/. Retrieved on November 5, 2010.

[4] Electric Power Research Institute. Coal Combustion By-Products and Low-Volume Wastes Comanagement Survey, TR-1082369, 1997. EPRI Distribution Center, Pleasant Hill, CA.

[5] Electric Power Research Institute. Engineering and Cost Assessment of Hazardous Waste Designation of Coal Combustion Residuals: Technical Update, 1020557, 2010a, EPRI, Palo Alto, CA.

[6] Electric Power Research Institute. Cost Analysis of Proposed National Regulation of Coal Combustion Residuals from the Electric Generating Industry, 1022296, 2010b, EPRI, Palo Alto, CA.

[7] Energy Information Administration. Form EIA-767 Database, 2005. Available at http://www.eia.doe.gov/cneaf/electricity/page/eia767.html. Retrieved on December 3, 2009.

[8] Energy Information Administration. Form EIA-860 Database Annual Electric Generator Report, 2007. Available at http://www.eia.doe.gov/cneaf/electricity/page/eia860.html. Retrieved on December 3, 2009.

[9] Energy Information Administration. Form EIA-860 Database Annual Electric Generator Report, 2008a. Available at http://www.eia.doe.gov/cneaf/electricity/page/eia860.html. Retrieved on September 14, 2010.

[10] Energy Information Administration. Form EIA-906, EIA-920, and EIA-923 Databases, 2008b. Available at http://www.eia.doe.gov/cneaf/electricity/page/eia906_920.html. Retrieved on September 14, 2010.

[11] Federal Remediation Technologies Roundtable. Remediation Technologies Screening Matrix and Reference Guide, Version 4.0, undated. Available at http://www.frtr.gov/matrix2/section4/4-27.html. Retrieved on January 17, 2010.

[12] Goddard, C.F. Letter to Matt Hale, U.S. Environmental Protection Agency, 2009. Florida Department of Environmental Protection, Tallahassee, FL.

[13] Jaffe, J., and Stavins, R.N. The Value of Formal Quantitative Assessment of Uncertainty in Regulatory Analysis, Related Publication 04-22, 2004. AEI-Brookings Joint Center for Regulatory Studies. Available at http://reg-markets.org/admin/authorpdfs/redirect-safely.php?fname=../pdffiles/phpai.pdf. Retrieved on January 8, 2010.

[14] North American Electric Reliability Corporation (NERC). 2010 Special Reliability Scenario Assessment: Resource Adequacy Impacts of Potential U.S. Environmental Regulations, 2010. Available at http://www.nerc.com/files/EPA_Scenario_Final.pdf. Retrieved on November 5, 2010.

[15] U.S. Environmental Protection Agency. Expected Maximum Commercial Subtitle C Management Capacity for Landfill (Tons), 2008. Available at http://www.epa.gov/osw/hazard/tsd/capacity/appb_lf.pdf. Retrieved on November 5, 2010.

[16] U.S. Environmental Protection Agency Office of Resource Conservation & Recovery. Regulatory Impact Analysis for EPA's Proposed RCRA Regulation of Coal Combustion Residues Generated by the Electric Utility Industry, 2010. Available at

http://www.regulations.gov/search/Regs/home.html#documentDetail?R=0900006480ae5d01. Retrieved on September 14, 2010.