SIERRA CLUB
FOUNDED 1892

October 21, 2011

Via Federal Express Overnight Delivery

Jeff Derouen
Cases Nos. 2011-161, 162
Kentucky Public Service Commission
211 Sower Blvd.
Frankfort, KY 40601

Re: Hard Copy of Environmental Intervenors Responses and Supporting Attachments to September 30, 2011 Data Requests by Louisville Gas and Electric Company and Kentucky Utilities Company

Dear Mr. Jeff Derouen,

On October 13, 2011, Environmental Intervenors filed responses to the September 30, 2011 Data Requests by Louisville Gas and Electric Company and Kentucky Utilities Company (collectively, the "Companies"). These responses were accompanied by a petition to deviate from the requirement that parties file with the Commission an original and fifteen (15) complete copies of all data responses and attachments and allow the Environmental Intervenors to instead produce the data responses and supporting attachment on DVD. In our Petition to Deviate, we noted that within seven days of that filing we would submit one complete hard copy of the data responses and supporting attachments, which were in a readable format (Microsoft Word, Excel, PDF, txt, or WordPerfect). Those documents are enclosed.

Sincerely,

Kristin A. Henry

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SIERRA CLUB
FOUNDED 1892

October 19, 2011

Via Federal Express Overnight Delivery

RECEIVED
OCT 20 2011
PUBLIC SERVICE COMMISSION

Jeff Derouen
Cases Nos. 2011-161, 162
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Frankfort, KY 40601

Re: Hard Copy of Environmental Intervenors Responses and Supporting Attachments to September 30, 2011 Data Requests by Louisville Gas and Electric Company and Kentucky Utilities Company

Dear Mr. Jeff Derouen,

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COMMONWEALTH OF KENTUCKY

BEFORE THE PUBLIC SERVICE COMMISSION

In the Matter of:

APPLICATION OF KENTUCKY UTILITIES COMPANY FOR CERTIFICATES OF PUBLIC CONVENIENCE AND NECESSITY AND APPROVAL OF ITS 2011 COMPLIANCE PLAN FOR RECOVERY BY ENVIRONMENTAL SURCHARGE	)	CASE NO. 2011-00161

In the Matter of:

APPLICATION OF LOUISVILLE GAS AND ELECTRIC COMPANY FOR CERTIFICATES OF PUBLIC CONVENIENCE AND NECESSITY AND APPROVAL OF ITS 2011 COMPLIANCE PLAN FOR RECOVERY BY ENVIRONMENTAL SURCHARGE	)	CASE NO. 2011-00162

RESPONSES AND OBJECTIONS OF NATURAL RESOURCES DEFENSE COUNCIL AND SIERRA CLUB TO DATA REQUESTS OF KENTUCKY UTILITIES COMPANY AND LOUISVILLE GAS AND ELECTRIC COMPANY

Interveners Natural Resources Defense Council and Sierra Club (collectively, "Intervenors") hereby submit their responses and objections to the Data Requests of Kentucky Utilities Company and Louisville Gas & Electric Company (collectively, "Companies"):

1. Please refer to Dr. Fisher's direct testimony at 16, wherein he states, "Using cost assumptions from a [sic] North American Electric Reliability Council (NERC), I estimate the cost of a cooling tower for Mill Creek unit 1 at around $70 million."

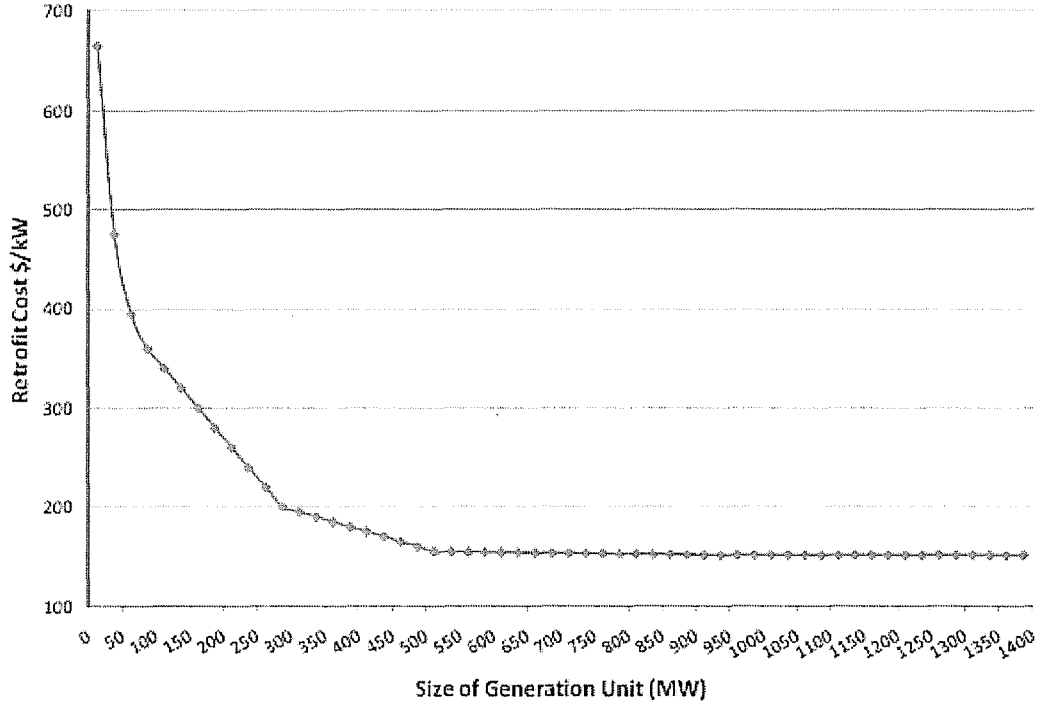
a. Please describe the type of cooling tower to which Dr. Fisher refers.

RESPONSE: Jeremy Fisher

"Cooling towers" here refers to conversion to a closed cycle cooling system using evaporative cooling towers. The source document from which these costs are derived is non-

specific to the type of cell or tower, or design specifications. Rather, the source supplies a curve with economies of scale (see figure below). The cost for Mill Creek 1 was obtained by multiplying the "retrofit cost" at 356 MW by the nameplate capacity of Mill Creek 1, and rounding.

Figure II-3: Base Case Retrofit Cost Curve for Section 316(b)($/kW)



b. Including the specific NERC reference document referred to in the direct testimony, please provide any and all documents or other information upon which Dr. Fisher based his cost projection.

RESPONSE: Jeremy Fisher

Dr. Fisher relied on the NERC report, which is being produced with these responses.

2. Please refer to Dr. Fisher's direct testimony at 42, wherein he states, "[T]he Commission should deny CPCNs and rate treatment for any upgrades to the Companies' coal units at this time."

a. How does Dr. Fisher propose LG&E and KU comply with the environmental regulations at issue in this proceeding while meeting their service obligations to customers if the Commission followed Dr. Fisher's recommendation?

b. Has Dr. Fisher attempted to calculate the costs of his recommendation?

c. For KU and LG&E for each year of the study period, what would be the rate impact of following Dr. Fisher's recommendation? Please provide all calculations and supporting work-papers in electronic format (the latter in Microsoft Excel format with formulas intact and unlocked).

RESPONSE: Jeremy Fisher

a. Intervenors object to this request to the extent that it suggests that Intervenors bear the burden of identifying resource proposals that satisfy the requirements for obtaining a CPCN. In fact, it is the Companies as the applicants who bear the burden of setting forth the facts necessary to demonstrate entitlement to a CPCN. 807 KAR 5:001(9)(2)(a). Subject to and without waiving the foregoing objection, Interveners state that Dr. Fisher's testimony does not specifically address how the Companies should meet their service obligations while complying with environmental regulations. Such matters are appropriately addressed within the context of an integrated resource plan (IRP) and with sufficient Company information and resources, unavailable at this time to interveners.

b. As described more fully in Intervenors' response to Commission Staff Request 3.a, Dr. Fisher's recommendation in direct testimony is that "the Commission deny CPCN and rate treatment for retrofitting the Brown 1 & 2 units... [and] deny CPCN and rate treatment for retrofitting Mill Creek 1 & 2 units... [and] assess, in greater detail and with a greater range of uncertainty, the risks posed in retrofitting the Mill Creek 1 & 2 units." Modeling indicates that the CPCN for Brown 1 & 2 and Mill Creek 1 & 2 should be denied because such a course of action ultimately saves ratepayer money relative to the plan put forth by the Companies. The recommendation of an assessment of the

compliance risks posed to Mill Creek 1 & 2 is an appropriate mechanism to ensure that the Companies' actions do not result in unnecessary costs to ratepayers.

It should be noted that additional modeling and assessment on the part of the Companies comprises a very small fraction of the costs and expenditures contemplated in this proceeding.

c. Dr. Fisher has not recommended a specific plan, and thus there is no "rate impact of following" his plan. The formulation of a plan, and resulting rate and bill impacts, are appropriately addressed within the context of an IRP and with sufficient Company information and resources, unavailable at this time to interveners. It is expected that the denial of CPCN for Brown 1 & 2 and Mill Creek 1 & 2 will save ratepayer money relative to the proposal put forth by the Companies. Further, regardless of if the ultimate decision results in capital expenses for retrofits or new generation, the Companies have mechanisms at their disposal, not contemplated in this filing, to reduce bill impacts and requirements, such as market purchases, PPAs, and the procurement of demand-side management measures.

3. Dr. Fisher states at page 37 of his direct testimony that he believes the Companies have used too high a cost for emergency energy in their modeling.

a. What is the value Dr. Fisher would place on unserved energy?

b. Please provide all reasoning and documents supporting Dr. Fisher's proposed value.

RESPONSE: Jeremy Fisher

a. The question is based on a false premise: the capacity gaps that the model fills with "emergency energy" does not necessarily represent "energy not served." The same gap could be filled with short term market purchases from connected utilities and RTOs,

demand response resources, and through emergency measures that do not include forced outages. In most RTOs, including PJM and MISO (both of which are connected to LG&E/KU), emergency measures dictate a variety of responses, from grid adjustments to calling interruptible load resources, that proceed last resort rolling blackouts. The Companies cost of "energy not served" only represents the most extreme cost as perceived by customers.

b. See response to request 3a.

4. At page 40 of Dr. Fisher's direct testimony, he suggests that the order of retirement the Companies used to evaluate whether to retrofit with environmental controls or to retire their coal units may have affected their proposed retrofit-versus-retire decisions for certain units.

a. Which order(s) of retirements would Dr. Fisher propose in the alternative?

b. What impact, if any, would Dr. Fisher's proposed retirement ordering(s) have on the retrofit-versus-retire decisions the Companies have proposed? Please provide all supporting work-papers and other related documents in paper and electronic formats.

RESPONSE: Jeremy Fisher, Rachel Wilson

a. Intervenors object to this request to the extent that it suggests that Intervenors bear the burden of identifying resource proposals that satisfy the requirements for obtaining a CPCN. In fact, it is the Companies as the applicants who bear the burden of setting forth the facts necessary to demonstrate entitlement to a CPCN. 807 KAR 5:001(9)(2)(a). Subject to and without waiving the foregoing objection, Interveners state as follows. Testing multiple "order(s) of retirements" is one mechanism of arriving at the optimal retire/retrofit plan, but it is the Companies' responsibility to show that their plan results in the lowest cost and lowest risk. Based on both our testimony and the late-breaking Supplemental Analyses provided by the Companies, the suite of retire/retrofit decisions proposed by LG&E/KU is not the optimal plan. It is incumbent on the Companies to

determine and apply a mechanism to find the optimal portfolio of retirement and retrofit decisions that results in the lowest risk and cost to customers, and establish definitively that the suite of retrofit and retirement decisions actually results in the lowest reasonable PVRR.

b. To test the question of what type of impact retirement reordering could have on the retrofit/retire decision, we conducted a simple test. For each unit, we tested the NPVRR of retiring only that unit against a no-retirements case. This test simply replicates the decision that would be made with the first unit examined in the Company's analysis scheme. Because retiring any given unit makes all other units appear marginally more economic, the relative economic merit of any given unit shrinks dramatically if the unit is examined first. The following tables show the Companies' analysis (with a corrected formula for the landfill year as described in my direct testimony) and "one-off" results, where the NPVRR of retiring each unit individually is tested. All other inputs are held constant with Company assumptions.

In this analysis, if Cane Run 6 is examined first, the net benefit of retrofitting this unit shrinks from positive $11 million to negative $55 million, while the Brown 1 & 2 units shrink from a net benefit of $230 million to $137 million, less than the PVRR of an SCR at these units. The data for the "one-off" studies are supplied in the accompanying Excel workbook.[1]

[1] For these studies, Ms. Wilson used the no-retirements Strategist modeling run, and created a series of runs where only one unit was retired per run. The resulting new unit and capital costs were output from Strategist and Dr. Fisher input these data into the Company's retire/retrofit analysis workbook. Formulae were altered to reflect that only one unit was retired per run, but all other assumptions were left intact.

The fact that simply changing the order in which units are examined could feasibly change the retire/retrofit decision suggests that the mechanism employed by the Company is flawed.

KU / LG&E Assumptions Original, Formula Corrected	
CPCN Results, Landfill Year Corrected	
Tyrone 3	-13
Green River 3	-80
Brown 3	603
Cane Run 4	-87
Cane Run 6	11
Brown 1-2	230
Cane Run 5	-57
Ghent 3	921
Ghent 1	800
Green River 4	-110
Mill Creek 4	859
Trimble County 1	996
Ghent 4	1,161
Mill Creek 3	756
Ghent 2	1,146
Mill Creek 1-2	1,022

KU / LG&E Assumptions One-Off Results	
Units Retired Individually	
Tyrone 3	-13
Green River 3	-104
Brown 3	566
Cane Run 4	-194
Cane Run 6	-55
Brown 1-2	137
Cane Run 5	-158
Ghent 3	612
Ghent 1	541
Green River 4	-155
Mill Creek 4	522
Trimble County 1	746
Ghent 4	806
Mill Creek 3	513
Ghent 2	800
Mill Creek 1-2	675

5. The Companies did not contemplate the transmission cost impacts of retiring units they did not recommend retiring. Has Dr. Fisher attempted to estimate what would be the transmission costs necessitated by the unit retirements his various modeling runs suggested, including retiring Brown Units 1 and 2?

a. If so, please provide the estimate and all supporting work-papers and other related documents in paper and electronic formats.

b. If not, please explain why Dr. Fisher recommended retiring the Brown units without taking into account such costs.

RESPONSE: Jeremy Fisher

It is not clear whether the Companies' factored in transmission costs even for units that were recommended for retirement. If such costs are anticipated by the Companies, Dr. Fisher recommends that these costs be incorporated into the Companies' retire/retrofit model as a cost or benefit. At this time, there is no indication that additional transmission costs would be "necessitated by the unit retirements" that the Companies have not already proposed.

a. Not applicable.

b. Intervenors object to this request to the extent that it mischaracterized Dr. Fisher's testimony. Dr. Fisher did not recommend retiring specific units. Instead, with regards to Brown Units 1 & 2, Dr. Fisher evaluated the Companies' retire/retrofit modeling, determined that more reasonable inputs should have been used in such modeling, and urged denial of the requested CPCNs because the available evidence suggests that retrofit of Brown Units 1 & 2 is not the least cost option. Subject to and without waiving the foregoing objection, see response, above.

6. Dr. Fisher states at page 13 of his direct testimony, "After accounting for expected retirements, the Companies anticipate retrofitting their remaining partially-controlled units (Brown 1-3, Ghent 1-4, Mill Creek 1-4, and Trimble County 1) with flue gas desulfurization (FGD) ...." Please explain where in the 2011 compliance filing the Companies state a plan to "retrofit" their remaining units at Brown, Ghent, Mill Creek and Trimble Co. 1 with FGD.

RESPONSE: Jeremy Fisher

This statement is in error, but does not substantively change Dr. Fisher's testimony nor recommendations. While MACT requirements may be partially met through the installation and permitted use of FGD, the Brown 1-3 units have already installed a new FGD system, and the Trimble County unit is already in possession of an FGD unit. Of the non-retiring units, the four units at Mill Creek are anticipated by the Companies to require new or retrofit FGD systems (Revlett at 6).

7. Please provide the forecast of natural gas prices utilized as an input to Strategist in Synapse's re-analysis.

RESPONSE: Jeremy Fisher

	AESC 2011 HH Price + Delivery Charge + Seasonal Adjustment (2010$/MCF) - REVISED
2011	5.32
2012	5.77
2013	5.95
2014	6.14
2015	6.81
2016	6.96
2017	6.92
2018	6.93
2019	6.96
2020	7.05
2021	7.16
2022	7.25
2023	7.55
2024	7.77
2025	7.84
2026	7.96
2027	8.12
2028	8.29
2029	8.52
2030	8.43
2031	8.45
2032	8.61
2033	8.76
2034	8.79
2035	8.98
2036	9.12
2037	9.27
2038	9.43
2039	9.57
2040	9.73
2041	9.88

8. Please confirm that the gas price forecast was the only input to Strategist that was changed in developing the NPVRR values for Box 3 in Exhibit JIF-2. If other Strategist inputs changed, please provide a summary of the changes.

RESPONSE: Wilson

The gas price forecast is the only input to Strategist changed in developing Box 3 in Exhibit JIF-2 (subsequently replaced Exhibit JIF-S3).

9. Please see page 8 of Dr. Fisher's direct testimony. What is the basis for the phrase, "ranging in size from 493 to 907 MW," at the bottom of the page?

RESPONSE: Jeremy Fisher

This statement is in error, and is revised to read as follows. The error does not substantively change Dr. Fisher's testimony, nor his recommendation.

"The Companies assume that replacement generation is only available from three types of natural gas plants, a single-cycle turbine of 194 MW, and two combined cycle sized at 605 and 907 MW (summer capacity), respectively (see p50 of the 2011 Air Compliance Plan). These large-size combined cycle units are larger than many of the coal units under consideration, forcing the model to only evaluate unduly expensive alternatives that present potentially non-optimal solutions."

10. Please produce in machine readable or txt format the input and output files for all Strategist modeling that Synapse completed in conjunction with its re-analysis.

RESPONSE: Jeremy Fisher

Intervenors are producing these files with these responses.

11. To the extent not provided in response to DR 10 above, please produce any work paper, source document, and, in machine readable or txt format, input and output files, used in or developed as part of the modeling carried out in developing Synapse's re-analysis.

RESPONSE: Jeremy Fisher

Attached. The folder contains seven variants on the Companies' analysis spreadsheet comprising Boxes 2-8 in Exhibit JIF-S3, as well as the spreadsheet for Exhibit JIF-S3, and the gas price forecast. The public version of this file has redacted the Company's natural gas price forecast.

12. Please see Dr. Fisher's direct testimony at page 24, lines 3-6.

a. Which 13 counties in Kentucky are estimated to violate the 2008 ozone standard at 0.075 ppm? Provide all support and documents indicating the 13 counties are estimated to violate the 2008 ozone standard.

b. Based on the most recent set of 3-year-average ozone data, which counties in Kentucky violate the 2008 ozone standard?

c. Which of the facilities in this 2011 Compliance Plan are located in counties that exceed the 2008 standard?

d. If facilities are not located in those counties, will those facilities be subject to the installation of NOx controls?

RESPONSE: Jeremy Fisher

a. There are 11 counties which are in violation of the 0.075 ppm 8-hr standard according to EPA data collected in 2006-2008. Christian, Daviess, Greenup, Hancock, Hardin, Henderson, Jefferson, Kenton, Oldham, Simpson, and Trigg Counties. Two additional counties, Boydd and McCracken Counties could be in violation, but are currently at the 2008 compliance limit of 0.075 ppm. This information is available to the public at http://www.epa.gov/air/ozonepollution/pdfs/CountyPrimaryOzoneLevels0608.pdf

b. This information is not yet available in a quality assured form, and we have not conducted this analysis. However, raw criteria pollutant data is reported in a raw form to the EPA at http://epa.gov/ttn/airs/airsaqs/detaildata/downloadaqsdata.htm

c. We have not compiled this information for all units in the 2011 Compliance Plan. I will note, however, that Mill Creek is located in Jefferson County, which is one of the counties in violation of the 0.075 ppm 8-hr standard.[2,3]

d. Potentially. If there is a new standard and certain counties become nonattainment counties, the Commonwealth and Louisville APCD will have to write a SIP that outlines how nonattainment areas will be brought into attainment. The Commonwealth has the authority to require controls on contributing sources under the Clean Air Act Section 110(a)(2)(A) which, generically, allows the state to adopt whatever controls are necessary to meet the requirements of the Clean Air Act. NOx is an ozone precursor, and as such, may be regulated to meet ozone standards.

13. Please see Dr. Fisher's direct testimony at page 25, lines 15-17. Based on the reference cited in footnote 17 on page 24, Fayette County's 3-year average ozone level was 0.072 ppm, which is not "so far out of compliance" if the revised standard in a future proposed rule was set at 0.070 ppm. What impact will the addition of the SCR at Brown 3 scheduled to be in service in 2012 have on the Fayette County ozone monitor averages?

RESPONSE: Jeremy Fisher

Interveners have not conducted such an analysis.

14. Please see Dr. Fisher's direct testimony at page 29, line 19. What is BACT (Best Available Control Technology) for CO2?

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[2] US EPA, 2010. Counties Violating the Primary Ground-Level Ozone Standard, 2006-2008. January 2010. http://www.epa.gov/air/ozonepollution/pdfs/CountyPrimaryOzoneLevels0608.pdf

[3] Kentucky Energy and Environment Cabinet. Commonwealth of Kentucky Boundary Recommendations: 8-Hour Ozone Standard, March 2009. http://www.epa.gov/ozonedesignations/2008standards/rec/letters/04_KY_rec.pdf

RESPONSE: Jeremy Fisher

Best Available Control Technology (BACT) is an emission limit based on the best available control technology that is established on a case-by-case basis. EPA's existing regulations state that BACT only applies to emission units that are physically or operationally changed (40 CFR 52.21(j)(3)). A permitting authority must evaluate the amount of emissions reductions that each available emissions-reducing technology or technique would achieve, as well as the energy, environmental, economic and other costs associated with each technology or technique. Based on this assessment, the permitting authority must establish a numeric emissions limitation that reflects the maximum degree of reduction achievable for each pollutant subject to BACT through the application of the selected technology or technique (42 U.S.C. § 7479(3), App. E; 40 C.F.R. § 52.21(b)(12), App. H.).

Given that BACT is an emission limit established on a case-by-case basis, it is impossible to state specifically cite "what is BACT." However, the EPA has produced guidance [4] discussing the control technologies that ought to be considered for GHG BACT. EPA notes that BACT might include efficiency improvements to the physical plant to effectively reduce the emissions rate, fuel switching (to higher heat content fuels or lower emissions fuels), or carbon capture and sequestration.

15. Please see Dr. Fisher's direct testimony at page 31, line 27.

a. If the Companies were to retain only Trimble Co. 1, Ghent 4, and Ghent 2 as suggested in Dr. Fisher's version of the model, what would be the cost imposed on the customers to replace the other generating units?

i. What would the expected rate impacts be in that case for LG&E and KU for each year of the study period?

[4] U.S. Environmental Protection Agency, PSD and Title V Permitting Guidance for Greenhouse Gases (March 2011), available at http://www.epa.gov/nsr/ghgdocs/ghgpermittingguidance.pdf

ii. Does Dr. Fisher recommend that the Companies also retire Trimble Co. 2?

iii. If the replacement energy were derived from natural gas generation, is there adequate gas infrastructure in Kentucky?

iv. If the replacement energy were derived from wind energy, how much capacity would be required to replace the capacity Dr. Fisher suggested would be uneconomic? Where would that wind energy originate? Is there adequate electric transmission infrastructure in place to support that alternative?

v. What would be the impact on the bulk electric system reliability if the transmission infrastructure is not available at the time of the expected compliance deadlines?

RESPONSE: Jeremy Fisher

15a.i. - Intervenors did not carry out an analysis of the rate impacts of the retirement of any of the Companies electric generating units. Interveners note, however, that with regards to Brown Units 1 & 2 and Mill Creek Units 1 & 2, the available evidence shows that CPCNs should be denied because retrofits of those units is not the least cost option. As such, denial of the CPCNs would likely save ratepayers money.

15a.ii. – Interveners did not review retirement of Trimble Unit 2, or recommend any particular retirement.

15a.iii. – Intervenors have not evaluated the extent of natural gas infrastructure in Kentucky at this time. It is unclear that such generation would need to be derived exclusively from Kentucky. A proper approach would be to evaluate a mix of portfolios, with varying levels of wind, energy efficiency, natural gas, and other supply side and demand side resources.

15a.iv. – Intervenors have not evaluated replacement of specific LG&E or KU coal units with wind power. A proper approach would be to evaluate a mix of portfolios, with varying levels of wind, energy efficiency, natural gas, and other supply side and demand side resources.

15a.v. – Intervenors have not evaluated this issue at this time.

16. Please provide the factual basis and supporting documentation for the CO2 price forecast discussed on page 31, lines 1-4, of Dr. Fisher's direct testimony. Please do not provide in response another copy of the Synapse 2011 Carbon Dioxide Price Forecast that was included as Exhibit JIF-4 to Dr. Fisher's testimony; rather, please provide searchable electronic versions of all documents cited in that forecast, as well as any and all other documentation and factual support for the CO2 pricing forecast discussed in Dr. Fisher's testimony.

RESPONSE: Jeremy Fisher, Counsel

Intervenors object to this request because the documents requested are obtainable from publicly available sources that are equally accessible to the Companies. Subject to and without waiving the foregoing objection, Intervenors respond that the" factual basis" for the forecast is set forth in the Synapse 2011 Carbon Dioxide Price Forecast. All documents cited in the 2011 Carbon Dioxide Price Forecast are publicly accessible. Nonetheless, we have provided electronic versions of the non-hyperlinked documents in the attached folder.

17. To the extent not provided in response to DR 16 above, please provide the factual basis and any supporting documentation for Dr. Fisher's statement on page 31, line 3, of his direct testimony, which necessarily implies that CO2 pricing will apply to utilities in Kentucky beginning in 2018.

RESPONSE: Jeremy Fisher

Please see response to Staff Discovery Request 11.

18. Please provide all models, assumptions, and data (in machine readable format) related to the preparation of the AESC natural gas price forecast discussed on page 21 of Dr. Fisher's direct testimony.

RESPONSE: Jeremy Fisher, Counsel

Intervenors object to this request as overly broad and burdensome. Subject to and without waiving the foregoing objection, Intervenors state that this information is not in the possession of the Interveners as they were not involved in the preparation of the AESC natural gas price

forecast. In addition, Dr. Fisher was neither an author nor a participant in the AESC study, and does not have access to this information. Ms. Wilson was an author on the report, but her role in the study was restricted to configuring and operating the Market Analytics (PROSYM) model.

19. Please provide all data and documentation that supports Dr. Fisher's statement on page 19, line 25, of his direct testimony that "most analysts believe that the [natural gas] price will rise slowly over the next two decades."

RESPONSE: Jeremy Fisher

The term "slowly" here is meant in contrast to the Companies' rapidly climbing natural gas price. With the apparent exception of the proprietary reports used by the Companies, other analyses appear to generally place the long-term real price of natural gas at a stable price, or rising only slowly. Please refer to Figure 1 of Dr. Fischer's testimony, the documents cited in footnotes 8-15 of Dr. Fischer's testimony, and the data in Companies' Discovery Request 10.

20. Please refer to Figure 2 on page 22 of Dr. Fisher's direct testimony.

a. Please provide all supporting documentation and assumptions that cause the lower growth rate of natural gas prices beginning in 2016 as compared to 2011 through 2015.

b. Please provide all supporting documentation and assumptions that cause the higher growth rate of natural gas prices beginning in 2022 as compared to 2016 through 2021.

RESPONSE: Jeremy Fisher

The referenced growth rates are from the AESC study. Outside of what is contained in that Study, the supporting documentation and assumptions are not in the possession of the Interveners as they were not involved in the preparation of the AESC natural gas price forecast. In addition, Dr. Fisher was neither an author nor a participant in the AESC study, and does not have access to this information. Ms. Wilson was an author on the report, but her role in the study was restricted to configuring and operating the Market Analytics (PROSYM) model

21. Please provide a list of the "recent legislative proposals to mitigate carbon dioxide (CO2) emissions" described on page 29, lines 8-9, in Dr. Fisher's direct testimony and the current status of those legislative proposals.

RESPONSE: Jeremy Fisher

Intervenors object to this request as information regarding legislative proposals to mitigate carbon dioxide emissions is publicly available and just as easily attainable by the Companies. Subject to and without waiving the foregoing objection, Interveners state that legislative proposals, at a state, regional, and national scale, continue to be pursued, even though federal proposals were not successful in 2009 under the American Clean Energy and Security Act. The Synapse 2011 Carbon Dioxide Forecast describes state and regional initiatives designed to mitigate CO_2 emissions, including twenty one states that are "pursuing a wide variety of policies across the country" (p4).

22. Please provide all documentation that supports the use of CO2 pricing as the basis for compliance with EPA's CO2 BACT regulations.

RESPONSE: Jeremy Fisher

Carbon dioxide pricing could not serve as the basis for compliance with EPA's CO2 BACT regulations. As noted above, BACT is an emission limit based on the best available control technology that is established on a case-by-case basis. Thus CO_2 pricing could never constitute BACT. However, the implementation of BACT controls, as discussed in Response to Companies' Discovery Request 14, would impose a cost on the unit under consideration – either in capital expenditures, increases in fuel costs, operational and maintenance costs, or combinations thereof. Therefore, both legislative action implementing a greenhouse gas pricing

mechanism or regulatory action by the EPA (including promulgated rules) "could reasonably impose a cost on the emissions of CO_2."

Based on this question, it seems that the Companies conflated two separate arguments that I raised in my testimony. The Companies had projected zero compliance costs related to the fleets greenhouse gas emissions. Such an assumption is unreasonable.

23. Please provide all documentation for Dr. Fisher's statement on page 36, lines 27-28, of his direct testimony, "In reality, the Companies are very well interconnected with their neighbors ...."

RESPONSE: Jeremy Fisher

According to the North American Reliability Corporation (NERC) control area bubble diagram (10/3/2011),[5] The KU/LG&E system at the juncture of two major RTOs (PJM and MISO) and is connected to the Ohio Valley Electric Corporation (OVEC), the Tennessee Valley Authority (TVA), the East Kentucky Power Cooperative (EKPC), and Electric Energy, Inc (EEI). Indeed, the ITO Semi-Annual Report from March 2011 – August 2011, filed by the Southwest Power Pool on September 30th, 2011,[6] lists numerous paths between the LGEE system and neighboring balancing authorities, including EEI, EKPC, MISO, PJM, and TVA.

24. Please provide all documentation supporting Dr. Fisher's statements on page 37, lines 3-7, of his direct testimony regarding the Companies' ability to purchase energy for "short periods" and for "fairly limited capacity requirements." How does he define "short" and "limited"?

RESPONSE: Jeremy Fisher

Intervenors object to this request on the grounds that it mischaracterizes Dr. Fisher's testimony. Subject to and without waiving this objection, Interveners state that Dr. Fisher's testimony on

[5] NERC, 2011. Regions and Balancing Authorities. http://www.nerc.com/docs/oc/rs/BA_BubbleDiagram_2011-10-03.jpg

[6] Available at: http://www.spp.org/publications/ITO%20Semi-Annual%20Report%20March%202011-%20August%202011.pdf

this point reads "...purchasing power from others... would present additional resources that could play a part in the energy mix replacing the generation that would otherwise [would] have come from the retired units over at least short periods of time or for fairly limited capacity requirements."

Interveners' testimony in this statement is that in modeling no transactions with neighboring utilities, the Companies have produced potentially erroneous findings because the Companies can and do currently purchase energy from their neighbors. The Company is in a far better position to state the extent to which they can purchase energy from wholesale markets or through bilateral contracts.

25. What is a "sustainability target" level of CO2 emissions as used on page 1-19 in the report referenced in footnote 15 on page 20 of Dr. Fisher's direct testimony?

RESPONSE: Jeremy Fisher

In the referenced AESC 2011 report, the sustainability target concept is described as follows (Pages 6-93 – 6-94):

> "The cost of control approach can also be based upon a "sustainability target" concept. With the sustainability target, we start with a level of damage or risk that is considered to be acceptable, and then estimate the marginal cost of achieving that target. It is important to note that, at this stage in our collective understanding of the science of climate change, as well as its social, economic, and physical impacts, the notion of a "sustainability target" is a construct useful for discussion, but not yet firmly established.
>
> The "sustainability target" approach relies on the assumption that the nations of the world will not tolerate unlimited damages. It also relies partly on an expectation that policy leaders will realize that it is cheaper to reduce emissions now and achieve a sustainability

target than it is not to address climate change. It is worth noting that a cost estimate based on a sustainability target will be a bit lower than a damage cost estimate because the "sustainability target" is going to be a calculus of what climate change the planet is already committed to, and what additional change we are willing to live with (again complicated by the fact that different regions will see different impacts, and have different ideas about what is dangerous and what is sustainable)."

The target utilized in the AESC report is based on not exceeding a temperature rise of 2°C above 2005 global average temperatures.

26. Please refer to Figure 1 on page 21 and Figure 2 on page 22 of Dr. Fisher's direct testimony.

a. Please provide the underlying data in machine readable tabular format for each of the forecasts shown on Figure 1 and Figure 2.

b. Please state and explain the assumptions included in the AESC 2011 Henry Hub natural gas price forecast concerning the existing and proposed environmental regulations that are discussed on pages 11 and 12 of Dr. Fisher's testimony (Section 3: Environmental Regulations Faced by LG&E/KU).

i. Are those assumptions consistent or inconsistent with the assumptions Dr. Fisher made regarding the same environmental regulations in the other parts of his analysis of the Companies' filing? Please explain in detail.

ii. If Dr. Fisher's assumptions about the environmental regulations discussed at pages 11-12 of his direct testimony are correct, will the likely effect of such regulations be to increase or decrease electrical generation's contribution to the demand for natural gas? Will that likely affect on natural gas demand tend to increase or decrease natural gas prices? Please explain in detail.

c. Explain the underlying assumptions for CO2 regulations included in the AESC 2011 Henry Hub natural gas price forecast and explain whether those assumptions are consistent or inconsistent with the assumptions regarding CO2 regulations made by Dr. Fisher in the other aspects of his analysis of the Companies' filing.

RESPONSE: Jeremy Fisher

a. Please see response to Companies' Discovery Request 11

b. As found in the AESC report on pages 2-14 through 2-19 (section 2.2.3) and in Appendix C of the report, the environmental regulations reviewed include the [proposed] Clean Air Transport Rule, the Air Toxics [Rule], proposed Coal Combustion Residuals mitigation and regulation, the proposed water intake rule, the Regional Haze Rule, and RGGI and possible federal CO_2 regulations. While the report makes reference to PM, ozone, SO2, and NOx National Ambient Air Quality Standards (NAAQS), it does not include an extensive discussion of the implications of these regulations. The regulations inform, in part, the assumption of coal unit retirements over the analysis period, as seen in Exhibit 2-8 and sections 2-31 through 2-35.

   i. These assumptions are generally consistent with the assumptions made in my testimony. The Clean Air Transport Rule (CATR), as proposed, applied to two New England states (MA and CT). The final Cross State Air Pollution Rule (CSAPR) does not apply to New England states. The assumed emissions allowance prices for NOx and SO2 in Exhibit 2-3 were based on assumptions made by the model vendor (Ventyx) based on the CATR. These emissions prices may need to be re-evaluated in light of New England's exclusion from the final rule.

   ii. Several groups, including the North American Reliability Corporation (NERC), Brattle, Bernstein, Credit Suisse, and Deutsche Bank, have all predicted that a suite of existing, proposed, and pending environmental regulations will lead to coal plant retirements. Intervenors are producing the reports referenced herein. Most of these projections have implied (although rarely explicitly) that the likely replacement power for retiring coal units will be natural gas fired. However,

decisions regarding replacement power, and which generators will produce that power (new or existing) will ultimately be made on a utility by utility basis. Similarly to the KU/LG&E analysis results that predict that both coal and gas will pick up load requirements after retirements, it is probable that a combination of existing resources (both economic coal and gas) as well as new resources of multiple forms (including demand-side management) will meet requirements. Consequently, the impact on natural gas prices is uncertain at this time without comprehensive system modeling, which was not conducted for this docket. One would have to evaluate if the amount of new gas generation resulting from economic coal retirements was sufficient to have a significant impact on gas demand, and hence prices.

c. The base case CO_2 prices utilized in the AESC report are consistent with the "Mid Case" of the Synapse 2011 Carbon Dioxide Price Forecast, and hence with Dr. Fisher's testimony. There is one exceptions to this consistency, not directly relevant to this proceeding: the AESC report has carried the current RGGI market price for CO_2 through to 2017, at which point it is assumed that federal legislation pre-empts RGGI.

27. Please refer to the document titled "Avoided Energy Supply Costs in New England: 2011 Report," dated July 21, 2011 (as referenced in Footnote 15 on page 20 of Dr. Fisher's direct testimony), which provides the basis for Dr. Fisher's recommended gas forecast labeled "AESC 2011" in Figure 1 on page 21 of Dr. Fisher's testimony.

a. Please describe the intended purpose of this report and explain if it has been used by the sponsoring utilities in their analysis of the construction of emissions controls and/or coal unit retirements.

b. Please provide the underlying data in machine readable tabular format for the following exhibits.

i. Chapter 1 – Exhibits 1-2, 1-3, 1-5, 1-14, 1-15, and 1-16

ii. Chapter 3 – Exhibits 3-4, 3-6, 3-8, 3-9, 3-10, 3-11, 3-12, 3-13, 3-14, 3-15

c. Referring to Exhibit 3-4 on page 3-9, please demonstrate how the monthly NYMEX futures gas prices were converted to the annual 2010 dollar values shown as part of the AESC 2011 forecast in Figure 1 on page 21 of Dr. Fisher's testimony. Please provide all assumptions made and workpapers used in that process.

d. Referring to page 3-14, please provide all documentation supporting the statement that "Our total uses a 50-50 weighting based on judgment and the approximate quantities of each category of reserves reported for 2010." Please explain the degree to which judgment was used in this process and demonstrate why the 50-50 weighting was judged to be appropriate.

e. Referring to page 3-14, please refer to the statement that "The net result of the rule changes is not clear but it may have increased PUDs." Please explain how this ambiguity around the impact of SEC rule changes was incorporated in the AESC 2011 Base Case gas price forecast or in the High Price or Low Price cases.

f. Referring to page 3-17, please refer to the following excerpt:

"There is some indication that the supply of natural gas from the U.S. may decline. The independent producers, particularly the large ones such as Chesapeake, Devon and EOG Resources, all plan to shift exploration and drilling to U.S. places where production will be liquids rich either for crude oil and condensate or at least larger volume NGL production associated with natural gas production. They plan to reduce drilling for dry gas. This shift appears to be under way."

Please explain how this ongoing shift in gas supply is incorporated in the AESC 2011 gas price forecast.

g. Referring to page 3-17, please refer to the statement that "The next step in developing a forecast of annual Henry Hub natural-gas prices is to review the forecasts available from AEO 2011 and AEO 2010 to determine which forecast is most consistent with our estimate of the Henry Hub price needed to cover the full-cost of shale gas." Please explain whether the AESC 2011 forecast is based on the assumptions in a specific AEO forecast or if a specific AEO forecast was chosen due to its similarity in results to Synapse's cost estimates.

h. Referring to page 3-18, please provide all documentation supporting the choice of the AEO 2010 High Shale Case as the basis for the AESC 2011 Base Case. Please explain the underlying assumption(s) for the size of the shale gas resource used.

i. Referring to page 3-20, please refer to the statement that "The estimate of the marginal cost of shale gas implicit in the various AEO 2011 cases are significantly less than our estimate of the full-cycle, all-in cost of finding, developing and producing shale gas." Does this statement imply that the AEO 2011 cases are less reliable than the AEO 2010 cases? How does Synapse ensure its cost estimates are more accurate than those in the AEO?

j. Referring to page 3-25, please refer to the statement, "The AESC High Price Case is drawn from the AEO 2010 Slow Oil & Gas Technology case." Please provide all documentation supporting the choice of this case as the "AESC 2011 High Price Case" compared to other potential AEO cases or compared to other forecasts considered by Synapse.

k. Referring to pages 3-25 and 3-26, please refer to the discussion of the "AESC 2011 Low Price Case."

i. Please refer to the statement on page 3-25, "The AESC 2011 Low Price case assumes a decrease in finding, development and production costs for natural gas due to developments in oil and gas technology 50% more rapid than in the Base Case." Please provide all documentation that supports using the 50% factor.

ii. Please explain why it is appropriate to use several forecasts and methods to develop the Low Price case over the different time periods of the forecast compared to using single AEO forecasts for the Base Case and High Price Case.

l. Referring to page 3-29, please refer to the statement, "However, other than the disclosure of chemicals in fracturing fluid, our review of the literature did not find any public projections of specific changes in existing Federal, state and local regulations, including scope and timing, from which to develop a credible estimate of a material impact on the cost of shale gas production." Please explain if any potential regulations regarding shale gas development were considered in the AESC 2011 Base Case, Low Price Case, or High Price Case. Also, please explain how this level of consideration is or is not appropriate and how it is or is not consistent with Dr. Fisher's expectations regarding other potential environmental regulations set forth in his testimony.

m. Please refer to the discussion on page 34 concerning the methodology used to quantify Henry Hub price volatility as shown in Exhibit 3-15. Please explain if this approach for measuring volatility is standard practice, and please cite other references in which this approach has been used.

RESPONSE: Jeremy Fisher, Counsel

Intervenors object that the information requested in Request 27 is not in their possession or control, as the Interveners were not involved in the preparation of the AESC natural gas price forecast. In addition, Dr. Fisher was neither an author nor a participant in the AESC study, and does not have access to this information. Ms. Wilson was an author on the report, but her role in the study was restricted to configuring and operating the Market Analytics (PROSYM) model. Subject to and without waiving this objection, Interveners respond as follows:

Dr. Fisher chose to use the AESC forecast simply for internal consistency with the latest Synapse research. The forecast was prepared by an expert contracting with Synapse, and was vetted by the utilities and companies participating in the research. Interveners would not object should the Companies instead choose to use a vetted public forecast, or, more specifically, a range of forecasts, such as are provided by the EIA in the Annual Energy Outlook.

While the question does not ask for Interveners' review of the Companies' behavior with regard to natural gas forecasts, it is worth noting that Synapse has provided a forecast of natural gas prices with significant documentation and explanation. The forecast and its underlying

assumptions and basis are open for examination by the Companies, Staff, other interveners, and the public. The same cannot be said for the forecast provided by the Companies.[7]

a. The AESC 2011 report describes its purpose in the first sentence of the executive summary: "This 2011 Avoided-Energy-Supply-Component Study ("AESC 2011," or "the Study") provides projections of marginal energy supply costs that will be avoided due to reductions in the use of electricity, natural gas, and other fuels resulting from energy efficiency programs offered to customers throughout New England." It is unknown if the sponsoring utilities, including both gas providers and electric utilities, have used this report or component parts "in their analysis of the construction of emissions controls and/or coal unit retirements."

b. See objection above.

c. See objection above. Subject to and without waiving the foregoing objection, Intervenors state that the forecast used in Dr. Fisher's testimony was extracted from Exhibit D-4 of the AESC 2011 report, column "Annual Henry Hub Price" in 2011$. See attachment to response to Question 11 for dollar conversion factors.

d. See b, above.

e. See b, above.

f. See b, above.

g. See b, above. Subject to and without waiving the foregoing objection, please see section 3.2.2.2 of the AESC 2011 report.

[7] The Companies only provided fuel price forecasts as ancillary information in response to intervener discovery. The Companies appear to have changed this forecast in a Supplemental Analysis supplied only 48 hours before intervener testimony, and yet have even redacted even the final gas price forecast from confidential documents. There is no accompanying documentation supporting these forecasts, and the references the forecasts are only given annual dates (2011), although it is clear that all three consultancies regularly update their medium and long-term forecasts as required, even if more regularly than on an annual basis.

h. See b, above.

i. See b, above.

j. See b, above. Subject to and without waiving the foregoing objection, please note that the "High Natural Gas Price" is roughly similar to the Wood Mackenize price trajectory used by the Companies in the Supplemental Analysis.

k. See b, above.

l. See b, above. Subject to and without waiving the foregoing objection, Intervenors state that in regards to the second clause of this discovery request, due consideration should be given to the mitigation of environmental and safety concerns from natural gas extraction. However, as the quoted statement implies, it is not clear what form environmental regulations might take in natural gas drilling, and we are not aware of price projections that explicitly take into account these unknown regulations. In September 2011, the New York State Department of Environmental Conservation released a revised Draft Supplemental Generic Environmental Impact Statement (SGEIS) on the environmental concerns associated with shale gas production and "fracking", as well as potential mitigation opportunities.[8] It is unclear how the mitigation measures would impact long-term natural gas price forecasts, if at all.

m. See b, above.

[8] Revised Draft SGEIS on the Oil, Gas and Solution Mining Regulatory Program (September 2011). http://www.dec.ny.gov/energy/75370.html

28. Please refer to Dr. Fisher's direct testimony at page 13, lines 1-3. Please explain in detail the "few critical exceptions."

RESPONSE: Jeremy Fisher

Please see Q&A in Fisher direct testimony at 14, lines 8-25, and at 15, lines 1 -13. The Companies have not accounted for ozone NAAQS, the expected emissions prices for CSAPR, the expected 316(b) ruling on water intake structures, or greenhouse gas emissions.

29. Please refer to Dr. Fisher's direct testimony at page 13, lines 10-11. Please provide all analysis that shows the controls included in the 2011 Plan are "not necessarily sufficient." Provide in detail what additional controls are necessary, including the timing of installation, technology, costs, and any other details concerning the control equipment.

RESPONSE: Jeremy Fisher

Dr. Fisher's testimony identifies environmental regulations that may impact the Companies' coal fleet but that are not considered in the Companies' submitted analysis. Interveners have not analyzed exactly what controls those regulations would require, as the Company is more appropriately equipped to conduct this analysis and bears the burden of demonstrating that the full costs facing its coal units are evaluated as part of this proceeding.

30. Please refer to Dr. Fisher's direct testimony at page 23, lines 10-16. Are there other technologies other than SCR for controlling NOx emissions? Did Dr. Fisher consider any other technology? Please explain which other technologies Dr. Fisher considered. If he did not consider any other technologies, please explain why he did not do so.

RESPONSE: Jeremy Fisher

There are several standard technologies for controlling NOx emissions, including low-NOx burners, overfire air combustion, SCR, and SNCR. Appendix D of the E.ON US Coal Fired Fleet Wide Air Quality Control Technology Assessment provides a sufficient technical discussion of

these technologies. Generally, SCR is considered a highly effective technology for reducing NOx emissions.

31. Please refer to Dr. Fisher's direct testimony at page 26, lines 5-7. Please provide all analysis supporting the statement, "[T]he operational plants that do not have SCR will require this control technology (Brown 1 & 2, Ghent 2, and Mill Creek 1 & 2), to meet local attainment." If no analysis was performed, what is the basis for the statement made?

RESPONSE: Jeremy Fisher

Please see response to Commission Staff Discovery Request 9a.

32. Please refer to Dr. Fisher's direct testimony at page 27, lines 18-20. Please provide all analysis supporting the statement, "[T]he ozone NAAQS will require SCR on the Companies coal plants." If no analysis was performed, what is the basis for the statement?

RESPONSE: Jeremy Fisher

Please see response to Commission Staff Discovery Request 9a.

33. Please refer to Dr. Fisher's direct testimony at page 33, lines 7-11. For each of the five concerns listed, please provide all documentation, analysis, and reports that justify and validate each concern.

RESPONSE: Jeremy Fisher

Please refer to Dr. Fisher's direct testimony, pages 33 through 40. Also, see responses to Companies' Discovery Requests 3, 4, 23, and 24, and response to Staff Discovery Request 2.

34. Please refer to Rachel Wilson's direct testimony at page 5. Please provide all output reports and documents that demonstrate in detail that she was "able to exactly reproduce the Companies' results."

RESPONSE: Rachel Wilson

Please see attached data files in subfolder "KU Replication". Note version release date (September 7, 2011). Files were opened and re-saved during discovery process, so timestamps in REP files read 10/12/2011. If requested, Synapse can provide on-site verification that the Strategist model, as operated at Synapse, can "exactly reproduce the Companies' results."

Respectfully submitted,

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Dated: October 13, 2011

BEFORE THE KENTUCKY PUBLIC SERVICE COMMISSION

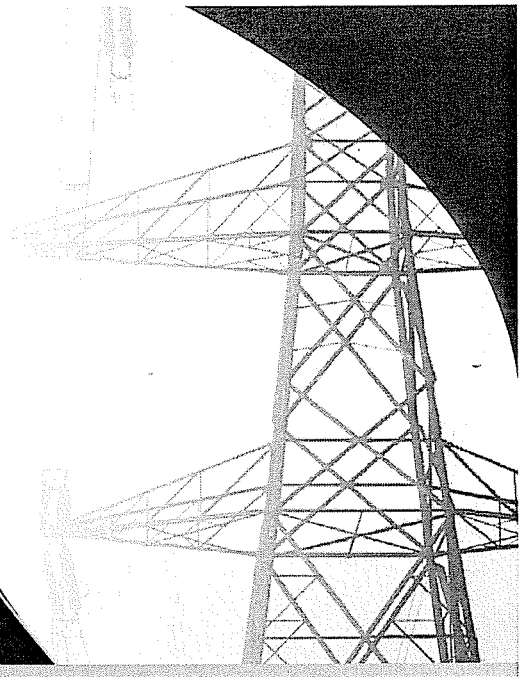
Docket Nos. 2011-00161 and 2011-00162

Environmental Intervenors' Responses and Supporting Attachments to September 30, 2011 Data Requests by Louisville Gas and Electric Company and Kentucky Utilities Company

Attachment in Response to Question 1B

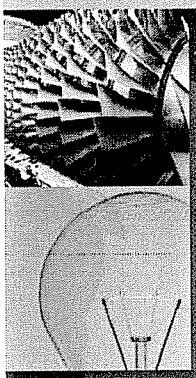
NERC

NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION



2010 Special Reliability Scenario Assessment:

Resource Adequacy Impacts of Potential U.S. Environmental Regulations



October 2010

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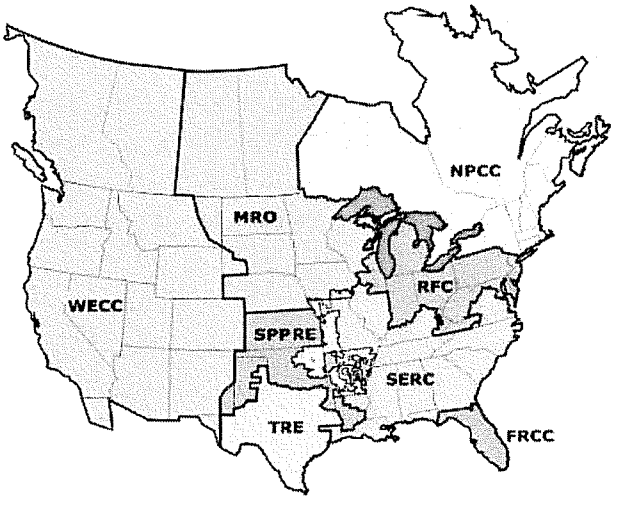
to ensure
the **reliability** of the
bulk power system

NERC's Mission

The North American Electric Reliability Corporation (NERC) is an international regulatory authority established to evaluate reliability of the bulk power system in North America. NERC develops and enforces Reliability Standards; assesses adequacy annually via a 10-year forecast and winter and summer forecasts; monitors the bulk power system; and educates, trains, and certifies industry personnel. NERC is the electric reliability organization for North America, subject to oversight by the U.S. Federal Energy Regulatory Commission (FERC) and governmental authorities in Canada.[1]

NERC assesses and reports on the reliability and adequacy of the North American bulk power system, which is divided into eight Regional areas, as shown on the map below and listed in Table A. The users, owners, and operators of the bulk power system within these areas account for virtually all the electricity supplied in the U.S., Canada, and a portion of Baja California Norte, México.



Note: *The highlighted area between SPP and SERC denotes overlapping Regional area boundaries. For example, some load serving entities participate in one Region and their associated transmission owner/operators in another.*

Table A: NERC Regional Entities

FRCC Florida Reliability Coordinating Council	SERC SERC Reliability Corporation
MRO Midwest Reliability Organization	SPP RE Southwest Power Pool Regional Entity
NPCC Northeast Power Coordinating Council	TRE Texas Reliability Entity
RFC Reliability*First* Corporation	WECC Western Electricity Coordinating Council

[1] As of June 18, 2007, the U.S. Federal Energy Regulatory Commission (FERC) granted NERC the legal authority to enforce Reliability Standards with all U.S. users, owners, and operators of the BPS, and made compliance with those standards mandatory and enforceable. In Canada, NERC presently has memorandums of understanding in place with provincial authorities in Ontario, New Brunswick, Nova Scotia, Québec, and Saskatchewan, and with the Canadian National Energy Board. NERC standards are mandatory and enforceable in Ontario and New Brunswick as a matter of provincial law. NERC has an agreement with Manitoba Hydro making reliability standards mandatory for that entity, and Manitoba has recently adopted legislation setting out a framework for standards to become mandatory for users, owners, and operators in the province. In addition, NERC has been designated as the "electric reliability organization" under Alberta's Transportation Regulation, and certain reliability standards have been approved in that jurisdiction; others are pending. NERC and NPCC have been recognized as standards-setting bodies by the *Régie de l'énergie* of Québec, and Québec has the framework in place for reliability standards to become mandatory. Nova Scotia and British Columbia also have frameworks in place for reliability standards to become mandatory and enforceable. NERC is working with the other governmental authorities in Canada to achieve equivalent recognition.

Table of Contents

Executive Summary

In the United States, several regulations are in the process of being proposed by the U.S. Environmental Protection Agency (EPA) that directly affect the electric industry. Depending on the outcome of any or all of these potential regulations, the results could accelerate the retirement of a significant number of fossil fuel-fired power plants. EPA is currently developing rules that would mandate existing power suppliers to either invest in retrofitted environmental controls at existing generating plants or retire them. The most significant proposed EPA rules have been in development for over ten years and are currently undergoing court-ordered revisions that must be implemented within mandatory timeframes.

The results of this assessment show a significant potential impact to reliability should the four EPA rules be implemented as proposed. The reliability impact will be dependent on whether sufficient replacement capacity can be added in a timely manner to replace the generation capacity that is retired or lost because of the implementation of these rules. Implementation of the rules must allow sufficient time to construct new capacity or retrofit existing capacity. Planning Reserve Margins appear to be significantly impacted, deteriorating resource adequacy in a majority of the NERC Regions/subregions. In this scenario, reduced Planning Reserve Margins are a result of a loss of up to 19 percent of fossil fuel-fired steam capacity in the United States by 2018.[2] Additionally, considerable operational challenges will exist in managing, coordinating, and scheduling an industry-wide environmental control retrofit effort.

This assessment examines four potential EPA rulemaking proceedings that could result in unit retirements or forced retrofits between 2013 and 2018. Specifically, the rules under development include:

1. Clean Water Act – Section 316(b), Cooling Water Intake Structures
2. Title I of the Clean Air Act – National Emission Standards for Hazardous Air Pollutants (NESHAP) for the electric power industry (referred to herein as Maximum Achievable Control Technology (MACT) Standard)
3. Clean Air Transport Rule (CATR)
4. Coal Combustion Residuals (CCR) Disposal Regulations

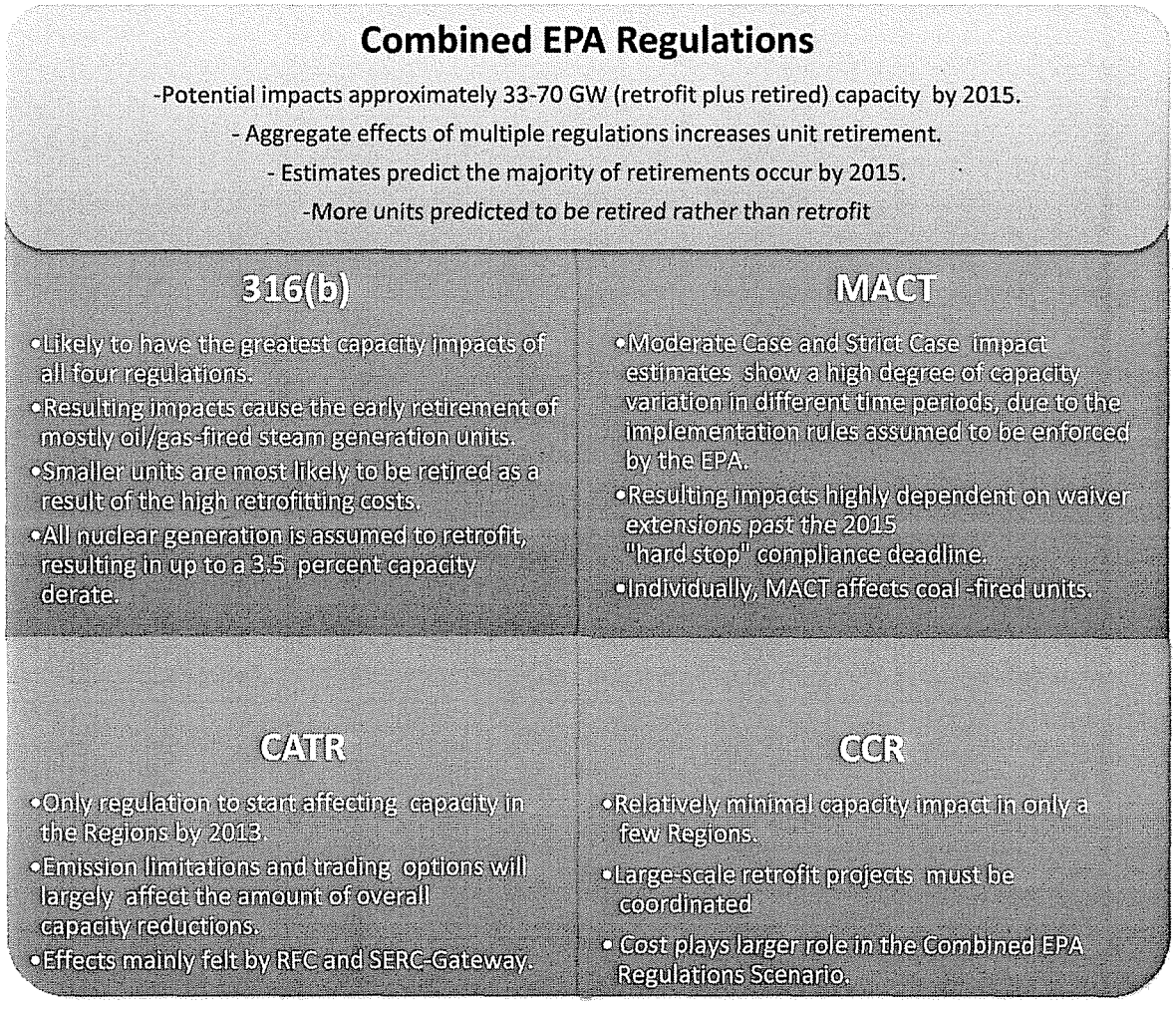
This assessment is designed to evaluate the potential impacts on Planning Reserve Margins, assuming that there would be no industry actions in the near term to address compliance issues or market response, and identify the need for additional resources that may arise in light of industry responses to each of these environmental regulations individually and in aggregate. Additionally, this assessment considers the number of generating units requiring retrofitting by NERC Region and subregion to demonstrate the magnitude of construction planning necessary for compliance in a timely fashion. The assessment relies on two separate scenario cases for each proposed rule, calculating the amount of capacity reductions due to accelerating unit retirements and increased station loads needed to power the additional environmental controls. For each

[2] A 19 percent reduction represents the results of the total capacity loss in the Strict Case for 2018 as a percentage of the total coal, gas, and oil steam units included in the 2009 Long-Term Reliability Assessment Reference Case. Refer to Appendix III and IV for details values.

proposed EPA rule and in aggregate, units were retired for this assessment based on an agreed upon cost calculation.[3]

Two scenario cases (Moderate Case and Strict Case) provide a range of sensitivities, with the Strict Case incorporating more stringent rule assumptions and higher compliance costs. The potential impacts of greenhouse gas (GHG) legislation are not considered in this assessment, but have been discussed separately in a recent NERC report.[4] Overall, the impact on reliability is a function of the timeline for finalizing the rules and ensuring compliance with the potential EPA regulations. The reliability impact of these rules will be dependent on whether sufficient replacement capacity can be added in a timely manner to replace the generation capacity that is retired or lost because of the implementation of these rules. This assessment does not account for industry's ability to acquire, construct, or finance replacement resources; however, implementation of the rules must allow sufficient time to construct new capacity or retrofit existing capacity.

Figure A: Summary and Highlights of the Four EPA Regulations Assessed[5]

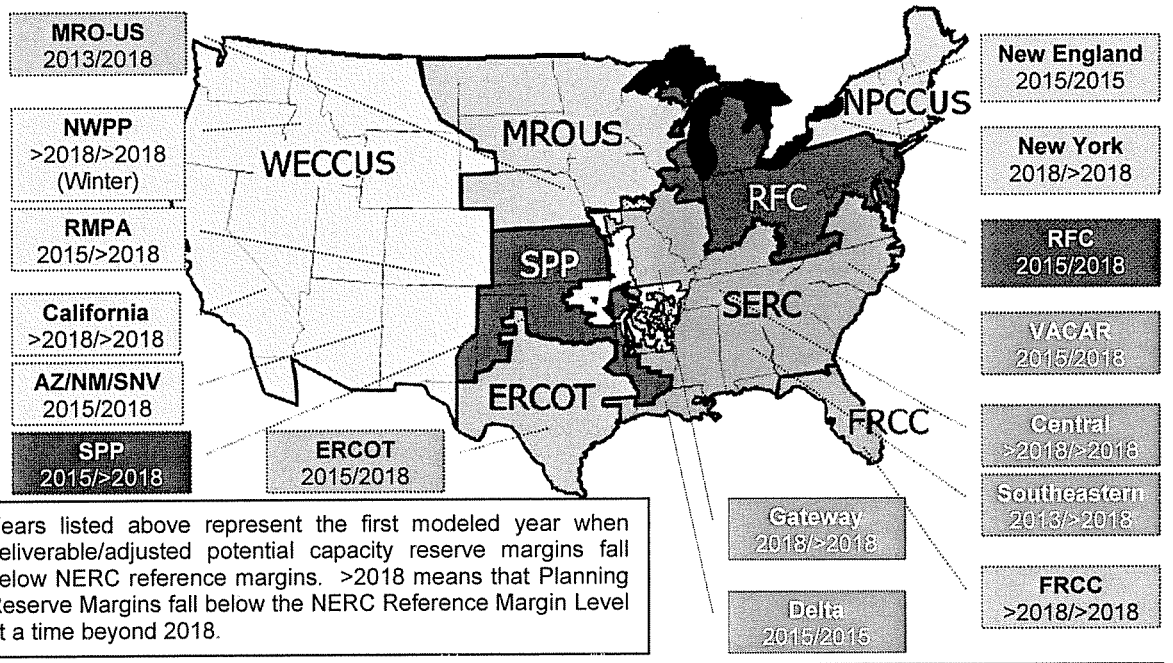


[3] Unit is retired if (CC+FC+VC) / (1-DR) > RC, where: CC = required compliance cost in $/MWH, FC = current fixed O&M in $/MWH, VC = variable O&M including fuel cost in $/MWH, RC = replacement cost in $/MWH and DR = derate factor that accounts for the incremental energy loss due to any new environmental controls. See *Appendix I, Assessment Methods*.

[4] http://www.nerc.com/files/RICCI_2010.pdf

[5] Individual EPA Regulations are listed in order of greatest potential impact to least top to bottom, left to right.

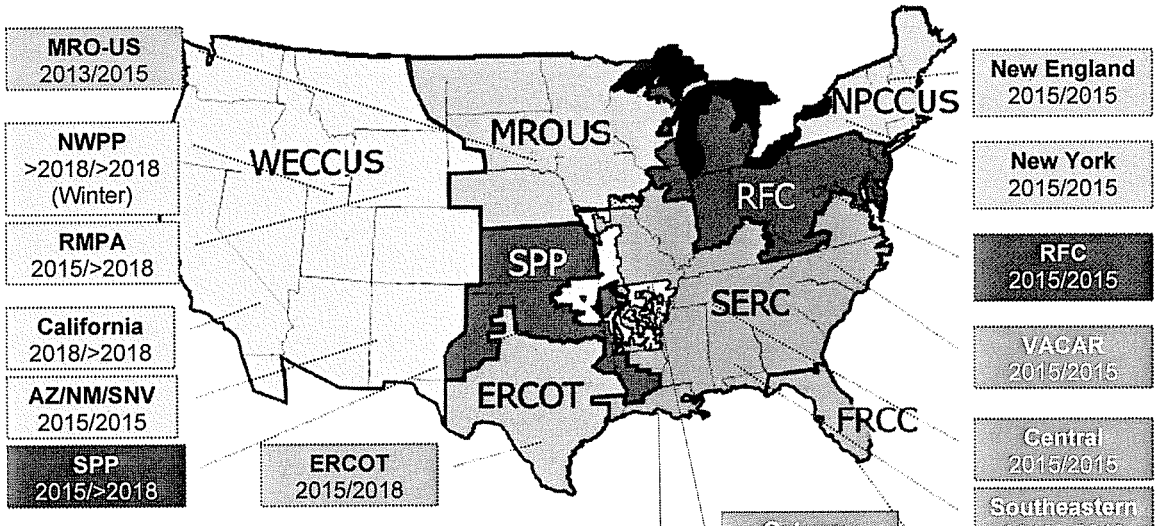
Figure B: Moderate Case Deliverable and Adjusted Potential Resources Reserve Margins Compared to NERC's Reference Margin Level



Years listed above represent the first modeled year when deliverable/adjusted potential capacity reserve margins fall below NERC reference margins. >2018 means that Planning Reserve Margins fall below the NERC Reference Margin Level at a time beyond 2018.

Deliverable Reserve Margin – Existing and Future-Planned Resources
Adjusted Potential Reserve Margin – Existing, Future-Planned, and Adjusted Potential Resources (Conceptual resources adjusted by a confidence factor)

Figure C: Strict Case Deliverable and Adjusted Potential Resources Reserve Margins Compared to NERC's Reference Margin Level



Years listed above represent the first modeled year when deliverable/adjusted potential capacity reserve margins fall below NERC reference margins. >2018 means that Planning Reserve Margins fall below the NERC Reference Margin Level at a time beyond 2018.

Proposed EPA Regulations May Have Significant Impacts on Forecast Planning Reserve Margins

Without additional power production or demand-side resources beyond those in current regional plans, the combined effects of the four EPA rules (Combined EPA Regulation Scenario) are shown to significantly affect Planning Reserve Margins and, in most Regions/subregions, more resources would be required to maintain NERC Reference Margin Levels. Up to a 78 GW reduction of coal, oil, and gas-fired generating capacity is identified for retirement during the ten-year period of this scenario. For the Moderate Case, this occurs in 2018; however, in the Strict Case a similar reduction occurs in 2015. The reduction in capacity significantly affects projected Planning Reserve Margins for a majority of the NERC Regions and subregions. Potentially significant reductions in capacity within a five-year period may require the addition of resources. For the United States as a whole, the Planning Reserve Margin is significantly reduced by nearly 9.3 percentage points in the Strict Case, significantly deteriorating future bulk power system reliability.

Rule Implementation Timeline Should Consider Reliability Impacts

Overall, impacts on Planning Reserve Margins and the need for more resources is a function of the compliance timeline associated with the potential EPA regulations. The Combined EPA Regulation Scenario affects a large amount of units, affecting some Regions more significantly than others. Based on the assessment's assumptions, the greatest risk to Planning Reserve Margins occurs by 2015 in the Combined EPA Regulation Scenario. The majority of the impacts will be seen within the next five years, requiring additional resources in a short timeframe. This situation is compounded by the large number of electric generation units that are likely to retrofit with environmental controls, as well as the convergence of overlapping replacement/retrofit generation capacity projects and heavy U.S. infrastructure projects in other sectors. Potential constraints of skilled construction labor, material shortages, financing, and escalation of compliance costs coupled with coordination of overlapping outages resulting in congestion expenses could present challenges in meeting the compressed time schedule.

Individually, the Section 316(b) Cooling Water Intake Structures Rule Has the Greatest Potential Impact on Planning Reserve Margins

Implementation of this rule will apply to 252 GW (1,201 units) of coal, oil steam, and gas steam generating units across the United States, as well as approximately 60 GW of nuclear capacity (approximately a third of all resources in the U.S.). Of this capacity, 33-36 GW (see Figure D) may be economically vulnerable to retirement if the proposed EPA rule requires power suppliers to convert to recirculating cooling water systems in order to continue operations. The remaining capacity may also be converted assuming it is unaffected by other proposed rules, resulting in a 5 GW derating across the United States. Therefore, the total capacity vulnerable to retirement increases to 37-41 GW. Planning Reserve Margins in almost half of NERC Regions/subregions are below the NERC Reference Margin Level by 2015. For example, in this scenario, Planning Reserve Margins are decreased by 18 percentage points in the SERC-Delta subregion, where the margin falls below zero. Other Regions/subregions significantly affected subregions include NPCC-New England and New York.

The MACT, CATR, and CCR Rules Also Contribute to Reductions in Capacity

Ranked in descending order of impact severity, the regulatory impacts of MACT, CATR and finally CCR on retirements, individually also accelerate retirements and will mostly affect existing coal-fired capacity:

- The **MACT Rule** considered alone could drive Planning Reserve Margins of 8 regions/subregions below the NERC Reference Margin Levels standards and trigger the retirement of 2-15 GW (Moderate to Strict Cases) of existing coal capacity by 2015. To comply, owners of the remaining capacity need to retrofit from 277 to 753 units with added environmental controls. The "hard stop" 2015 compliance deadline proposed by the MACT Rule makes retrofit timing a significant issue and potentially problematic.

- The **CATR** could have significant impacts as soon as 2015 should EPA require emission limits with no offset trading, resulting in potentially 3-7 GW of potential retirements and derated capacity, requiring retrofitting of 28-576 plants with environmental controls by 2015 (Moderate to Strict Cases). Planning Reserve Margins are affected most in the SERC-Gateway subregion with reductions starting in 2013.

- The **CCR Rule** alone is projected to have the least impact, triggering the retirement of up to 12 coal units (388 MW). Cost sensitivity assessment for CCR reveals that retirements could reach capacity of 2 GW (53 units) should costs exceed the assessment's Strict Case expenditure estimate by a factor of ten. While the resulting impacts of the CCR scenario may not have significant impacts to capacity by themselves, the associated compliance costs of CCR contribute to the Combined EPA Regulation Scenario.

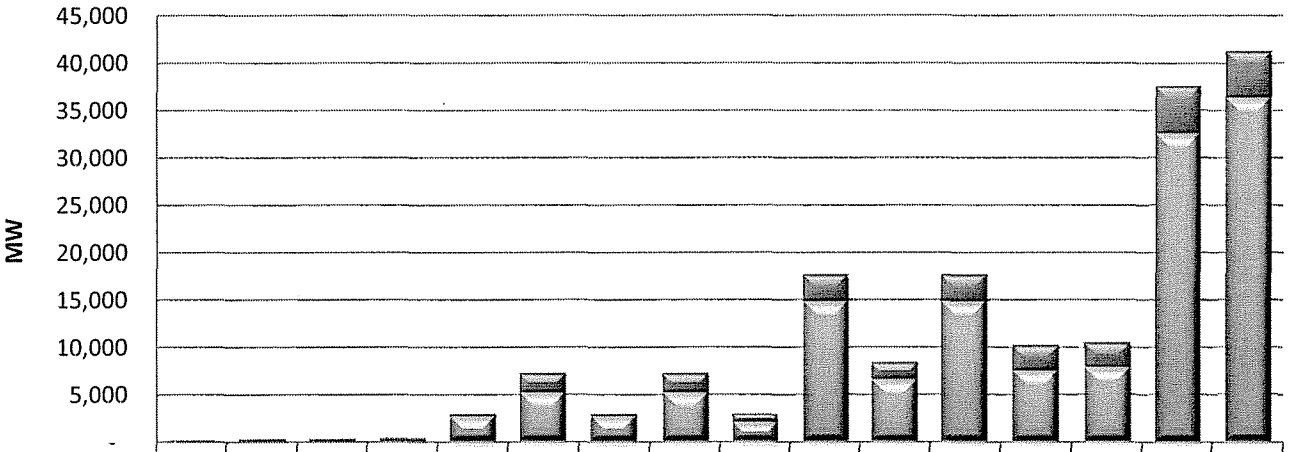
EPA Regulations Create a Need for Prompt Industry Response and Action

This report also identifies a number of tools the industry has for mitigating potential reliability impacts from the implementation of EPA regulations. For example, advancing Future or Conceptual resource in-service dates or the addition of new resources not yet proposed could help partially alleviate projected capacity losses in severely affected regions. Price signaling for the need of new resources will be important.

Industry coordination will be vital to ensure retrofits are completed in a way that does not diminish reliability. In addition, statutory and regulatory safeguards also allow the EPA, the President of the United States, and the Department of Energy to extend or waive compliance under certain circumstances. Implementing these industry and regulatory tools may be critical to maintain the reliability of the bulk power system.

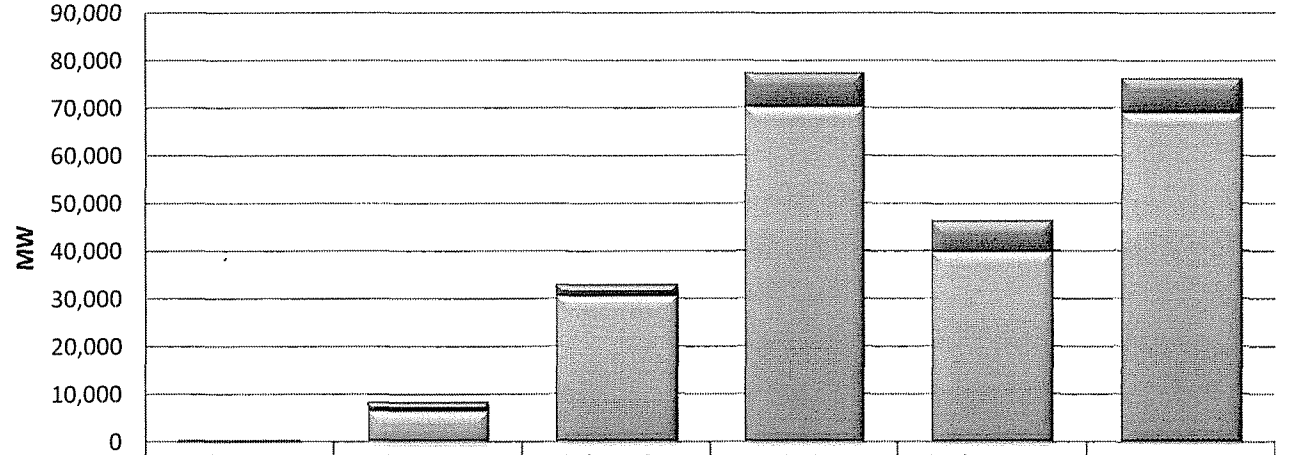
Second tier effects, including generation deliverability or stability impacts, must also be considered. For example, transmission system construction, enhancements, reconfiguration and development of new operating procedures may be necessary in some areas, all of which can create additional timing considerations.

Figure D: Potential Capacity Reduction Impacts Due to Each Potential EPA Regulation



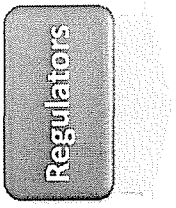
	CCR				CATR				MACT				316(b)			
	2015		2018		2015		2018		2015		2018		2015		2018	
	M Case	S Case	M Case	S Case	M Case	S Case	M Case	S Case	M Case	S Case	M Case	S Case	M Case	S Case	M Case	S Case
Derate (MW)	0	0	0	0	142	1,952	142	1,952	806	2,746	1,750	2,746	2,575	2,551	4,954	4,848
Retired (MW)	130	287	287	388	2,740	5,221	2,740	5,221	2,061	14,879	6,617	14,879	7,597	7,880	32,522	36,366

Figure E: Potential Capacity Reduction Due to the Combined EPA Regulation Scenario

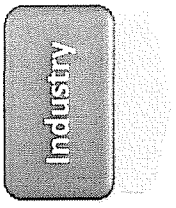


	2013		2015		2018	
	Moderate Case	Strict Case	Moderate Case	Strict Case	Moderate Case	Strict Case
Derate (MW)	17	1,934	2,394	7,289	6,479	7,348
Retired (MW)	538	6,457	30,563	70,059	39,867	68,979

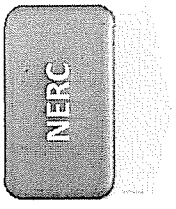
Recommendations



In the future, a variety of demands on existing infrastructure will be made to support the evolution from the current fuel mix, to one that includes generation that can meet proposed EPA regulations. The pace and aggressiveness of these environmental regulations should be adjusted to reflect and consider the overall risk to the bulk power system. EPA, FERC, DOE and state utility regulators, both together and separately, should employ the array of tools at their disposal to moderate reliability impacts, including, among other things, granting required extensions to install emission controls.



Regulators, system operators, and industry participants should employ available tools to ensure Planning Reserve Margins are maintained while forthcoming EPA regulations are implemented. For example, regional wholesale competitive markets should ensure forward capacity markets are functioning effectively to support the development of new replacement capacity where needed. Similarly, stakeholders in regulated markets should work to ensure that investments are made to retrofit or replace capacity that will be affected by forthcoming EPA regulations.



NERC should further assess the implications of the EPA regulations as greater certainty or finalization emerges around industry obligations, technologies, timelines, and targets. Strategies should be communicated throughout the industry to maintain the reliability of the bulk power system. This assessment should include impacts to operating reliability and second tier impacts (e.g., deliverability, stability, localized issues, outage scheduling, operating procedures, and industry coordination) of forthcoming EPA regulations.

Note: *The results in this report are based on assumptions of potential EPA regulations. The regulations discussed in this report are not yet final and all compliance deadlines, emission limitations, and retrofit costs may differ once the rules are finalized. This is a scenario of potential bulk power system impacts based on what is known today about the potential implementation of these rules. The resulting resource loss from these potential rules represent the loss of capacity should no more resources be added beyond the reference case.*

Introduction

In the United States (U.S.), the electric power industry has made significant capital investment in air pollution control technologies to remove sulfur dioxide (SO_2), particulate matter and nitrogen oxide (NO_x) emissions at fossil-fired power plants. The bulk of these capital investments were made to existing coal plants in order to comply with evolving environmental regulations.

Several regulations are in the process of being proposed by the U.S. Environmental Protection Agency (EPA) requiring additional retrofits. Depending on the final determinations, the cost to comply with the final regulations may result in retirements of generation. This assessment is designed to consider four potential EPA regulations and their potential impacts on Planning Reserve Margins individually and in aggregate.[6] The four regulations assessed are:

1. Clean Water Act – Section 316(b), Cooling Water Intake Structures;
2. Title I of the Clean Air Act – National Emission Standards for Hazardous Air Pollutants (NESHAP), or Maximum Achievable Control Technology (MACT) Standards;
3. Clean Air Transport Rule (CATR); and
4. Coal Combustion Residuals (CCR)

Assumptions (described in detail later in this section) have been made in this assessment to measure the potential impacts on Planning Reserve Margins from these potential regulations before knowing how companies will actually respond to these requirements and market conditions. The goal is to provide industry and regulators additional information regarding the scope of generating units financially affected by the potential EPA Regulations and about the necessity for replacement capacity to maintain reliability during the implementation process—it is a hypothetical set of scenarios employing agreed upon assumptions.[7] Ultimately, plant owners will determine the costs of compliance and make decisions about investment versus unit retirement. For this assessment, a unit is assumed to retire if (CC+FC+VC) / (1-DR) > RC, where: CC = required compliance cost, FC = current fixed O&M, VC = variable O&M including fuel cost, RC = replacement cost all in $/MWH, and DR = derate factor that accounts for the incremental energy loss due to any new environmental controls. See *Appendix I: Assessment Methods* for more details.[8]

Below is a summary of the aforementioned regulations, listed in order of magnitude:

1. **Clean Water Act – Section 316(b), Cooling Water Intake Structures**
   A significant number of thermal (coal, nuclear, oil and gas steam) generation plants use cooling water to support the process of generating electricity and therefore, they are located on large water bodies or high flow-rate rivers. Many of these facilities use once-through cooling systems that draw large volumes of water from the ocean, lake, or river used to condense steam, returning the warmer water back into the body of water immediately after use. Section 316(b) of the Federal Water Pollution Control Act (FWPCA), more commonly known as the Clean Water Act, regulates intake structures for surface waters in the U.S. and calls for Best Technology Available (BTA) to

[6] Analysis performed by Energy Ventures Analysis, Inc. (http://www.evainc.com) for NERC in February-July 2010 serves as the basis for this report. Detailed status of the assessed regulations can be found in *Appendix II, Environmental Regulations*

[7] NERC vetted assumptions used in this assessment with the Reliability Assessment Subcommittee and multiple industry groups.

[8] The potential effects of pending CO_2 regulations were not included.

minimize adverse environmental impact (AEI). EPA has interpreted that to mean impingement mortality of fish and shellfish and entrainment of their eggs and larvae. EPA's rulemaking is expected to set significant new national technology-based performance standards to minimize AEI. EPA is revising its rules for cooling water intake structures at "existing" facilities – including electric power generating stations. EPA has moved to combine the Phase II (large existing generators) and Phase III (small existing generators, offshore oil & gas facilities and other manufacturing facilities) rules into one proceeding and plans to propose a revised rulemaking by February 2011 and a final rule is to be promulgated by July 2012.

In 2004, EPA originally adopted Phase II regulations to minimize impingement and entrainment of aquatic life in the water intake structures that applied to large existing power plants withdrawing 50 million or more gallons per day and using at least 25 percent of the water withdrawn for cooling purposes. Sources could comply using several alternatives.

However, a January 2007 ruling by the Second U.S. Circuit Court of Appeals remanded several provisions of the Phase II rule and EPA subsequently suspended its Phase II implementation[9] and is in process of developing a new rule to address the court concerns. Steam generating units employing once-through cooling systems could be required to replace their cooling water systems with closed-loop cooling systems.

This can affect Planning Reserve margins in two ways: 1) the cost of such retrofits may result in accelerated unit retirements and 2) closed-loop cooling retrofitting results in derating a unit's net output capacity, due to additional ancillary or station load requirements to serve generator equipment. This resource assessment and its implications for responses in the power generation market should inform and affect power plant owner's choices about plant retirements, plant additions, and unit retrofits.

2. **Title I of Clean Air Act – National Emission Standards for Hazardous Air Pollutants for the electric power industry, or Maximum Achievable Control Technology (MACT) Standards**
NESHAP or MACT requires coal-fired plants to reduce their emissions of air toxics, including mercury. In December 2000, the U.S. EPA issued a "regulatory determination" under the 1990 Clean Air Act Amendments that regulation of mercury is "appropriate and necessary" for coal- and oil-fired power plants. Title I of the Amendments required EPA to adopt MACT standard for air toxic control. In March 2005, EPA issued its final Clean Air Mercury Rule (CAMR) for coal-based power plants. The CAMR used a market-based cap-and-trade approach to require emissions reductions in two phases: 1) a cap of 38 tons in 2010 and 2) fifteen tons after 2018, for a total reduction of 70 percent from current levels. Facilities were to demonstrate compliance with the standard by holding one "allowance" for each ounce of mercury emitted in any given year. In the final rule, EPA stated the regulation of nickel emissions from oil-fired plants is not "appropriate and necessary." In February 2008, the U.S. Court of Appeals for the District of Columbia Circuit issued an opinion in a case, which was initiated by 15 states and other groups, challenging the CAMR and EPA's decision to "de-list" mercury as a hazardous air pollutant (HAP). The Court held that EPA's reversal of the December 2000

[9] http://www.epa.gov/waterscience/316b/phase2/implementation-200703.pdf

regulatory finding was unlawful.[10] The Court vacated both the reversal and the CAMR. In February 2009, the acting Solicitor General, on behalf of EPA, filed a motion with the Supreme Court to dismiss the CAMR case. The motion states unequivocally that EPA will develop MACT standards for the utility industry under section 112 of the Clean Air Act. EPA is now obligated under a consent decree to propose a MACT rule by March 16, 2011 and to finalize the rule by November 16, 2011. In the interim, 19 states have already adopted their own mercury control requirements.

Section 112 in Title I of the Clean Air Act requires EPA to develop MACT standards for all the other listed air toxics emitted by coal- and oil-fired power plants. Based on an Information Collection Request (ICR), EPA is likely to set MACT standards for mercury, acid gases, heavy metals, and organics for coal- and oil-fired power plants. This could require significant additional emissions control equipment beyond what is necessary for compliance with mercury-only regulations. Under the Clean Air Act, EPA is obligated to implement the stricter standards within three years after the regulation becomes final.

3. **Clean Air Transport Rule (CATR)**
On July 6, 2010, EPA proposed a CATR program to reduce long-range transport of pollutants significantly contributing to downwind state ground-level ozone and fine particle non-attainment problems. This program would replace EPA's earlier Clean Air Interstate Rule that was overturned by the U.S. Court of Appeals in 2008 and temporarily reinstated until a replacement program was developed. As drafted, CATR would sharply reduce emissions of sulfur dioxide and nitrogen oxide from power plants in 31 states and the District of Columbia. EPA proposed three program options for public comment:
    1) the EPA preferred option which sets state emission budget caps and allows intrastate trading and limited interstate trading among power plants;
    2) the EPA Alternative 1 option which sets state emission budget caps and allows intrastate trading among power plants within a state; and
    3) the EPA Alternative 2 option which sets a pollution limit for each state and specifies the allowable unit-specific emission limit

Each of these options poses different reliability impacts. EPA will revise future state emission budgets as new stricter ozone and fine particulate ambient air quality standards are implemented. Depending on the outcome of the final regulation, power plant owners will likely need to retrofit additional emissions controls and, in some cases, retire units.[11]

4. **Regulations on Coal Combustion Residuals (CCR)**
Coal-fired power plants currently dispose of more than 130 million tons per year of coal-ash and solid byproducts. The failure of an ash disposal cell in December 2008 highlighted the concerns of coal-ash disposal and triggered calls for tighter regulation.[12] In May 2010, EPA proposed two options to regulate coal combustion residual disposal.[13]

[10] http://pacer.cadc.uscourts.gov/docs/common/opinions/200802/05-1097a.pdf
[11] A follow-on rule "Transport Rule 2" is also being developed for proposal by the EPA that would require more environmental controls not covered by CATR, regulating NOx in particular. This would apply to a majority of the states in the Eastern Interconnection plus Texas. This rule is not assessed in this report, but may contribute to more investments in required control technologies needed.
[12] Disposal cells are used for settling and storing the coal fly ash. This accident occurred at TVA's Kingston Fossil Plant East Tennessee. http://www.tva.gov/kingston/index.htm
[13] http://www.epa.gov/wastes/nonhaz/industrial/special/fossil/ccr-rule/ccr-rule-prop.pdf

1) Regulate the coal fly ash as a special waste under subtitle C (hazardous waste) of the Resource Conservation and Recovery Act (RCRA). Under this option, facilities would need to close their surface ash impoundments within five years and dispose of the ash (past and future) in a regulated landfill with groundwater monitoring.

2) Regulate ash disposal as a non-hazardous waste under subtitle D of RCRA. This alternative would require the facility to remove the solids and retrofit the impoundment pond with a liner to protect against groundwater contamination. Any landfill CCR disposal would require liners for new landfills and groundwater monitoring of existing landfills.

Beyond regulating coal-ash and residuals being landfilled or placed into a surface impoundment, the EPA regulation may also affect the use of the remaining coal-ash and reused or recycled residuals in products such as cement, concrete, roadbed material, drywall, etc. The EPA has indicated it will not prevent beneficial uses of the coal fly ash; however, there would be a higher cost for added ash disposal volume and a potential stigma created by regulating ash as a hazardous material, potentially resulting in lost revenue from the recycling market.

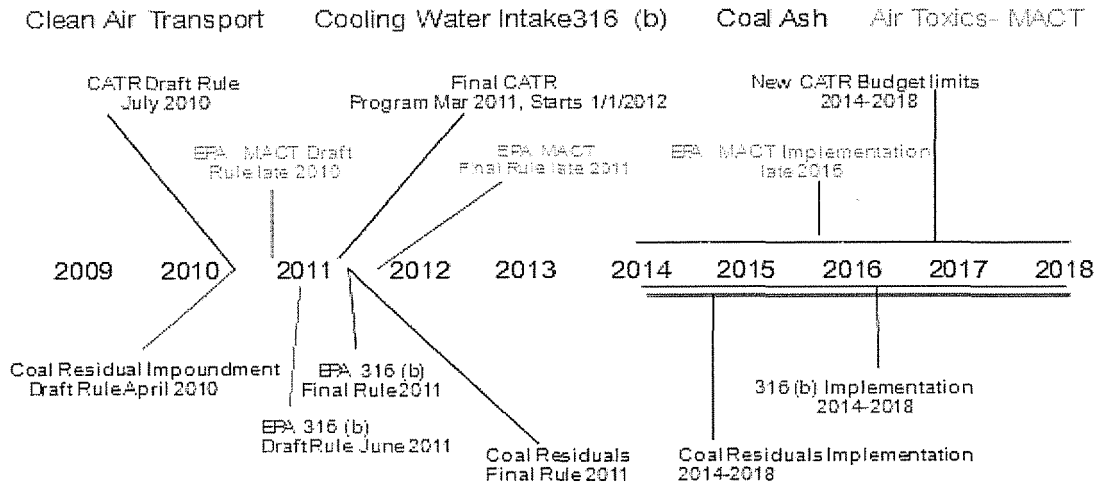
Furthermore, EPA is also considering a potential modification to the subtitle D option, called "D prime." Under the "D prime" option, existing surface impoundments would not have to close or install composite liners but could continue to operate for their useful life. Also in the "D prime" option, the other elements of the subtitle D option would remain the same. However, because no proposal has been made, this option is not included.

Timeline for Potential EPA Regulations

EPA has some flexibility in setting its compliance schedule for all potential rules except MACT (see Figure 1). Based upon current EPA schedules and historic implementation deadlines, EPA's air and solid waste regulations will likely be finalized by the end of 2011 with full compliance being anticipated by 2015–2016. The 316(b) water regulations are expected to be finalized in July 2012. It is anticipated that at least five years will be provided for compliance.

The overlapping compliance schedules for the air and solid waste regulations, along with required compliance for rule 316(b) following shortly thereafter, may trigger a large influx of environmental construction projects at the same time as new replacement generating capacity is needed. Such a large construction increase could cause potential bottlenecks and delays in engineering, permitting and construction. The risk of project delay increases if EPA decides on a compressed compliance schedule. The timing for scheduling unit outages to tie-in the environmental equipment becomes critical. Further, demand for critical equipment and supplies could potentially exceed production capacity and result in shortages and price escalations. However, surveys of labor or manufacturing were not conducted beyond the 25 percent cost increase in the Strict Case in this assessment.

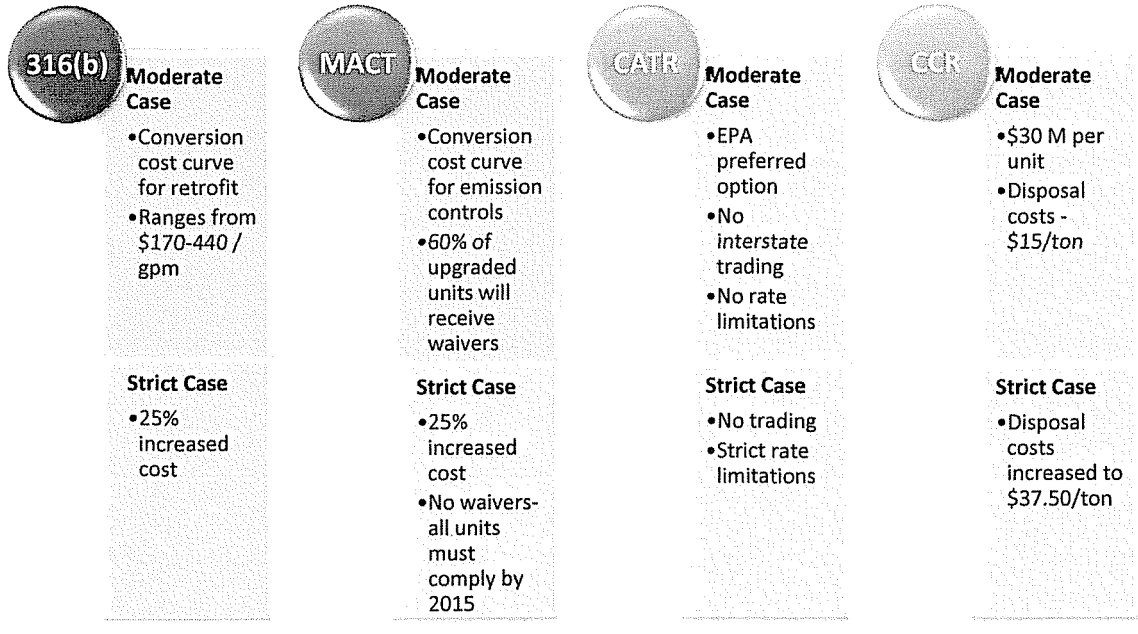
Figure 1: Timeline for Potential U.S. EPA Regulations Impacting the Electric Industry



Reliability Assessment Design

This reliability assessment used a plant-by-plant assessment. The cost factors for each unit were generic, based on its size and location and did not include engineering-level cost factors. Potential retirements and Planning Reserve Margin impacts are assessed for two cases (Moderate Case and Strict Case), for three different years (2013, 2015 and 2018), and for each regulation individually. The Combined EPA Regulation Scenario reflects the effects of the outcomes from the individual regulation cases working in aggregate. The Moderate Case assumes the costs as identified in *Appendix I: Assessment Methods and Appendix II: Environmental Regulations*. The Strict Case scenarios reflect the coupled effects of a higher increase in costs with more stringent requirements for the proposed rules. As the EPA proposed rules are not yet final, the Moderate Case and the Strict Case require expert judgment and sound assumptions on potential outcomes of the potential EPA rules.

Figure 2: Differences in Scenario Cases



In this reliability assessment, "economically vulnerable" generation capacity identifies units that would retire because of a specific potential environmental regulation. Unit retirement is assumed when the generic required cost of compliance with the proposed environmental regulation exceeds the cost of replacement power. In some cases, the costs imposed by the potential EPA regulations may cause "accelerated" or "early" retirement of unit generation capacity for an unknown time period. For the purpose of this assessment, replacement power costs were based on new natural gas generation capacity.[14] If the unit's retrofit costs are less than the cost of replacement power, then the unit is marked to be upgraded and retrofitted to meet the requirements of the potential environmental regulation, *i.e.*, it is not considered "economically vulnerable" for retirement. More discussion of the approach can be found in *Appendix I, Assessment Methods.*[15]

The assessment does not examine the possibility that the industry may be unable to meet its tight compliance deadlines. The Strict Case for 316(b) and MACT imposes a 25 percent cost increase to account for potential impacts if industry is unable to engineer, permit, build, or finance required retrofit environmental controls within the tight EPA compliance periods. Should multiple regulations phase-in simultaneously, replacement generation projects may encounter scheduling difficulties and scheduled retrofits may not be completed before deadlines. Where timing issues exist, waivers and extensions may be needed in order to complete a retrofit project instead of retiring the plant.

The assessment develops compliance costs based upon current average retrofit costs with existing technology market conditions. It does not assess the compliance cost risk from a run-up in labor and/or material costs caused by a construction boom from environmental control and replacement power projects. By applying average retrofit control costs by size in lieu of a detail engineering study, capital retrofit costs may be underestimated for sites with design, tight physical footprint and/or poor geologic considerations.[16]

This reliability assessment focused on measuring the potential resource implications through impacts on Planning Reserve Margins and identification of Regions/subregions where additional Regional resources may be required. The reference case for this study is based on resource projections contained in NERC's 2009 *Long-Term Reliability Assessment.*[17]

The impacts of potential EPA regulations may also have second tier effects on reliability, beyond resource adequacy. Resource deliverability, outage scheduling/construction constraints, local pockets of retirements, and transmission needs may also affect bulk power system reliability. While these issues were not studied in this assessment, the industry will need to resolve these concerns.

[14] The model does not consider potential natural gas price fluctuations.

[15] Using a different retirement method may produce different results. For instance, assessing generation on future asset performance may potentially increase the amount of capacity 'vulnerable' to retirement when economics are unprofitable, depending on the model input assumptions.

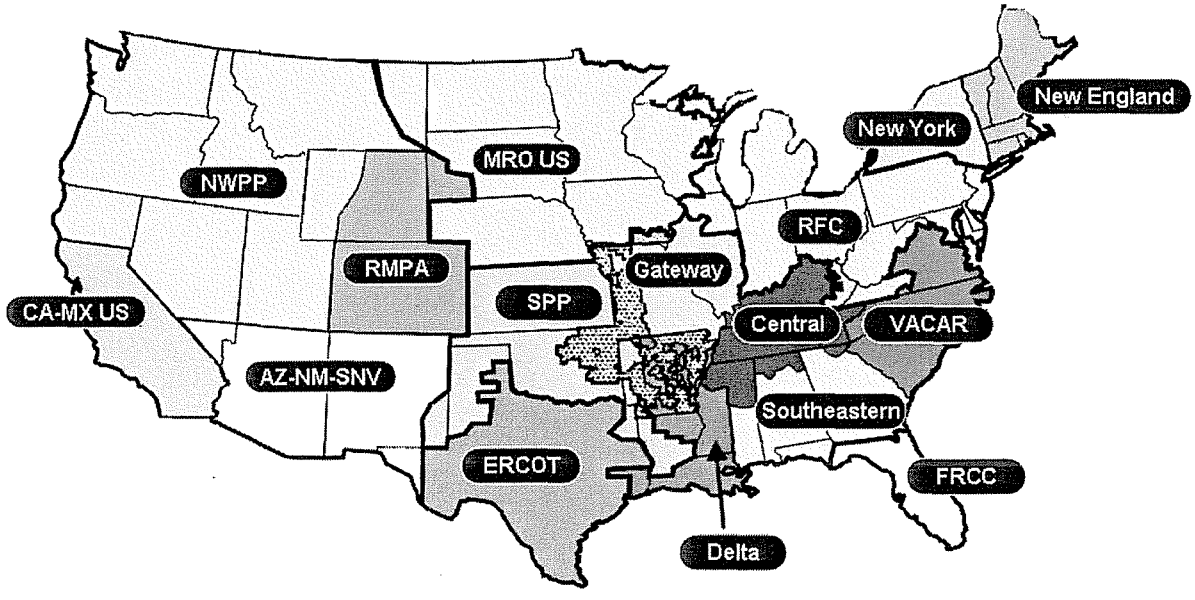
[16] This assessment did not include implementation. Because the compliance deadlines are short, generation owners may be challenged to engineer, permit, finance and build all required retrofit environmental controls within the proposed compliance periods. This may be especially challenging due to the phase-in of multiple regulations simultaneously. Further, some generation replacement projects also face similar risk of scheduling difficulties and may shutdown awaiting control completion, unless EPA grants waivers.

[17] http://www.nerc.com/files/2009_LTRA.pdf

The assessment objectives were:

1. identify potential future outcomes of EPA's active rulemaking for each of the Clean Water Act Section 316(b),[18,19] CCR, CATR, MACT and other air toxics individually and in aggregate (Combined EPA Regulation Scenario);
2. quantify and project impacts on Planning Reserve Margins for two sensitivity cases (Moderate Case and Strict Case) for each regulation (Clean Water Act Section 316(b), CCR, CATR, MACT and other air toxics), as well as their combined projected impacts for the years 2013, 2015, and 2018;
3. examine the impacts of potential unit retirement on future Regional reliability. Specifically, assess the impacts on Planning Reserve Margins to measure the relative impacts to resource adequacy across NERC Regions and Subregions (see Figure 3); and
4. provide the results to NERC's stakeholders, industry leaders, policymakers, regulators, and the public.

Figure 3: NERC US Subregions Assessed in this Report



Cost factors affect generating units as a "snapshot" in time, requiring unit operators to make the decision to finance retrofits for existing units or retire the units, replacing them with natural gas generation. Units "retire" if there are more economical replacement power alternatives available for compliance. Therefore, modeled years illustrate the scope of the U.S. bulk power industry that may be affected and the magnitude of attention required for nationwide compliance.

[18] http://www.nerc.com/files/NERC_SRA-Retrofit_of_Once-Through_Generation_090908.pdf

[19] DOE provided NERC a listing of vulnerable units (totaling approximately 240 GW). This information was supplemented by identifying those units that were expected to retire during the study timeframe, along with permitting dates. NERC reviewed the impact of either retrofitting units with existing once-through-cooling systems to closed-loop cooling systems (4 percent reduction in nameplate capacity) or unit retirements (capacity factors less than 35 percent) on NERC-U.S. and Regional capacity margins for 2012-2015.

Summary of Assumptions Used in This Report

The approach used in this assessment assumes that there are only two basic choices to consider when complying with the potential EPA regulations. The two choices are:

1. retrofit the generation unit and continue operations; or
2. retire the generation unit and replace it with a natural gas unit,

It was beyond the scope of this assessment to complete in-depth, individual plant assessment using site-specific cost factors to comply with each of the proposed EPA regulations. NERC contracted Energy Ventures Analysis Inc. (EVA)[20] to model potential reliability impacts. This model does not consider Planning Reserve Margin commitments, reliability-must-run conditions or transmission constraints. Instead, the model applied generic cost factors related to unit size and location to each unit as it was assessed. An economic approach is used that identifies which units may retire if the generic required cost of compliance with the proposed environmental regulation exceeds the cost of replacement power. As mentioned before, replacement power was considered to be gas-fired capacity. A more detailed discussion of the approach can be found in *Appendix I: Assessment Methods of This Report*.[21]

This assessment does not examine the additional impacts of adopting future greenhouse gas (GHG) control legislation, or other Clean Air Act requirements, including NAAQS, Regional haze/visibility, and GHG regulation,[22] national renewable portfolio standards, or other future EPA environmental rules that may lead to carbon reduction requirements. In practice, however, power suppliers are likely to consider the additional risk from uncertain future actions/rules in the U.S., such as future CO_2 legislation, when making plant investment decisions. Depending on how power suppliers quantify these risks, unit retirements may be higher than those projected in this assessment. Additionally, the report did not address any other climate change legislation.

Other assumptions affecting this reliability assessment include the following:

- Excludes plant retirements already committed or announced (13 GW) and excludes generation units not included in the NERC *2009 Long Term Reliability Assessment*[23] published in October 2009 (15 GW). Together these are equal to nearly 28 GW of capacity. These units were not included in this assessment because these units are not relied on to meet resource adequacy requirements nor do they have capacity

[20] EVA is contracted by domestic and international power producers, transportation companies, energy marketing companies and traders, industry organizations, etc.
http://evainc.com/

[21] Ibid. 11

[22] The analysis also did not address National Ambient Air Quality Standards (NAAQS) [June 2010 1-hour sulfur dioxide standard, February 2010 1-hour nitrogen dioxide standard, October 2010 revised 8-hour ozone standards (primary and possibly secondary), November 2011 revised particulate matter standards (primary and possibly secondary), the mid-2012 Transport Rule II following the October 2010 revised ozone standards, and the 2013 Transport Rule III following the November 2011 revised particulate matter standards], which could all force compliance actions by approximately 2015. The analysis also did not address regional haze. The Best Available Retrofit Technology (BART) controls in regional haze State Implementation Plans may be implemented could be required around 2015-16. The analysis did not address GHG regulation under the Clean Air Act, which will proceed in 2011 for new sources and modified sources. In step 1, starting on January 2, 2011, for sources subject to permitting for pollutants other than GHGs, new and modified sources emitting 75,000 tons per year (tpy) will be subject to Best Available Control Technology (BACT) requirements. In step 2, from July 2011 through June 2013, all sources above these thresholds – 100,000 tpy for new and 75,000 tpy for modified sources for CO2 - emissions – will be subject to Best Available Control Technology (BACT) requirements.

[23] http://www.nerc.com/files/2009_LTRA.pdf

commitments based on the *2009 Long Term Reliability Assessment.* Therefore, any capacity reduction from these units has already been considered in the *2009 Long Term Reliability Assessment* (reference case). The base generation capacity for each NERC Region/subregion is located in *Appendix III, Capacity Assessed by NERC Subregion.*

- Excludes a detailed assessment of the ability of generation owners to permit, engineer, finance, and build the required environmental controls within the short compliance timeframe. However, implementation will pose a large challenge to the equipment and construction sectors since multiple EPA programs are phased-in over the same timeframe. Compliance costs could escalate beyond the 25 percent increase of the high case (Strict Case), should the EPA require compliance within three years of the final rulemaking dates for some of the proposed rules (*i.e.*, 2014 or 2015). This situation is compounded by the large number of electric generation units that are likely to retrofit environmental controls, as well as from the competition created by replacement generation capacity projects and other heavy U.S. infrastructure projects in other sectors. A potential shortage of skilled construction labor, material shortages, and escalation of compliance costs could present challenges to meet the compressed time schedule.

- Compliance costs (capital, O&M and performance changes) are based upon current average retrofit costs with existing technology. The assessment does not evaluate the compliance cost increases resulting from a run-up in labor and material costs caused by demand increase for environmental control and replacement power projects. By applying average retrofit control costs by size in lieu of a detailed engineering study, capital retrofit costs may also underestimate the cost for sites with design, tight layout and/or poor geologic considerations. The assessment also assumes that each unit must make a decision on whether or not to retrofit with environmental controls. For example, if a plant has two units, the cost of two SCRs are used, not just one, as this is the most reliable option.

- Increased CCR disposal costs can vary widely based upon land availability, geology, and state disposal permit requirements. In this assessment, an EPA assumption of onsite disposal is adopted, and the EPA calculated disposal costs are similar to those employed. However, if onsite disposal were prohibited, the plant would incur additional costs to transport the ash and residuals to a properly permitted landfill. These costs could be significant, but cannot be estimated without a site-specific assessment. For these reasons, sensitivity comparisons were completed for CCR disposal costs.

- Power suppliers will need to bring their units offline to interconnect their new or retrofitted environmental controls. During these periods, suppliers will lose potential revenues and require use of replacement power. While the capital and O&M costs are incorporated into the compliance decision criteria, the replacement purchased power costs during these integration shutdowns have not been included and are unlikely to change or accelerate unit retirement decisions. However, these impacts would have the greatest effect on the nuclear plants that would incur the largest replacement power costs due to the duration of the retrofit outage.

- For retrofit of once-through-water cooling units, all nuclear plants are assumed to become exempted,[24] be subjected to alternative requirements as in the case of California's two operating nuclear plants,[25] or will be able to make the required investments due to the characteristics[26] of nuclear generation versus traditional fossil-fired generation.[27] Therefore, this assessment does not include any derate effects for nuclear capacity from Section 316(b). However, the maximum loss of capacity due to derate is estimated to be about 1.8 GW due to retrofit. Should 316(b) cause nuclear unit retirement, additional generation capacity loss may result.

- Generating units identified in this assessment may choose to wait until immediately prior to the compliance deadline before retiring the generation unit. This ability to delay retirement may act as a binary option causing many units to retire on December 31 prior to a January 1 deadline, and in some cases, may wait until January 1, 2018. The assumptions used for decision-making timing in this study are described in the *Some Unit Retirements Spread Through Time* section.

- All combined-cycle plants are assumed to make required investments to avoid being forced into early retirement. This may not be the case. For MACT, oil-fired units are assumed to meet emission limits through availability of suitable quality specifications of refined oil products.

- The assessment excludes any fossil-fuel market price or supply risks that are created by a large shift in the power generation mix from environmental compliance measures (*e.g.*, a shift from coal to natural gas fuel). Delivered natural gas and coal prices are fixed and do not change based on the level of retirements or the level of new replacement capacity that may be required.

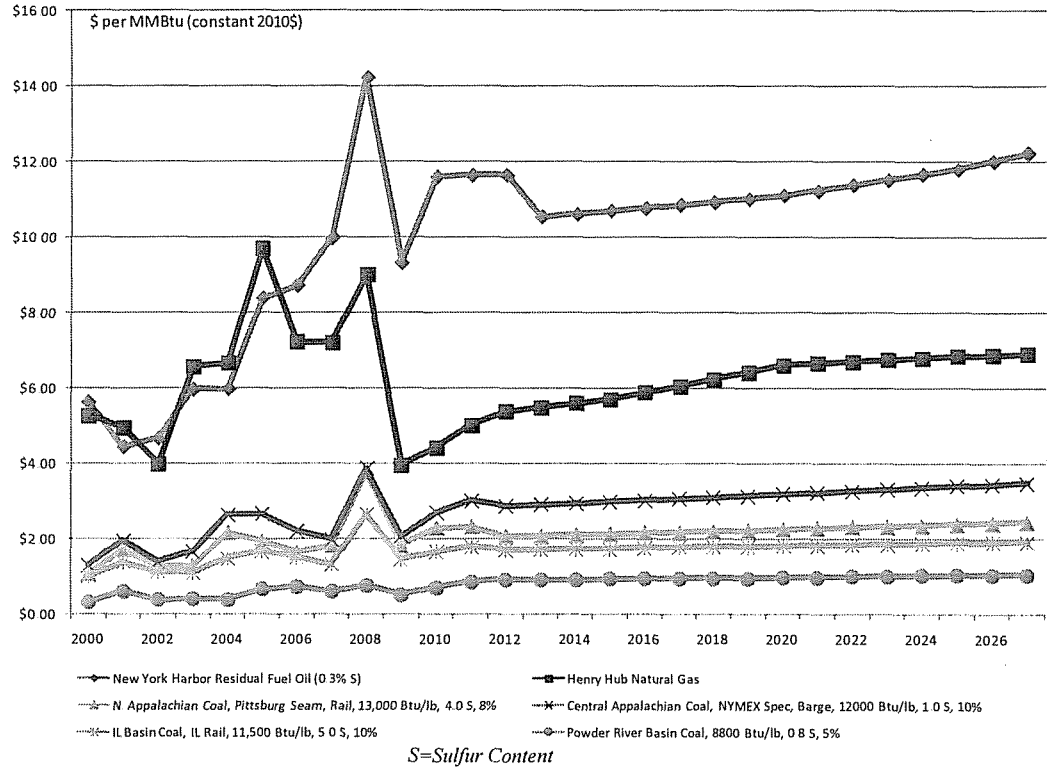
- If a coal plant is retired under this method, there is nothing to prevent a secondary, after-the-fact decision. For instance, a coal unit may convert into a biomass-based unit, or convert to natural gas burners and continue operating as a steam plant. In addition, plant owners may decide to invest in construction at existing construction sites after retirement. Such decisions are beyond the scope of this assessment.

- The assessment did not examine or model the use of other sorbent injection technologies (*e.g.*, trona) as an alternative. For trona, capital costs would be lower, but higher operating costs would result. Limestone scrubbers are the norm in the United States, although, this technology has been used at older plants where owners did not want to make the larger capital investment. Further, while some future plants may opt for trona vs. a limestone scrubber, a majority of plants (greater than 97 percent) will use limestone.

- Delivered natural gas, coal and oil prices were based on the forecasts of EVA as of May 2010. Ten-year forward averages are applied for 2013, 2015 and 2018. Varying these price assumptions may produce different results. The base wholesale fuel price forecasts are depicted in Figure 4 on an undelivered basis.

[24] http://www.snl.com/InteractiveX/article.aspx?CDID=A-10616386-10806&KPLT=2
[25] http://www.swrcb.ca.gov/water_issues/programs/npdes/docs/cwa316may2010/otcpolicy_final050410.pdf
[26] *e.g.*, Lower GHG emissions, longer in-service operations, higher availability, baseload resource
[27] DOE, 2008 http://www.oe.energy.gov/DocumentsandMedia/Cooling_Tower_Report.pdf

Figure 4: Wholesale Fuel Price Assumptions Used for This Assessment



S=Sulfur Content

Some Unit Retirements Spread Through Time

Because the implementation of multiple EPA regulations is tightly stacked through time, a large number of retirements may occur in the same year, requiring new resources to offset the capacity reductions. To simulate a more realistic and expected outcome, in certain instances, some of the retirement and waivers were simulated earlier in time, rather than reflecting all retirements in one year, such as in 2015 or 2018, depending on the regulation. These results are included in the scenario of the four potential regulations. In addition:

- **Section 316(b) and Coal Combustion Residuals:** As the EPA implementation deadlines are expected to be January 1, 2018, no units theoretically would need to be retired until 2018. However, this assessment assumes that 20 percent of designated units are retired in each year from 2013 through 2017 for the Moderate Case and the Strict Case. To select which individual units are simulated to retire, each designated plant's economics are ranked from the most expensive to least expensive production costs. The units with the most expensive plant costs were retired first for Section 316(b) and CCR. Conversely, the units with the lowest cost plant economics were upgraded first.

- **MACT:** For the Moderate Case only, 60 percent of units that are designated to upgrade environmental controls by 2015 receive waivers as of January 1, 2015. The most expensive 20 percent of units are retired by 2014 (no effects as of January 1, 2013), and then the next most expensive 20 percent of units are retired by 2015. Also conversely, the units with the lowest cost plant economics are upgraded first when the highest cost plants are retired.

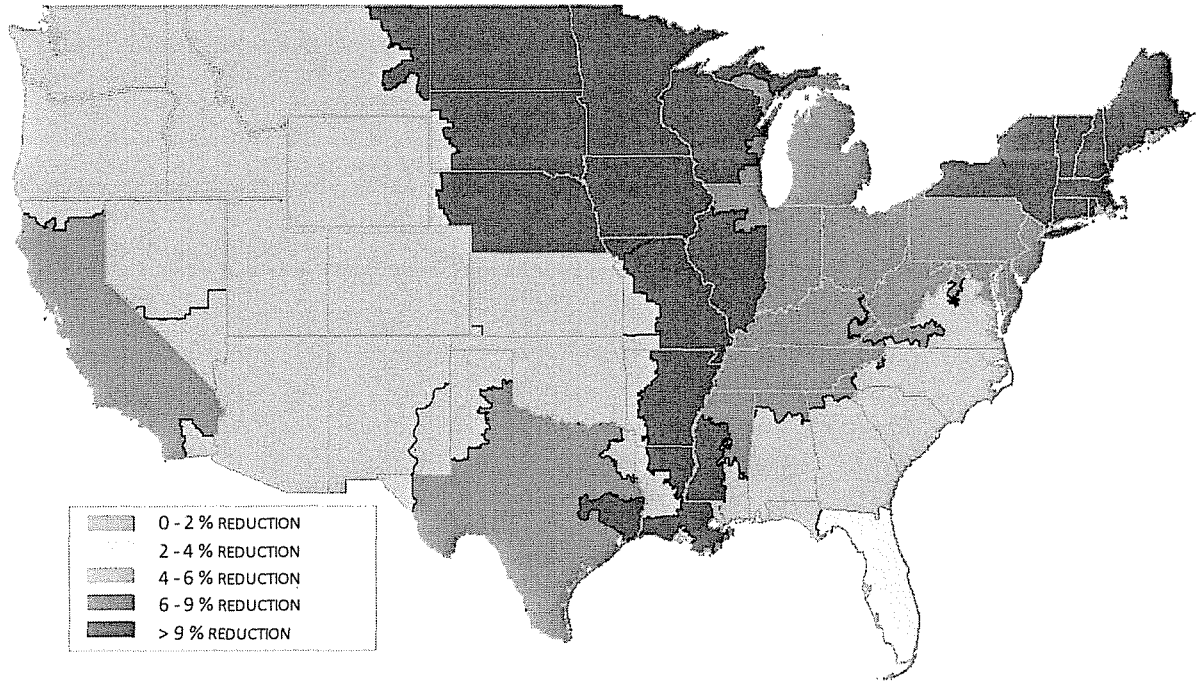
- **CATR:** The Strict Case simulated the highest 40 percent of units were retired by 2013 and the 40 lowest cost units were retrofitted by 2013.

Scenario Results

U.S. power suppliers will assess the impact of all future environmental requirements when making their environmental compliance decisions. Even in the absence of future GHG legislation, the combination of the four potential EPA rules may have significant economic impacts on generating units, potentially affecting the reliability of bulk power system as measured by significant declines in Planning Reserve Margins. Based on the design of this assessment, the overall total compliance cost impact would place between 40 and 69 GW of existing capacity (441-761 units) as "economically vulnerable" for accelerated retirement due to more cost efficient compliance alternatives by 2018. On-site stations loads for equipment operation derate the net generating capacity of the retrofitted units by 6.7-7.4 GW. The overall affect would be a total of 46-76 GW of capacity reductions significantly affecting Planning Reserve Margins if no additional resources are built beyond what is included in the *2009 NERC Long-Term Reliability Assessment* plans (see Figure 5). In many Regions/subregions, Planning Reserve Margins fall below the NERC Reference Margin Level, indicating the need for more resources.

The potential retirement and deratings affect resource portfolios in all eight NERC Regions, but especially in the ERCOT, MRO, NPCC, SERC, and NPCC Regions. The most significant individual impacts are due to the Section 316(b) regulation, then MACT, CATR and finally CCR. However, the Combined EPA Regulation Scenario has the greatest impact to reliability.

Figure 5: 2018 Reduction in Adjusted Potential Capacity Resources due to the Combined EPA Regulation Scenario



Section 316(b) Cooling Water Intake Structures

In the Moderate Case scenario, the Section 316(b) rule alone could potentially increase the unit production costs above replacement power costs at 347 stations, retiring 33 GW of current generating capacity. This retired generating capacity was spread across the rule implementation period (2014-2018). The majority of the "economically vulnerable" units are older oil/gas steam units (253 units with 30 GW of capacity). An additional 94 coal steam units (capacity of 2.5 GW) are also "economically vulnerable". The remaining 688 would also incur a five GW capacity derating to support increases in station loads. Table 1 shows how these retirements and capacity derating penalties affect the NERC subregions for the year 2015 while 2018 impacts are shown in Table 2. For this assessment, no units were affected in 2013. As shown, SERC-Delta, RFC, WECC-CA, and ERCOT account for 65 percent of the unit retirements.

Table 1: 316(b) Impacts - 2015

	Moderate Case			Strict Case		
	Derated (MW)	Retired (MW)	Total	Derated (MW)	Retired (MW)	Total
ERCOT	187	556	743	187	752	939
FRCC	69	68	137	69	68	137
MRO	340	450	789	338	479	817
NPCC-NE	0	1,061	1,061	0	1,061	1,061
NPCC-NY	22	958	980	22	958	980
RFC	988	763	1,751	954	763	1,717
SERC-Central	275	0	275	275	0	275
SERC-Delta	82	1,774	1,856	82	1,774	1,856
SERC-Gateway	288	266	555	288	266	555
SERC-Southeastern	60	224	284	52	224	276
SERC-VACAR	101	92	193	120	92	212
SPP	113	501	614	113	531	644
WECC-CA	0	786	786	0	786	786
WECC-AZ-NM-SNV	0	24	24	0	25	25
WECC-NWPP	36	39	75	36	39	75
WECC-RMPA	13	36	49	13	64	77
TOTAL	2,575	7,597	10,172	2,551	7,881	10,432

Should the cooling tower conversion costs be 25 percent higher than prior engineering studies indicated ($300/gpm versus $240/gpm), an additional 17 units (four GW) could retire resulting in a total of 37 GW.

Section 316(b) marginally affects coal units in comparison to its effects on oil/gas steam units (*i.e.*, 92–93 percent of capacity). In the Strict Case, most of the incremental retirements are older oil/gas steam units located in WECC-CA, NPCC, SERC-Delta, ERCOT, and RFC, ranked from highest to lowest. For the coal units, most "economically vulnerable" capacity is in RFC. The "economically vulnerable" capacity in the Strict Case is 12 percent greater than in the Moderate Case.

Table 2: 316(b) Impacts - 2018						
	Moderate Case			Strict Case		
	Derated (MW)	Retired (MW)	Total	Derated (MW)	Retired (MW)	Total
ERCOT	322	5,055	5,377	316	5,295	5,611
FRCC	177	862	1,039	164	1,367	1,531
MRO	400	1,259	1,659	400	1,264	1,664
NPCC-NE	194	2,504	2,698	180	2,904	3,084
NPCC-NY	347	3,011	3,357	327	3,618	3,946
RFC	1,532	5,503	7,035	1,526	5,661	7,187
SERC-Central	388	71	459	388	71	459
SERC-Delta	282	5,524	5,806	282	5,524	5,806
SERC-Gateway	296	526	822	295	543	838
SERC-Southeastern	209	469	678	209	469	678
SERC-VACAR	378	664	1,042	377	689	1,066
SPP	143	933	1,076	141	994	1,135
WECC-CA	227	5,055	5,283	182	6,881	7,063
WECC-AZ-NM-SNV	5	773	778	5	773	778
WECC-NWPP	40	129	169	40	129	169
WECC-RMPA	16	184	200	16	184	200
TOTAL	4,954	32,522	37,476	4,848	36,366	41,214

These estimates are slightly less, but comparable, to the October 2008 DOE study, *Electricity Reliability Impacts of a Mandatory Cooling Tower Rule for Existing Steam Generating Units* that resulted in approximately 40 GW of potential retirements. Some differences may be attributable to this study excluding more already announced generating unit retirements (more than 28 GW) and incorporating a more comprehensive retirement replacement cost method (versus applying a capacity factor criterion).

National Emissions Standards for Hazardous Pollutants (NESHAP) or Maximum Achievable Control Technology (MACT)

National Emissions Standards for Hazardous Pollutants (NESHAP) or Maximum Achievable Control Technology (MACT) will apply to all existing and future coal and oil fired steam capacity. The Moderate Case scenario rulemaking varies for MACT emission rate limitations by coal type. This assessment assumes that the EPA deadline is January 1, 2015. However, in the Moderate Case, only 40 percent of units that will eventually retire do so by January 1, 2015. As EPA has no authority under the Clean Air Act to grant waivers for a MACT standard, one of these two[28] conditions must occur:

- the EPA Administrator (or state with program approval) grants an extension of one additional year, finding more time is "necessary for the installation of controls"– §112(i)(3)(B). This may occur on a case-by-case basis; or

- a Presidential exemption for a period of not more than two years is granted, assuming the President finds (1) the technology to implement such standard is not available and (2) it is in the national security interests to do so. Additional one year extensions are also available –§112(i)(4).

The Moderate Case outcome is that there are no forced retirements as of January 1, 2013. Twenty percent of units retire by January 1, 2014, reaching 40 percent of units retired by January 1, 2015 followed by an additional 20 percent in each subsequent year, such that all designated units are retired by January 1, 2018. In 2015, the impact of the Moderate Case is roughly 2.1 GW of existing coal-fired capacity (59 units) "economically vulnerable" for retirement; another 0.8 GW may be derated. The figure triples by 2018 to 6.6 GW of coal capacity that may be retired and 1.8 GW derated for a total impact of 8.4 GW.

The Strict Case assumes that no waivers are granted and all electric generation units must be in compliance by January 1, 2015. Obtaining these waivers appears difficult; the EPA granted a sector-wide extension of one year only once, in a marine MACT rule. The Strict Case also assumes that all retirements occur in the two years leading up to the deadline, *i.e.*, during 2013 and 2014, with none as of January 1, 2013. The Strict Case also increases compliance costs by 25 percent. These two assumptions significantly change the assessment results, such that by 2015 there is 14.9 GW of existing coal-fired capacity (228 units) "economically vulnerable" for early retirement and 2.8 GW derated for a total of 17.6 GW. The 2015 result carries over into 2018.

MACT depicts the greatest variation between the two cases of all the EPA regulations. There is a 12 GW difference in capacity loss between the Moderate Case and the Strict Case by 2015. There is a nine GW difference by 2018. Distribution of this capacity by Region/subregion for 2015 and 2018 are shown in Table 3 and Table 4.

[28] Under section 202(c) of the Federal Power Act, the Secretary of Energy has authority when an emergency exists "by reason of a sudden increase in the demand for electric energy, or a shortage of electric energy or of facilities for the generation or transmission of electric energy, or of fuel or water for generating facilities, or other causes," to order such temporary interconnection of facilities or generation, delivery, interchange, or transmission of electric energy as in his/her judgment "will best meet the emergency and serve the public interest." However, section 202(c) does not specifically mention EPA or the Clean Air Act.

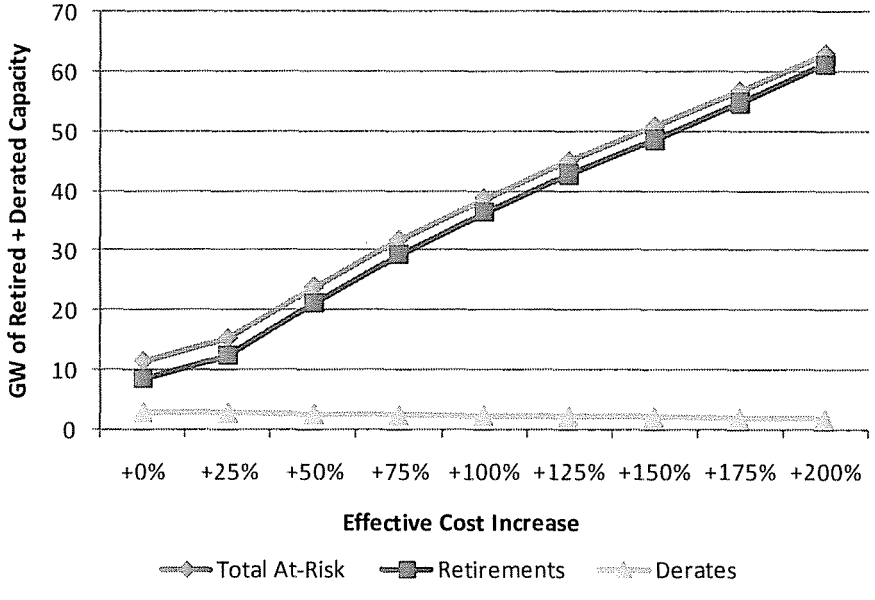
Table 3: MACT Impacts - 2015						
	Moderate Case			Strict Case		
	Derated (MW)	Retired (MW)	Total	Derated (MW)	Retired (MW)	Total
ERCOT	73	0	73	73	0	73
FRCC	0	0	0	78	121	199
MRO	125	202	327	144	764	908
NPCC-NE	0	0	0	32	616	647
NPCC-NY	0	0	0	16	694	710
RFC	103	1,061	1,164	1,060	5,493	6,553
SERC-Central	61	71	132	305	1,000	1,305
SERC-Delta	69	18	87	69	95	164
SERC-Gateway	84	35	119	110	365	475
SERC-Southeastern	33	140	173	337	1,208	1,545
SERC-VACAR	0	465	465	255	2,649	2,905
SPP	127	0	127	130	52	181
WECC-CA	0	0	0	3	0	3
WECC-AZ-NM-SNV	49	0	49	49	1,580	1,629
WECC-NWPP	72	39	111	73	129	202
WECC-RMPA	10	0	10	10	100	110
TOTAL	806	2,032	2,838	2,746	14,865	17,611

Table 4: MACT Impacts - 2018						
	Moderate Case			Strict Case		
	Derated (MW)	Retired (MW)	Total	Derated (MW)	Retired (MW)	Total
ERCOT	73	0	73	73	0	73
FRCC	16	0	16	78	121	199
MRO	144	708	853	144	764	908
NPCC-NE	25	0	25	32	616	647
NPCC-NY	16	58	74	16	694	710
RFC	514	2,540	3,055	1,060	5,493	6,553
SERC-Central	167	184	351	305	1,000	1,305
SERC-Delta	70	46	116	69	95	164
SERC-Gateway	100	96	196	110	365	475
SERC-Southeastern	227	140	367	337	1,208	1,545
SERC-VACAR	132	970	1,102	255	2,649	2,905
SPP	130	52	181	130	52	181
WECC-CA	3	0	3	3	0	3
WECC-AZ-NM-SNV	49	1,580	1,629	49	1,580	1,629
WECC-NWPP	73	129	202	73	129	202
WECC-RMPA	10	100	110	10	100	110
TOTAL	1,750	6,602	8,352	2,746	14,865	17,611

The impacts could be more severe if costs escalate due to tighter implementation timelines of three years and the large number of plants (840 units) that may need to upgrade their environmental controls at the same time. This could require additional new generation and expanded use of existing lower emission generation like natural gas. In circumstances in which power plant retirements trigger localized reliability concerns, EPA can follow established precedent, including use of consent decrees, to permit continued operation for reliability purposes only, pending necessary upgrades or generation additions.

A sensitivity comparison was completed for the 2015 Strict Case for MACT accounting for the compressed implementation timeline (see Figure 6). The risk that generation units will retire simply due to insufficiently available third party engineering services is not modeled in the sensitivity test. Because the 2015 Strict Case already includes a 25 percent cost premium, the sensitivity comparisons were completed at cost increase intervals of 25 percent from 0 percent up to 200 percent. As a result, retirements increased at an approximate linear rate from a low of 11.4 GW (retirements of 8.5 GW and derated capacity of 2.9 GW) at no cost increase up to 63 GW (retirements of 61.2 GW and derated capacity of 1.8 GW) at a 200 percent cost increase.

Figure 6: Sensitivity of Retirements Plus Derated Capacity as a Function of Higher Assumed Costs due to the MACT Regulation



Clean Air Transport Rule (CATR)

Starting in 2012, the CATR will apply to fossil fuel units with greater than 25 MW capacity that are located in 31 states. Although EPA provided three different options in July 2010, the EPA preferred option was selected for the Moderate Case. An analysis of this option found that the rule would have the greatest impact in the state utilities that relied heavily upon purchased allowances for compliance with their Acid Rain program and CAIR program obligations. By significantly limiting the use of out-of-state utility purchases and/or banked allowances after 2013, some utilities would be forced to retrofit FGD and SCR emission controls on their larger units or retire to comply. The oil and gas steam units would remain largely untouched because of their limited emissions. As described earlier in this report, these reductions would be concentrated to a few states.

The extent of retirements triggered by CATR is heavily linked to:

1. the flexibility provided to affected sources to avoid reductions in smaller emitting stations by retrofitting controls in larger emitting units (through allowance trading); and
2. the final budget state cap (the July 2010 draft emission caps are interim limits that will be reduced further as stricter future ambient fine particulate and ozone standards are adopted). The EPA preferred option (Moderate Case) would result in the retirement of five coal-fired units (538 MW) by 2013 and 18 coal-fired units (2,740 MW) by 2015 (see Tables 5 and 6).[29]

Table 5: CATR Impacts - 2013

	Moderate Case			Strict Case		
	Derated (MW)	Retired (MW)	Total	Derated (MW)	Retired (MW)	Total
ERCOT	0	0	0	64	0	64
FRCC	0	0	0	4	0	4
MRO	0	0	0	162	155	318
NPCC-NE	0	162	162	1	0	1
NPCC-NY	0	0	0	0	0	0
RFC	1	376	377	191	781	972
SERC-Central	11	0	11	87	71	158
SERC-Delta	0	0	0	99	29	128
SERC-Gateway	0	0	0	94	35	129
SERC-Southeastern	5	0	5	145	130	275
SERC-VACAR	0	0	0	47	548	594
SPP	0	0	0	110	26	136
WECC-CA	0	0	0	0	0	0
WECC-AZ-NM-SNV	0	0	0	0	0	0
WECC-NWPP	0	0	0	0	0	0
WECC-RMPA	0	0	0	0	0	0
TOTAL	17	538	555	1,004	1,775	2,779

[29] Impacts from CATR would begin in 2014. For this report, only 2013, 2015, and 2018 were assessed.

Alternatively, EPA could elect to pursue emission rate limitations on the coal-fired units. This approach would provide no ability to trade at all and units would be forced to retrofit the needed controls or retire. With the impending changes in NAAQS unknown, the Strict Case assumes that EPA will adopt much stricter rate limits on all coal-fired capacity that only can be met through post combustion controls. Given the large demand created for emission controls, the capital cost will likely increase by 25 percent or more from current levels. Overall, 86 coal units (5,221 MW) would have their operating costs pushed above new replacement capacity and force their retirement. Although tied to the changing of the NAAQS, these retirements would likely occur in or before 2015. Further impacts, past 2015, are not expected to materialize.

Table 6: CATR Impacts - 2015

	Moderate Case			Strict Case		
	Derated (MW)	Retired (MW)	Total	Derated (MW)	Retired (MW)	Total
ERCOT	0	0	0	91	0	91
FRCC	0	0	0	16	0	16
MRO	0	33	33	216	1,007	1,223
NPCC-NE	0	162	162	14	370	384
NPCC-NY	0	0	0	22	50	73
RFC	67	1,667	1,734	552	2,192	2,744
SERC-Central	15	0	15	154	136	290
SERC-Delta	0	0	0	127	29	155
SERC-Gateway	0	878	878	171	35	206
SERC-Southeastern	60	0	60	258	230	488
SERC-VACAR	0	0	0	130	1,056	1,186
SPP	0	0	0	202	115	317
WECC-CA	0	0	0	0	0	0
WECC-AZ-NM-SNV	0	0	0	0	0	0
WECC-NWPP	0	0	0	0	0	0
WECC-RMPA	0	0	0	0	0	0
TOTAL	142	2,740	2,882	1,952	5,221	7,173

The analysis affects coal units only and the most significant impact of the Strict Case occurs in RFC, SERC and MRO, which have the most remaining coal plants that require upgrading in the 31 states and the District of Columbia affected by CATR

Coal Combustion Residuals (CCR) Disposal Regulations

A distribution of the coal units "economically vulnerable" from the potential coal combustion byproducts rule is shown in Table 7 for both the Moderate Case and the Strict Case scenarios in 2018. As shown, the additional capital and annual operating cost increases under both scenarios would trigger the retirement of only four coal units with capacity of 287 MW in the Moderate Case and 12 units with capacity of 388 MW in the Strict Case. This "economically vulnerable" coal-fired capacity is located in three to four SERC subregions and MRO. Under the estimated compliance timeline, these coal unit retirements would likely not occur until the 2015—2018 period. A larger number of coal units are affected in the Strict Case, since the Moderate Case affects only those plants using ponds for ash disposal, whereas the Strict Case assumes that all coal plants will need to store coal combustion byproducts in a lined landfill.

Table 7: CCR Impacts - 2018

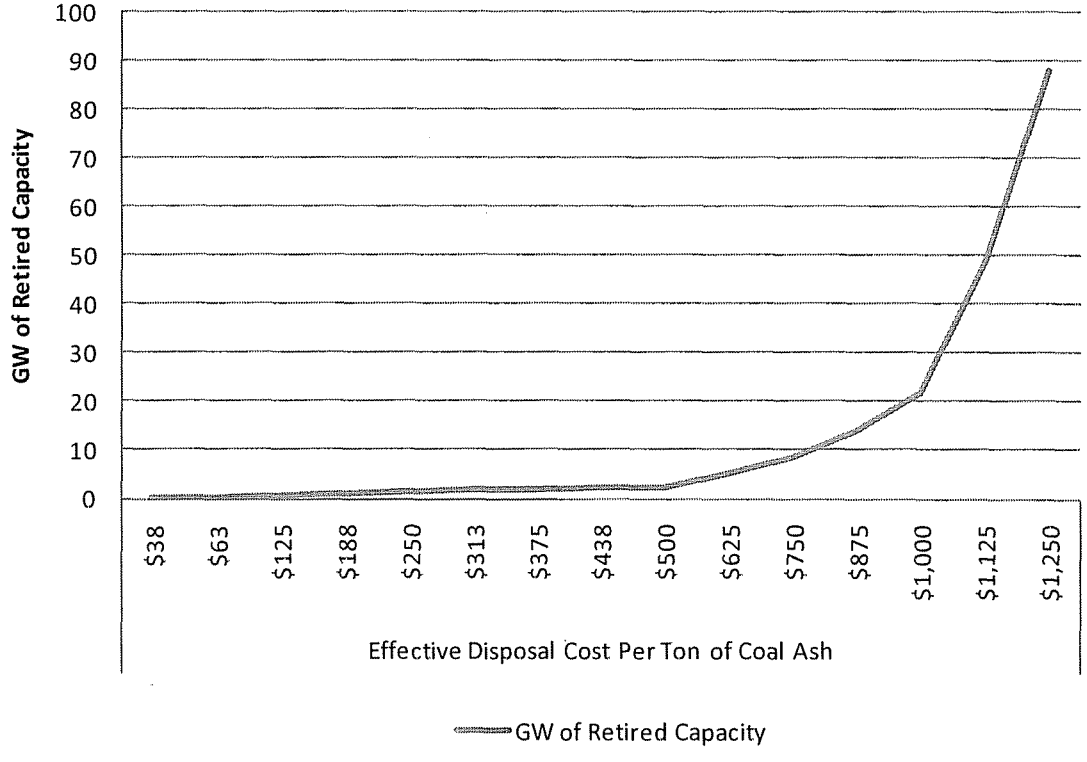
	Moderate Case			Strict Case		
	Derated (MW)	Retired (MW)	Total	Derated (MW)	Retired (MW)	Total
ERCOT	0	0	0	0	0	0
FRCC	0	0	0	0	0	0
MRO	0	0	0	0	83	83
NPCC-NE	0	0	0	0	0	0
NPCC-NY	0	0	0	0	0	0
RFC	0	0	0	0	0	0
SERC-Central	0	71	71	0	71	71
SERC-Delta	0	0	0	0	18	18
SERC-Gateway	0	86	86	0	86	86
SERC-Southeastern	0	130	130	0	130	130
SERC-VACAR	0	0	0	0	0	0
SPP	0	0	0	0	0	0
WECC-CA	0	0	0	0	0	0
WECC-AZ-NM-SNV	0	0	0	0	0	0
WECC-NWPP	0	0	0	0	0	0
WECC-RMPA	0	0	0	0	0	0
TOTAL	0	287	287	0	388	388

These estimates are substantially less than the EOP Group Study titled *Cost Estimates for the Mandatory Closure of Surface Impoundments Used for the Management of Coal Combustion Byproducts at Coal Fired Utilities* that resulted in 35 GW of "economically vulnerable" coal-fired capacity. Some differences are likely to be attributable to this assessment excluding already announced generating unit retirements (more than 28 GW) and incorporating a more comprehensive retirement replacement cost method (versus applying a unit size criterion).

Because of the large difference in results, sensitivity comparisons were conducted to determine how the number of "economically vulnerable" units would vary under higher disposal cost assumptions. Disposal costs can vary significantly based upon suitable land availability and state landfill requirements. Like EPA, this assessment assumed that suitable landfill sites could be found, permitted and operated near to existing coal plants. If no suitable sites can be permitted, power suppliers may be forced to transport their residuals to appropriately permitted offsite landfills and pay tipping fees that could increase disposal costs.

In lieu of conducting site-specific assessment, a sensitivity comparison was completed across a wide range of ash disposal costs from $37.50 up to $1,250 per ton (see Figure 7). The economic retirements slope gradually upward from 0.3 to 2.1 GW as costs increase from $37.50 to $500 per ton, then retirements begin to jump significantly with amounts reaching 22 GW at $1,000 per ton, and exponentially increase to 49 GW at $1,125 and nearly 88 GW at $1,250 per ton. However, the costs are believed to be well contained within the flat slope portion of the line on the far left side. However, the additional costs that may become associated with distance removal of the hazardous substance to existing certified landfills could drive costs upward.

Figure 7: Sensitivity of Retirements as a Function of Higher Assumed Coal-Ash Disposal Costs due to Coal Combustion Residuals regulations



Combined EPA Environmental Rulemaking

The reliability impact of each rule outlined above reflects the cost and retirement decisions for each individually. However, power suppliers will likely make their retirement decisions based upon compliance costs for the combination of all future environmental requirements. Although some environmental control overlap exists between the CATR and MACT (*i.e.*, for FGD and SCR retrofits), most compliance costs are expected to be additive between the different EPA rules.

The cumulative effect of the four potential EPA rules is provided in Tables 8, 9, and 10 for each of the three years assessed. In 2015, anywhere from 31–70 GW of existing fossil fuel capacity (351–678 generation units; beyond the 28 GW of retirements already announced and not included in NERC's Long Term Reliability Assessment) are "economically vulnerable" for retirement from these four potential EPA rules. Additionally the 273–700 units of continuing operation will be derated by a total of 2.4-7.3 GW from the increased parasitic loads from the control operation. The projected retirements are significantly lower in 2013 and significantly higher for the Moderate Case in 2018.

Table 8: Combined EPA Regulations Impacts - 2013

	Moderate Case			Strict Case		
	Derated (MW)	Retired (MW)	Total	Derated (MW)	Retired (MW)	Total
ERCOT	0	0	0	91	0	91
FRCC	0	0	0	16	0	16
MRO	0	0	0	216	1,007	1,223
NPCC-NE	0	162	162	12	532	545
NPCC-NY	0	0	0	19	258	278
RFC	1	376	377	541	2,876	3,418
SERC-Central	11	0	11	153	211	364
SERC-Delta	0	0	0	127	29	155
SERC-Gateway	0	0	0	171	35	206
SERC-Southeastern	5	0	5	258	230	488
SERC-VACAR	0	0	0	128	1,163	1,291
SPP	0	0	0	58	89	147
WECC-CA	0	0	0	144	26	170
WECC-AZ-NM-SNV	0	0	0	0	0	0
WECC-NWPP	0	0	0	0	0	0
WECC-RMPA	0	0	0	0	0	0
TOTAL	17	538	555	1,934	6,457	8,391

For the combined potential EPA rulemaking, the retirement and derating penalties are concentrated in five NERC Regions/subregions for the 2015 Moderate Case -- SERC, NPCC, RFC, ERCOT, and WECC, ranked in order of highest to lowest. For the 2015 Strict Case, the rank order is SERC, RFC, WECC, NPCC, and finally ERCOT.

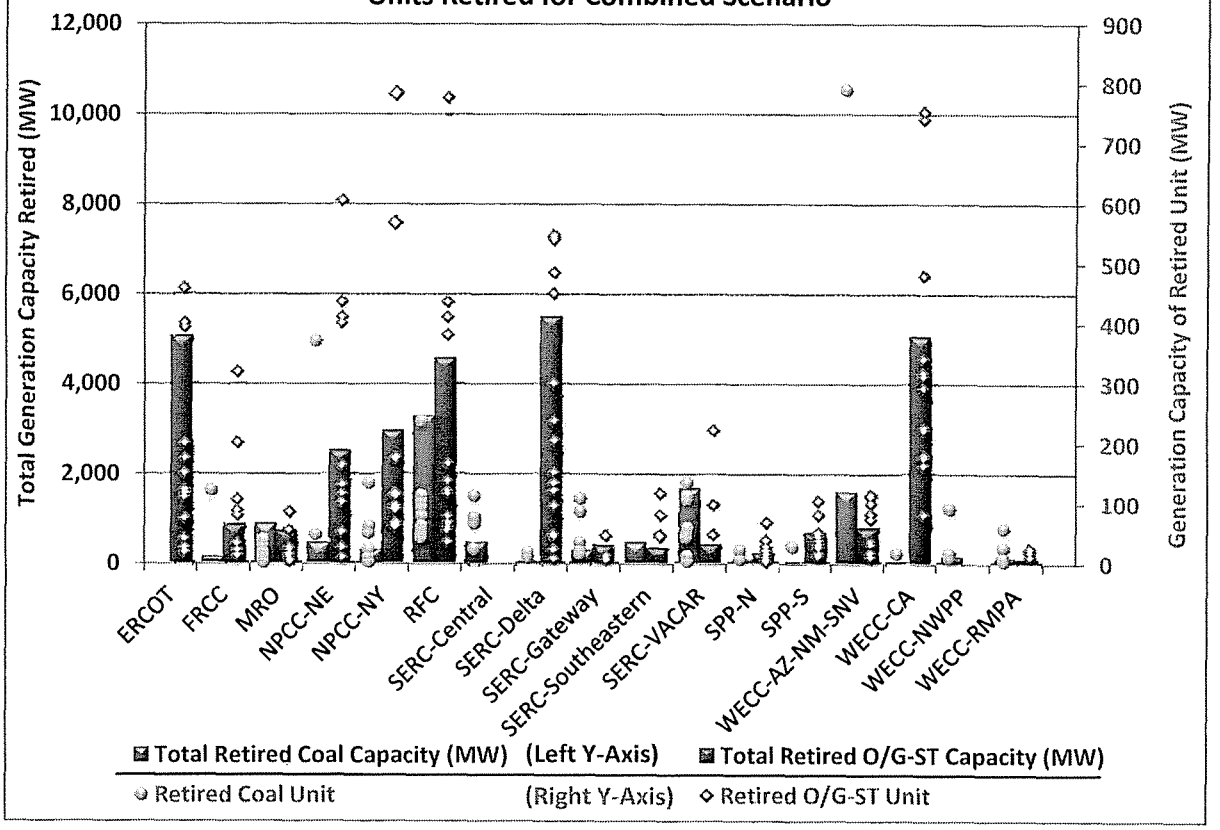
Table 9: Combined EPA Regulations Impacts - 2015						
	Moderate Case			Strict Case		
	Derated (MW)	Retired (MW)	Total	Derated (MW)	Retired (MW)	Total
ERCOT	246	5,055	5,301	480	5,295	5,775
FRCC	71	862	933	239	1,488	1,727
MRO	319	1,259	1,578	612	4,424	5,036
NPCC-NE	0	2,504	2,504	169	3,938	4,107
NPCC-NY	35	3,011	3,046	309	4,759	5,068
RFC	607	4,890	5,497	2,224	16,423	18,648
SERC-Central	237	71	308	509	4,546	5,055
SERC-Delta	113	5,524	5,636	465	5,803	6,268
SERC-Gateway	113	526	639	413	3,902	4,315
SERC-Southeastern	140	469	609	537	3,132	3,669
SERC-VACAR	132	915	1,047	515	5,042	5,557
SPP	198	831	1,029	428	2,149	2,577
WECC-CA	0	3,560	3,560	195	6,452	6,647
WECC-AZ-NM-SNV	49	773	822	54	2,353	2,407
WECC-NWPP	108	129	237	113	129	242
WECC-RMPA	25	184	208	25	225	251
TOTAL	2,394	30,563	32,957	7,289	70,059	77,349

Table 10: Combined EPA Regulations Impacts - 2018						
	Moderate Case			Strict Case		
	Derated (MW)	Retired (MW)	Total	Derated (MW)	Retired (MW)	Total
ERCOT	366	5,055	5,421	480	5,295	5,775
FRCC	188	983	1,171	239	1,488	1,727
MRO	534	1,553	2,087	612	4,424	5,036
NPCC-NE	196	2,970	3,166	169	3,938	4,107
NPCC-NY	353	3,239	3,592	309	4,759	5,068
RFC	1,965	7,848	9,813	2,266	15,451	17,717
SERC-Central	541	445	986	509	4,546	5,055
SERC-Delta	352	5,541	5,892	465	5,803	6,268
SERC-Gateway	390	694	1,084	442	3,299	3,741
SERC-Southeastern	423	781	1,204	537	3,132	3,669
SERC-VACAR	476	2,066	2,542	515	5,042	5,557
SPP	271	972	1,243	428	2,149	2,577
WECC-CA	230	5,055	5,285	182	6,947	7,130
WECC-AZ-NM-SNV	54	2,353	2,407	54	2,353	2,407
WECC-NWPP	113	129	242	113	129	242
WECC-RMPA	27	184	210	25	225	251
TOTAL	6,479	39,867	46,346	7,348	68,979	76,327

This assessment models both coal and oil/gas-steam unit capacity retirement. Figures 8 and 9 depict total capacity loss for both unit types, as well as the size of individual retired units by Region for the 2018 Moderate and Strict Case assessments.

In Figures 8 and 9, each retired unit is plotted on the scatter chart based on unit size (Right Y-Axis). In some cases, data points for units with the same unit size (MW) may overlap and be hidden. The blue and red bars (Left Y-Axis) show the total retired capacity by subregion. Overall, a majority of the retired units are less than 200 MW.

Figure 8: 2018 Moderate Case
Units Retired for Combined Scenario



The Strict Case (see Figure 9) has a significant impact on coal units in the MRO, RFC, SERC-Central, SERC-Gateway, SERC-Southern, and SERC-VACAR Regions/subregions.

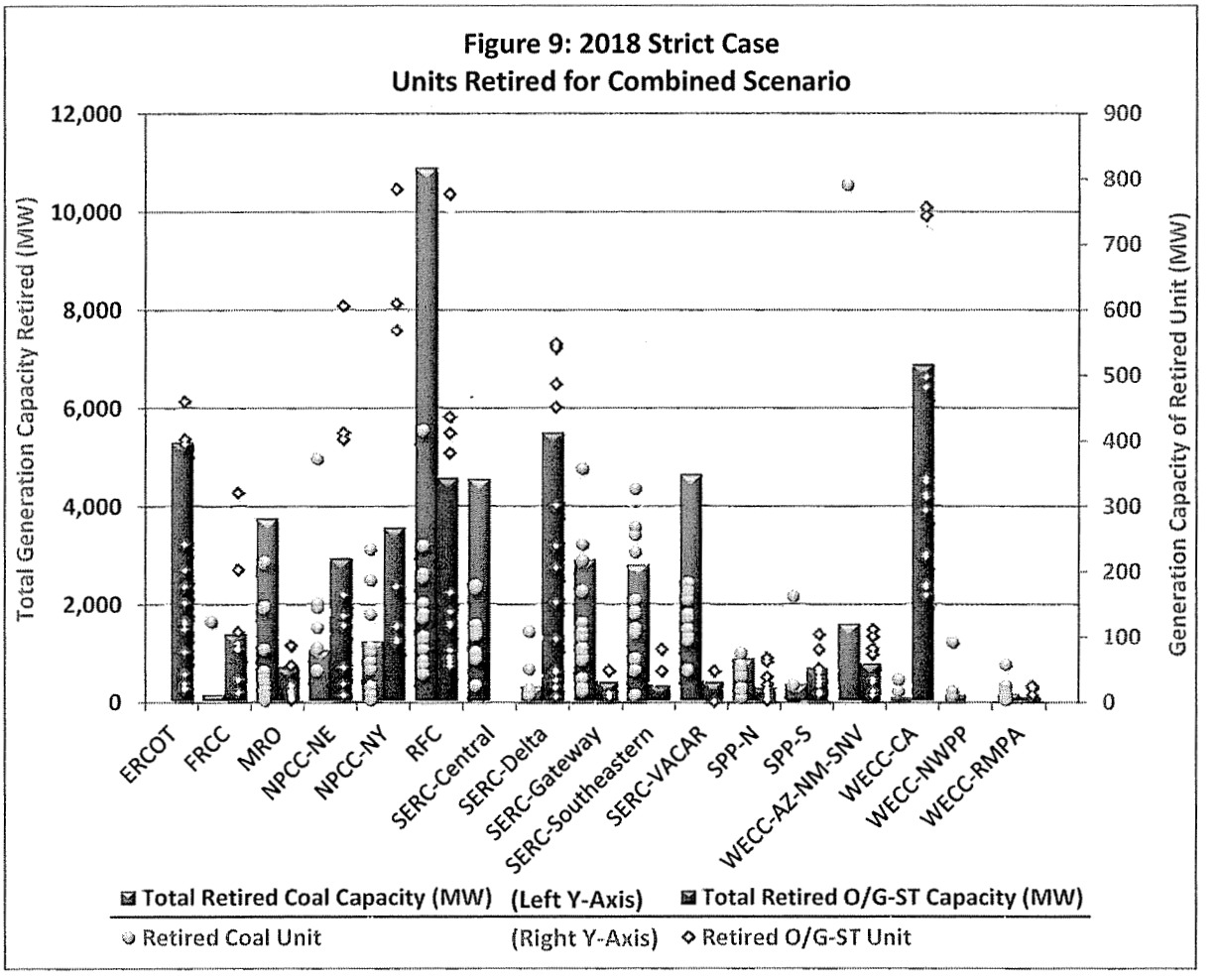
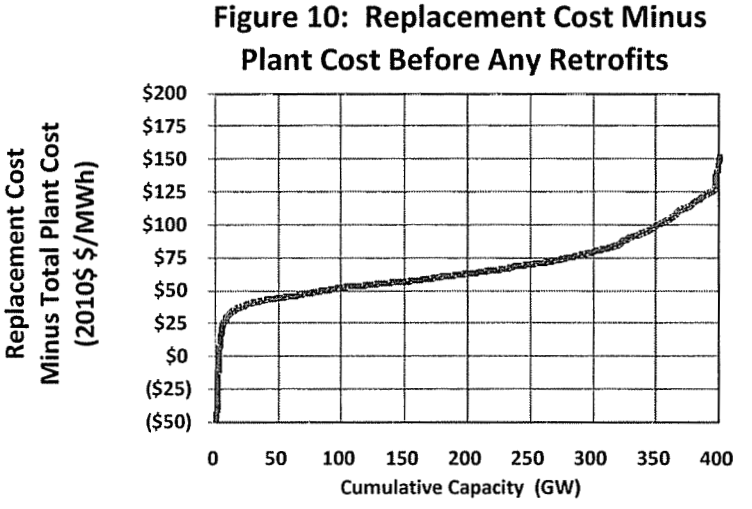


Figure 10 illustrates the model's representation of the differential between two items: the cost of a new gas plant and today's operating/ongoing costs for any new investment that has incremental costs, regardless of its source or mandate.



Reliability Assessment

Impacts on Bulk Power System Adequacy

Early retirement of multiple units in the short-run can stress the bulk power system if plans are not in place to add resources. This can affect both short- and long-term planning strategies and reduce Planning Reserve Margins.[30] Sufficient Planning Reserve Margins must be maintained to provide reliable electric service. With fewer resources, flexibility is reduced and the risk of a capacity shortage may increase, unless additional resources are available. Where Planning Reserve Margins fall below zero, there is a basic inability to serve load with available resources.

For this assessment, NERC studied the effects on Planning Reserve Margins from both unit retirement (assuming retired capacity is not replaced) and retrofits, which cause capacity reductions due to increased station loads to support emission controls or new intake structures. Planning Reserve Margins are presented using Deliverable Capacity Resources and Adjusted Potential Capacity Resources.[31] The assessment of effects to Planning Reserve Margins does not consider the ability of the electric power industry to replace retired capacity. Each modeled year portrays a "snapshot" of potential effects caused by the potential EPA regulations, rather than an ongoing timeline of retrofits and retirements. Models do not account for units coming out of retirement due to future conditions. The demand and resource projections from the *2009 Long-Term Reliability Assessment* are used as the reference case and can be found in *Appendix III, Data Tables.*

Models for each year in all cases show identical Planning Reserve Margin reductions for Deliverable and Adjusted Potential Capacity Resources, indicating that the potential EPA regulations have little to no effect on Existing-Other, Future Other, and Conceptual Resources. Therefore, comparative analysis of Deliverable Capacity Resources and Adjusted Potential Capacity figures indicates the magnitude of future resource additions required to maintain future reserve requirements.

Resources from these ten-year projections are reduced to form the scenario cases (Moderate Case and Strict Case—previously described in the report) and calculate the resulting Planning Reserve Margins. This reliability assessment includes a comparison of the impacts on Planning Reserve Margin for the years 2013, 2015, and 2018 based on the 2009 reference case. The resulting Planning Reserve Margin was compared to the NERC Reference Margin Level to determine if

[30] Planning Reserve Margin is designed to measure the amount of generation capacity available to meet expected demand in the planning horizon. Coupled with probabilistic analysis, calculated planning reserve margins have been an industry standard used by planners for decades as a relative indication of resource adequacy. Planning Reserve Margin is the difference between available capacity and peak demand, normalized by peak demand (as a percentage) needed to maintain reliable operation while meeting unforeseen increases in demand (*e.g.* extreme weather) and/or unexpected outages of existing capacity. From a planning perspective, Planning Reserve Margin trends identify whether capacity additions are keeping up with demand growth.

[31] Deliverable Capacity Resources (DCR)—defined as Existing-Certain and Net Firm Transactions plus Future-Planned capacity resources plus net transactions—and Adjusted Potential Capacity Resources (APCR)—defined as the sum of Deliverable Capacity Resources, Existing-Other Resources, Future-Other Resources (reduced by a confidence factor), Conceptual Resources (reduced by a confidence factor), and net transactions—account for future generation capacity planned for in the reference case.[31] DCR represents existing generation that has been identified as "Certain" plus future firm resources. APCR prevents this assessment from being overly conservative in two ways: 1) Conceptual resources measure industry's future response towards maintaining Planning Reserve Margins and 2) APCR represents the portion of the interconnection queue that is historically built. A range of resource projections is identified and evaluated from these two values in this assessment.

more resources are needed in the scenario case (see Table 11).[32] For the resource adequacy assessment, NERC chose a range of resource categories to evaluate Planning Reserve Margins for this scenario. The range includes Deliverable Capacity Resources on the low-end and Adjusted Potential Capacity Resources on the high-end. Refer to the *Terms Used in This Report* section for detailed definitions regarding supply/resource categories.

Table 11: NERC Reference Margin Levels

ERCOT	12.5%
FRCC	15.0%
MRO	15.0%
NPCC	
New England	15.0%
New York	16.5%
RFC	15.0%
SERC	
Central	15.0%
Delta	15.0%
Gateway	12.7%
Southeastern	15.0%
VACAR	15.0%
SPP	13.6%
WECC	
AZ-NM-SNV	17.8%
CA-MX US	22.3%
NWPP	16.3%
RMPA	17.1%

Overall, impacts on Planning Reserve Margins and the need for more resources is a function of the compliance timeline associated with the potential EPA regulations. Up to a 78 GW reduction of coal, oil, and gas-fired generation capacity is identified for retirement during the ten-year period of this scenario. For the Moderate Case, this occurs in 2018; however, in the Strict Case similar reduction occurs in 2015. The reduction in capacity significantly affects projected Planning Reserve Margins for a majority of the NERC Regions and subregions. Potentially significant reductions in capacity within a five-year period may require heightened concentration towards the addition of resources. For the United States as a whole, the Planning Reserve Margin is significantly reduced up to 9.3 percentage points in the Strict Case.

Additionally, more transmission resources may be needed as the industry responds to resolve identified capacity deficiencies. As replacement generation is constructed, new transmission may be needed to interconnect new generation. Additionally, existing generation that may not be deliverable due to transmission limitations may need enhancements to the transmission system in order to allow firm and reliable transmission service.

While NERC did not model deliverability or stability impacts to the transmission system (second tier effects) in this assessment, constructing new transmission or refurbishing existing transmission may be required. Transmission system enhancements and reconfiguration may be necessary in some areas, which may create additional timing issues as transmission facilities will take relatively longer to construct than generation.

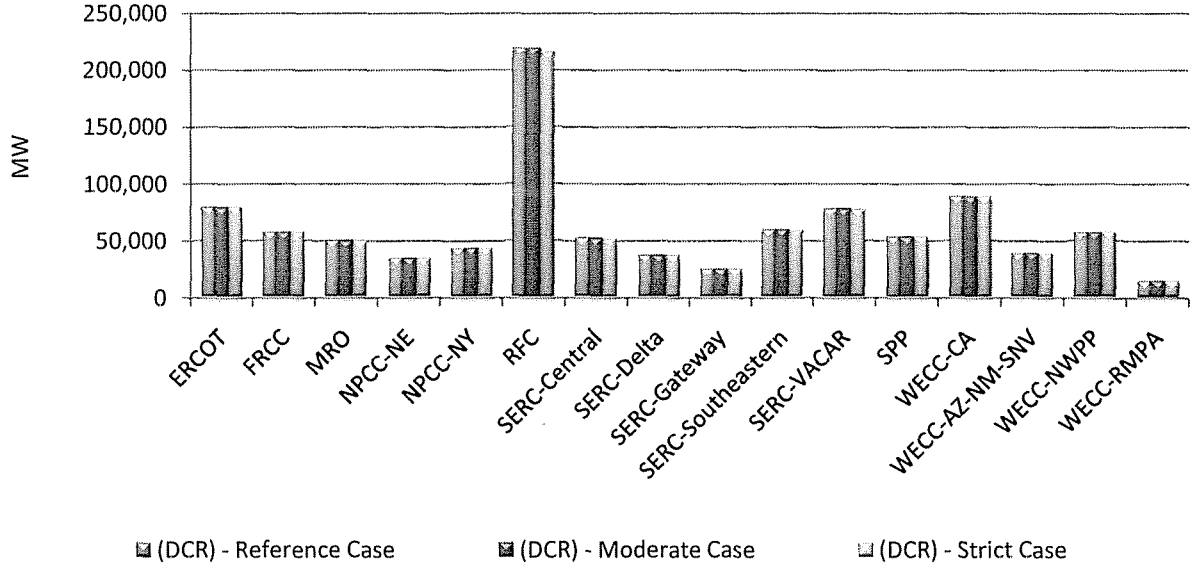
[32] NERC's Reference Reserve Margin Level is equivalent to the Target Reserve Margin Level provided by the Region/subregion's own specific margin based on load, generation, and transmission characteristics as well as regulatory requirements. If not provided, NERC assigned 15 percent Reserve Margin for thermal systems and 10 percent for predominately hydro systems.

Resource Adequacy Assessment Results: 2013

There are virtually no impacts to Planning Reserve Margins in the short term (2013). CATR is the only regulation that affects units in 2013. MRO, New England, RFC, SERC-Gateway, and SERC-Southeastern are the only Regions/subregions affected by CATR in the Moderate Case—ERCOT, FRCC, and all SERC subregions are affected in the Strict Case.

However, when CATR is modeled in the Combined EPA Regulation Scenario, the Strict Case results in a coal-fired capacity reduction of 8,391 MW by 2013 (see Figure 12). Overall, this amount does not appear to be significant and represents less than one percent of total capacity resources across the United States, but represents just fewer than 100 electric generation plants. The increased capacity reduction is a result of the increased costs being considered by generator owners, not only to comply with CATR, but with the 316(b), MACT, and CCR regulations. Because of these reductions, Planning Reserve Margins are reduced slightly in the affected Regions/subregions. The MRO Planning Reserve Margin decreases the most (about 2.7 percentage points when considering both the Deliverable and Adjusted Potential Planning Reserve Margins) to approximately 19 percent (see Figure 13 and 14). Other affected Regions/subregions include NPCC-New England and RFC, which result in a net Planning Reserve Margin reduction of less than two percentage points. There is no change to the Moderate Case when comparing the results of CATR modeled separately and the Combined EPA Regulation Scenario.

Figure 11: 2013 Summer Peak Deliverable Capacity Resources (DCR) Impacts of Combined EPA Regulation Scenario



In MRO and the SERC-Southeastern subregion, Deliverable Planning Reserve Margin is below the NERC Reference Margin Level in both scenario cases. However, this is also true when considering the Reference Case. This indicates more resources may be needed regardless of impacts from potential EPA regulations. These two subregions must rely on Adjusted Potential Capacity Resources to meet the NERC Reference Margin Level in 2013.

Figure 12: 2013 Summer Peak Adjusted Potential Capacity Resources (APCR) Impacts of Combined EPA Regulation Scenario

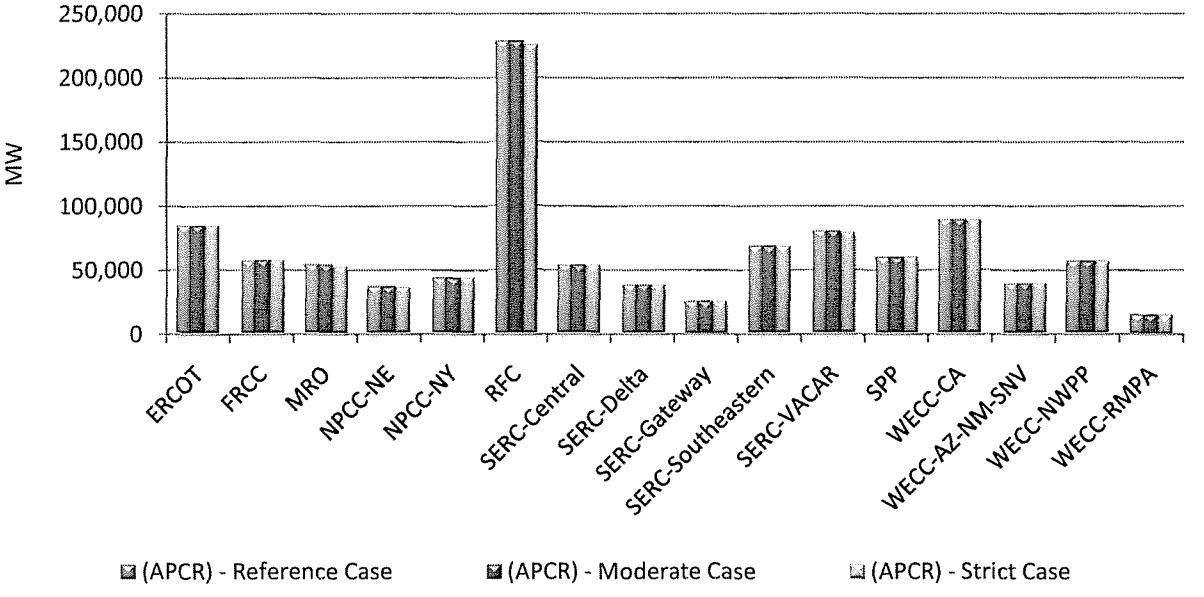


Figure 13: 2013 Summer Peak Deliverable Capacity Resources (DCR) Planning Reserve Margin Impacts of Combined EPA Regulation Scenario

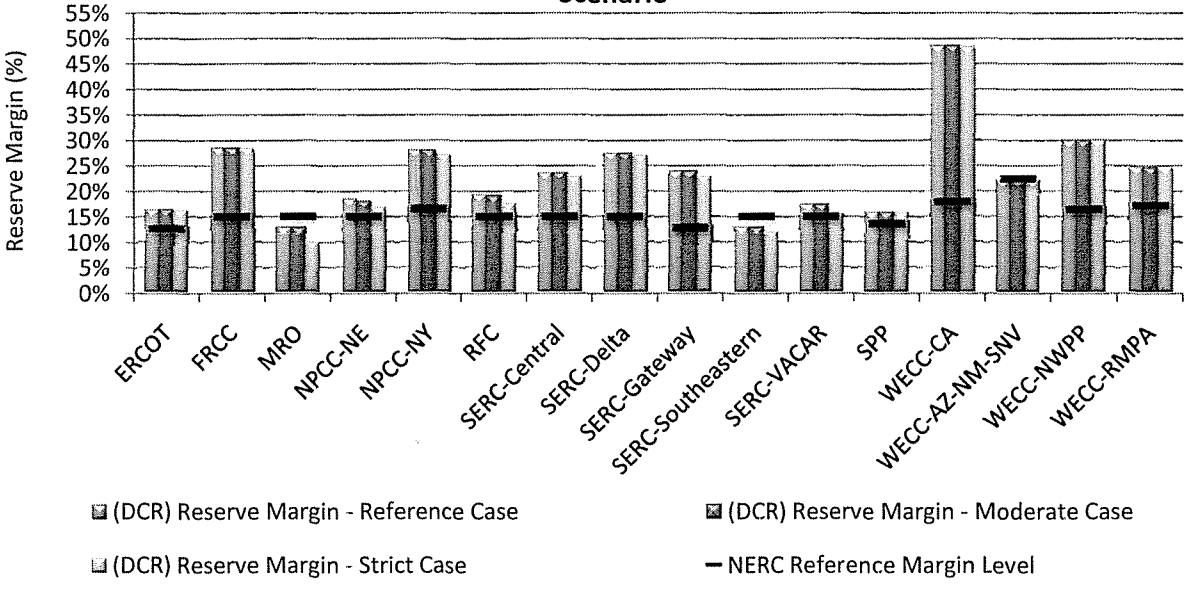


Figure 14: 2013 Summer Peak Adjusted Potential Capacity Resources (APCR) Planning Reserve Margin Impacts of Combined EPA Regulation Scenario

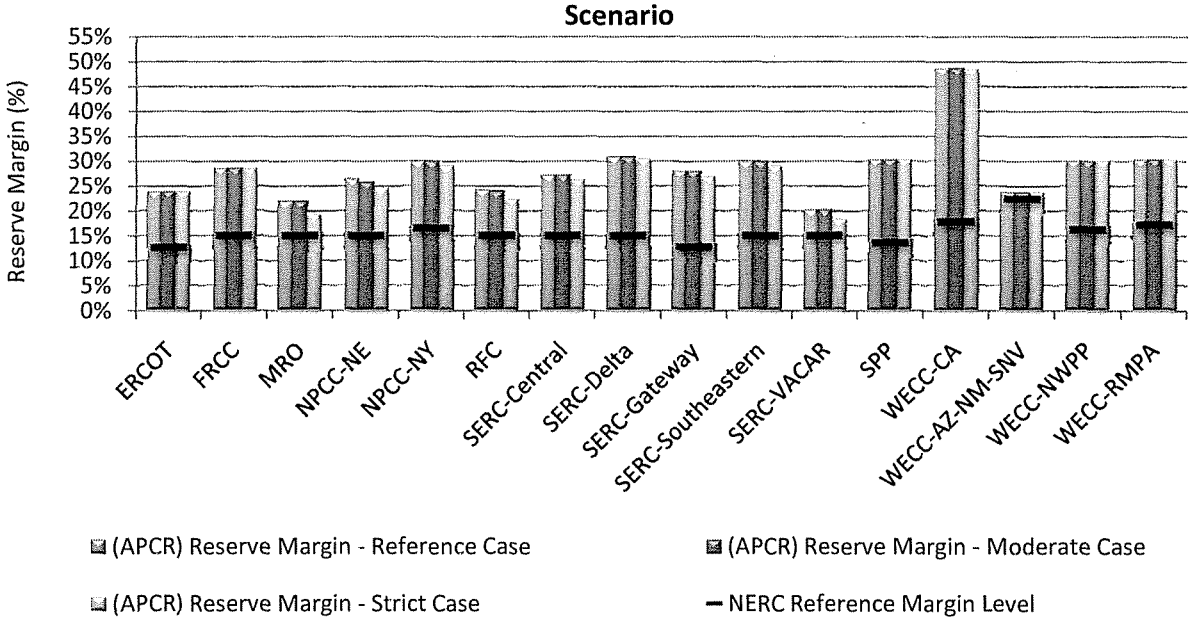


Table 12: Combined Impacts - 2013

	Moderate Case		Strict Case	
	Resulting Reserve Margin (%) (DCR to APCR)	Percentage Point Change in Reserve Margin	Resulting Reserve Margin (%) (DCR to APCR)	Percentage Point Change in Reserve Margin
ERCOT	16.5% – 23.9%	0.0 – 0.0	16.3% – 23.8%	-0.1 – -0.1
FRCC	28.6% – 28.6%	0.0 – 0.0	28.5% – 28.5%	0.0 – 0.0
MRO	12.9% – 22.1%	0.0 – 0.0	10.1% – 19.3%	-2.7 – -2.7
NPCC-NE	18.0% – 25.9%	-0.6 – -0.6	16.7% – 24.6%	-1.9 – -1.9
NPCC-NY	28.1% – 29.8%	0.0 – 0.0	27.3% – 29.0%	-0.8 – -0.8
RFC	19.2% – 24.0%	-0.2 – -0.2	17.6% – 22.4%	-1.9 – -1.9
SERC-Central	23.6% – 27.2%	0.0 – 0.0	22.8% – 26.4%	-0.9 – -0.9
SERC-Delta	27.5% – 30.9%	0.0 – 0.0	27.0% – 30.4%	-0.5 – -0.5
SERC-Gateway	24.0% – 28.0%	0.0 – 0.0	22.9% – 27.0%	-1.0 – -1.0
SERC-Southeastern	13.0% – 29.8%	0.0 – 0.0	12.1% – 28.9%	-0.9 – -0.9
SERC-VACAR	17.5% – 20.3%	0.0 – 0.0	15.5% – 18.3%	-1.9 – -1.9
SPP	15.9% – 30.3%	0.0 – 0.0	15.9% – 30.3%	0.0 – 0.0
WECC-CA	48.6% – 48.6%	0.0 – 0.0	48.4% – 48.4%	-0.3 – -0.3
WECC-AZ-NM-SNV	22.1% – 23.7%	0.0 – 0.0	22.1% – 23.7%	0.0 – 0.0
WECC-NWPP	29.9% – 30.1%	0.0 – 0.0	29.9% – 30.1%	0.0 – 0.0
WECC-RMPA	24.7% – 30.3%	0.0 – 0.0	24.7% – 30.3%	0.0 – 0.0
TOTAL	22.3% – 27.7%	-0.1 – -0.1	21.4% – 26.7%	-1.0 – -1.0

Resource Adequacy Assessment Results: 2015

For the modeled year 2015, the assessment results have a greater impact on Planning Reserve Margin. Most notably, the Combined Proposed EPA Regulations Scenario shows considerable reductions, reducing Planning Reserve Margins across the United States during the next five years.

As previously discussed, the Moderate Case and the Strict Case differ in key assumptions. In 2015, capacity reductions range from 33 GW (Moderate Case) to 77 GW (Strict Case). For the Moderate Case, ERCOT, RFC, and the SERC-Delta Regions/subregions are the most affected, each with approximately a 5,500 MW reduction in capacity (Figure 16). For the Strict Case, RFC capacity is reduced by 16.4 GW.

Figure 15: 2015 Summer Peak Deliverable Capacity Resources (DCR) Impacts of Combined EPA Regulation Scenario

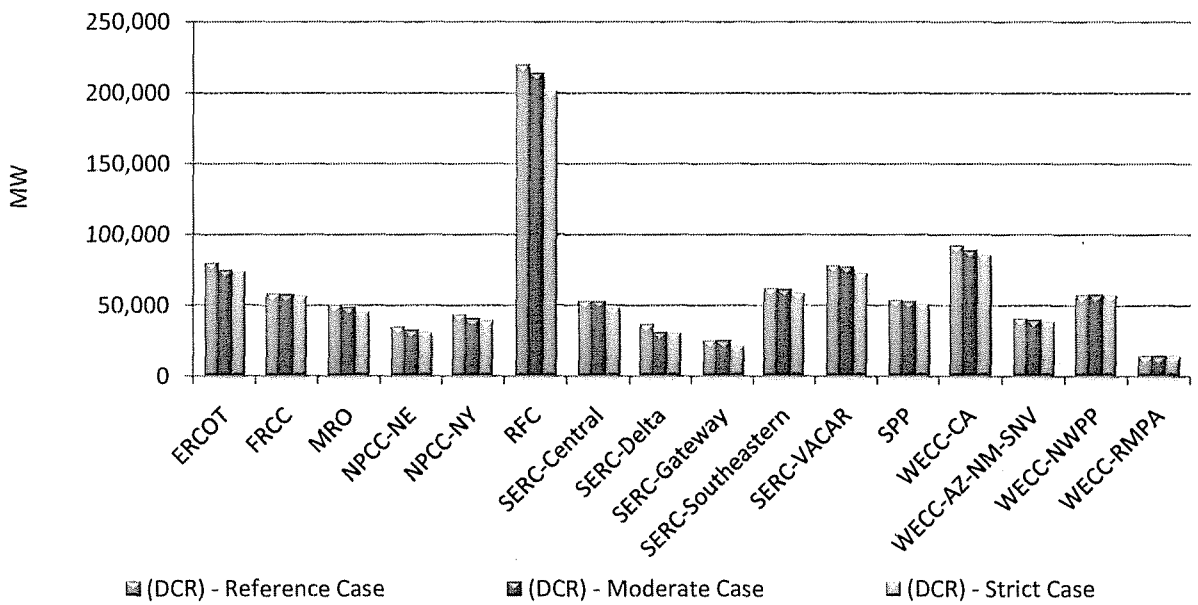
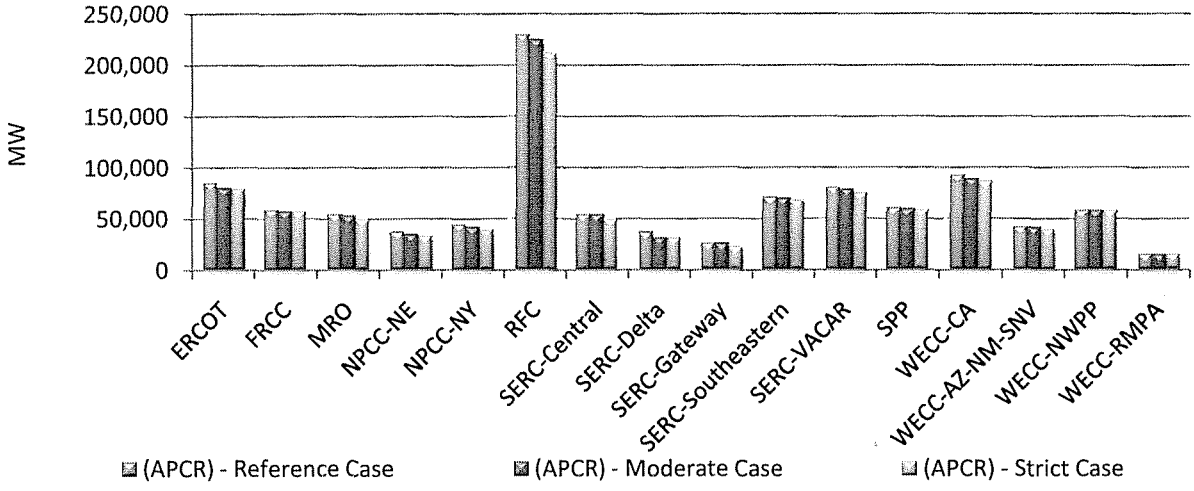


Figure 16: 2015 Summer Peak Adjusted Potential Capacity Resources (APCR) Impacts of Combined EPA Regulation Scenario



For the Moderate Case, a 3.2 percent reduction in overall capacity results in Planning Reserve Margin reductions for a majority of the NERC Regions/subregions. Accordingly, the SERC-Central, SERC-Southeastern, SERC-VACAR, WECC-NWPP, and WECC-RMPA subregions show less than a two percentage point reduction in Planning Reserve Margin. When considering the Deliverable Planning Reserve Margin a majority of the Regions/subregions fall below the NERC Reference Margin Level in 2015 for both cases. In MRO, Deliverable Planning Reserve Margins fall below zero in the Strict Case (Figure 17). Additionally, because of a 15 percent reduction in SERC-Delta capacity resources, the Planning Reserve Margin is reduced to 1.9 percent (Deliverable—see Figure 17) and 5.2 percent (Adjusted Potential—see Figure 18). In this scenario, more resources will be needed in the SERC-Delta subregion under the Moderate Case assumptions.

Figure 17: 2015 Summer Peak Deliverable Capacity Resources (DCR) Planning Reserve Margin Impacts of Combined EPA Regulation Scenario

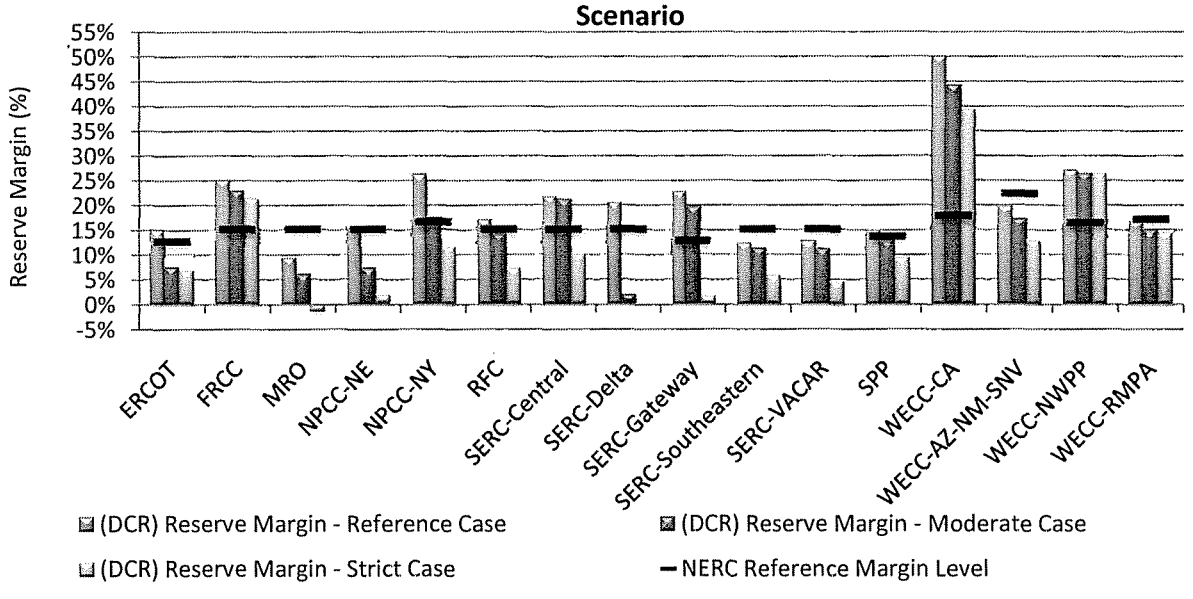
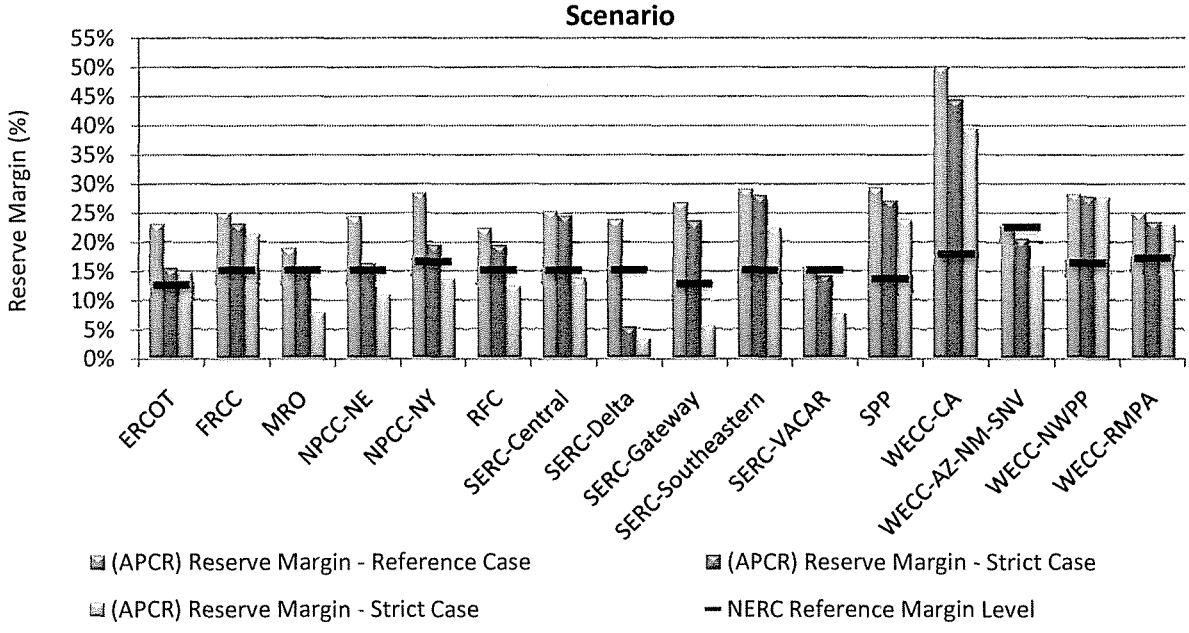


Figure 18: 2015 Summer Peak Adjusted Potential Capacity Resources (APCR) Planning Reserve Margin Impacts of Combined EPA Regulation Scenario



For the Strict Case, a 7.2 percent reduction in overall capacity results in significant Planning Reserve Margin reductions for all NERC Regions and subregions, except the WECC subregions of NWPP and RMPA. Planning Reserve Margins are significantly due to over a nine percent of capacity resources in MRO, NPCC-New England, NPCC-New York, SERC-Central, SERC-Delta, and SERC-Gateway. When considering Deliverable Planning Reserve Margins, nearly all Regions/subregions fall below the NERC Reference Margin Level (see Figure 17).Additionally, these Regions/subregions are below NERC's Reference Margin Levels under the Strict Case assumptions, indicating reductions in those Regions'/subregions' ability to maintain sufficient reserve levels. Most notably, SERC-Delta has a 3.1 percent Planning Reserve Margins in 2015. Additionally, capacity reductions in NPCC-New England, SERC-Gateway, and SERC-VACAR result in Planning Reserve Margins below 10 percent. In these Regions/subregions, more resources will be needed for this scenario.

The impacts to Planning Reserve Margins are highly dependent on which resources are projected to be in-serving in the Reference Case. As such, Adjusted Potential Capacity Resources Planning Reserve Margins are not as impacted as Deliverable Capacity Resources Planning Reserve Margin. Therefore, in order to help mitigate resource adequacy issues, Adjusted Potential Resources (which include Conceptual Resources), which carry a level of uncertainty, may be needed to meet the NERC Reference Margin Level. However, as indicated above, even these additional resources may not be sufficient.

Table 13: Combined Impacts - 2015				
	Moderate Case		Strict Case	
	Resulting Reserve Margin (%) (DCR to APCR)	Percentage Point Change in Reserve Margin	Resulting Reserve Margin (%) (DCR to APCR)	Percentage Point Change in Reserve Margin
ERCOT	7.5% – 15.4%	-7.7 – -7.7	6.8% – 14.7%	-8.4 – -8.4
FRCC	23.0% – 23.0%	-2.0 – -2.0	21.3% – 21.3%	-3.7 – -3.7
MRO	5.9% – 15.5%	-3.5 – -3.5	-1.7% – 7.9%	-11.0 – -11.0
NPCC-NE	7.2% – 16.2%	-8.3 – -8.3	1.8% – 10.8%	-13.6 – -13.6
NPCC-NY	17.4% – 19.5%	-8.9 – -8.9	11.5% – 13.6%	-14.8 – -14.8
RFC	14.2% – 19.4%	-2.9 – -2.9	7.2% – 12.4%	-9.9 – -9.9
SERC-Central	21.0% – 24.5%	-0.7 – -0.7	10.1% – 13.6%	-11.6 – -11.6
SERC-Delta	1.9% – 5.2%	-18.6 – -18.6	-0.2% – 3.1%	-20.6 – -20.6
SERC-Gateway	19.6% – 23.6%	-3.1 – -3.1	1.5% – 5.5%	-21.3 – -21.3
SERC-Southeastern	11.3% – 27.9%	-1.1 – -1.1	5.7% – 22.4%	-6.6 – -6.6
SERC-VACAR	11.1% – 14.2%	-1.5 – -1.5	4.6% – 7.6%	-8.0 – -8.0
SPP	12.7% – 27.1%	-2.2 – -2.2	9.3% – 23.8%	-5.5 – -5.5
WECC-CA	44.3% – 44.3%	-5.8 – -5.8	39.3% – 39.3%	-10.8 – -10.8
WECC-AZ-NM-SNV	17.3% – 20.6%	-2.4 – -2.4	12.6% – 15.9%	-7.1 – -7.1
WECC-NWPP	26.5% – 27.6%	-0.5 – -0.5	26.5% – 27.6%	-0.5 – -0.5
WECC-RMPA	14.9% – 23.2%	-1.7 – -1.7	14.6% – 22.9%	-2.1 – -2.1
TOTAL	16.1% – 21.7%	-4.0 – -4.0	10.8% – 16.4%	-9.3 – -9.3

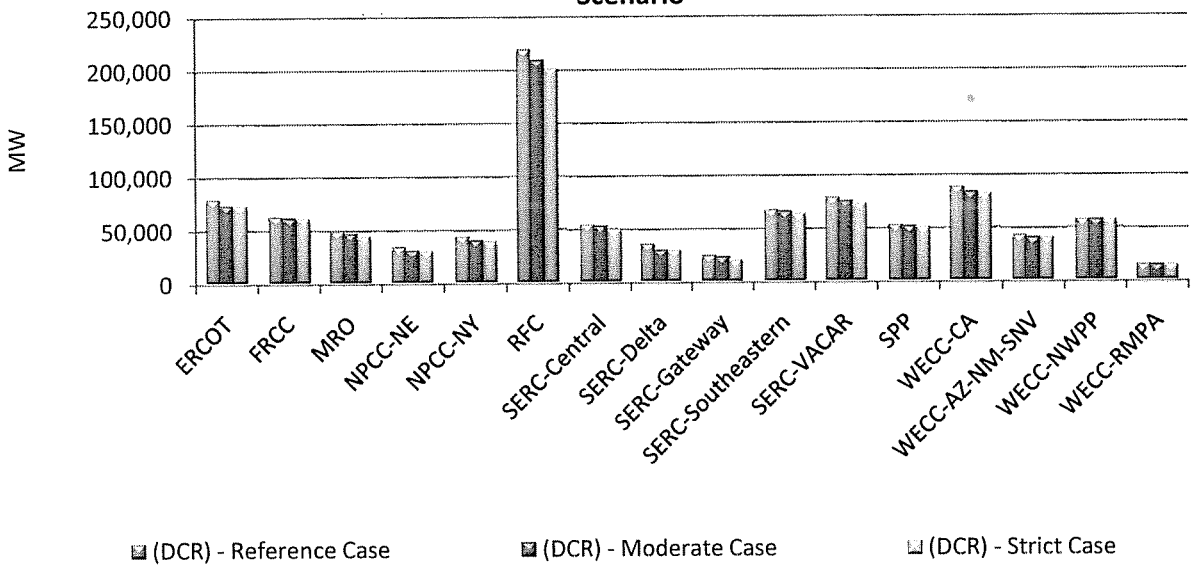
Resource Adequacy Assessment Results: 2018

Further reductions in capacity resources and Planning Reserve Margins are the results in 2018. Most notably, the Combined EPA Regulations Scenario shows considerable reductions, effectively reducing Planning Reserve Margins across the United States within the next eight years.

The Combined Regulation Scenario shows the most notable capacity resources reductions. As previously discussed, the Moderate Case and the Strict Case differ in key assumptions that have been made to the model. In 2018, capacity reductions range from 46 GW (Moderate Case) to 76 GW (Strict Case).[33] For the Moderate Case, RFC is the more affected Region with just under a 10 GW reduction in capacity resources, followed by ERCOT, SERC-Delta, and the WECC-CA Regions/subregions, each with approximately a 5.5 GW capacity reduction (Figure 15).

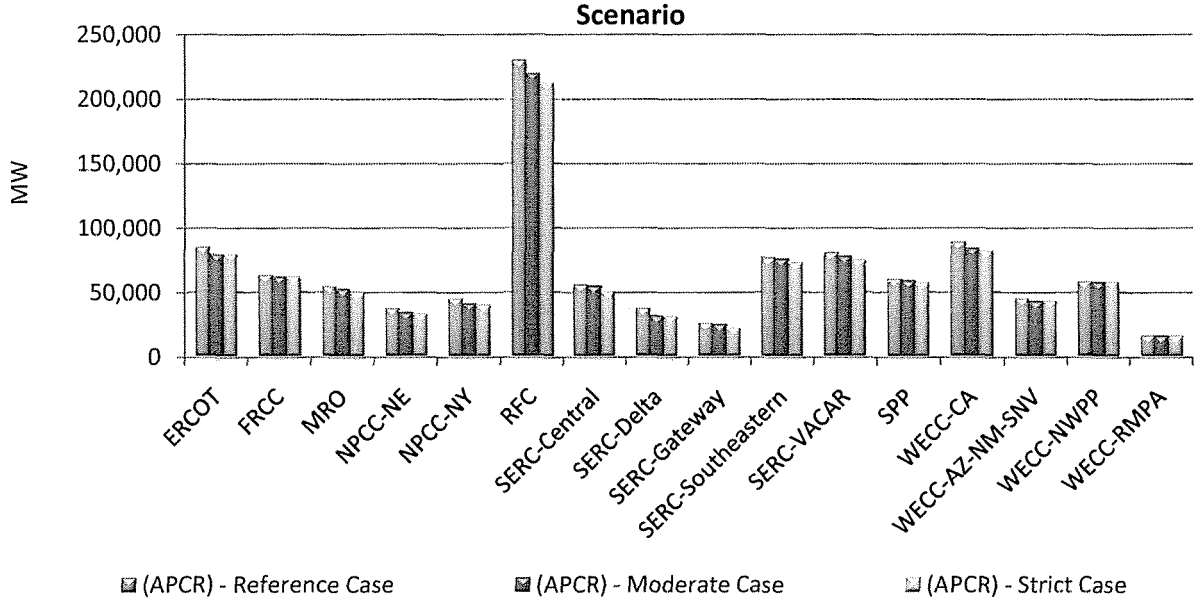
For the Strict Case, RFC capacity is reduced by 17.7 GW. With the exception of FRCC, WECC-NWPP, and WECC-RMPA, all Regions/subregions show at least a five percent reduction in capacity resources. MRO, NPCC-New England, NPCC-New York, SERC-Central, SERC-Delta, and SERC-Gateway all show at least a nine percent reduction in capacity resources; SERC-Delta shows a 17 percent reduction, suggesting more resources will be needed in these areas.

Figure 19: 2018 Summer Peak Deliverable Capacity Resources (DCR) Impacts of Combined EPA Regulation Scenario



[33] The total reductions for the 2018 Combined Regulation-Strict Case (76 GW) is less than the total reductions for the 2015 Combined Regulation-Strict Case (77 GW) due to slightly higher gas prices assumed for the year 2018. Therefore, plants may opt to retrofit rather than purchase replacement generation. Each modeled year portrays a "snapshot" of potential effects caused by the EPA regulations, rather than an ongoing timeline of retrofits and retirements.

Figure 20: 2018 Summer Peak Adjusted Potential Capacity Resources (APCR) Impacts of Combined EPA Regulation Scenario



The capacity reductions identified in this scenario significantly reduce Planning Reserve Margins. The Moderate Case depicts a 4.4 percent reduction in overall capacity resulting in sizeable Planning Reserve Margin reductions for a majority of the NERC Regions/subregions. The WECC-NWPP and WECC-RMPA subregions show less than a two percentage point reduction. When considering the Deliverable Planning Reserve Margin a majority of the Regions/subregions fall below the NERC Reference Margin Level in 2018 for both cases (Figure 21). Significant capacity reductions in ERCOT, MRO, NPCC-New England, and SERC-Delta result in Planning Reserve Margin below 10 percent (see Figure 22) when considering the Adjusted Potential Planning Reserve Margin.

When considering Deliverable Capacity Resources, ERCOT, MRO, NPCC-New England, and SERC-Delta fall below zero. With Adjusted Potential Capacity Resources, the SERC-Delta Planning Reserve Margin is reduced 18.7 percentage points to -0.5 percent because of a 16 percent reduction in SERC-Delta resources.

The Strict Case shows that a 7.2 percent reduction in overall capacity results in significant Planning Reserve Margin reductions for almost all NERC Regions and subregions, except the WECC subregions of NWPP and RMPA. Planning Reserve Margins are significantly reduced as a result of capacity resource reductions greater than 10 percent in MRO, NPCC-New England, NPCC-New York, SERC-Delta, and SERC-Gateway (see Figure 22). A majority of the NERC Regions/subregions are below NERC's Reference Margin Level under the Strict Case assumptions. Most notably, MRO and SERC-Delta Planning Reserve Margin in 2018 are 3.7 and -1.7 percent, respectively. Additionally, capacity reductions in ERCOT, NPCC-New England, RFC, SERC-Gateway, SERC-Southeastern, SERC-VACAR, and SPP result in Planning Reserve Margins below10 percent.

Figure 21: 2018 Summer Peak Deliverable Capaity Resources (DCR) Planning Reserve Margin Impacts of Combined EPA Regulation Scenario

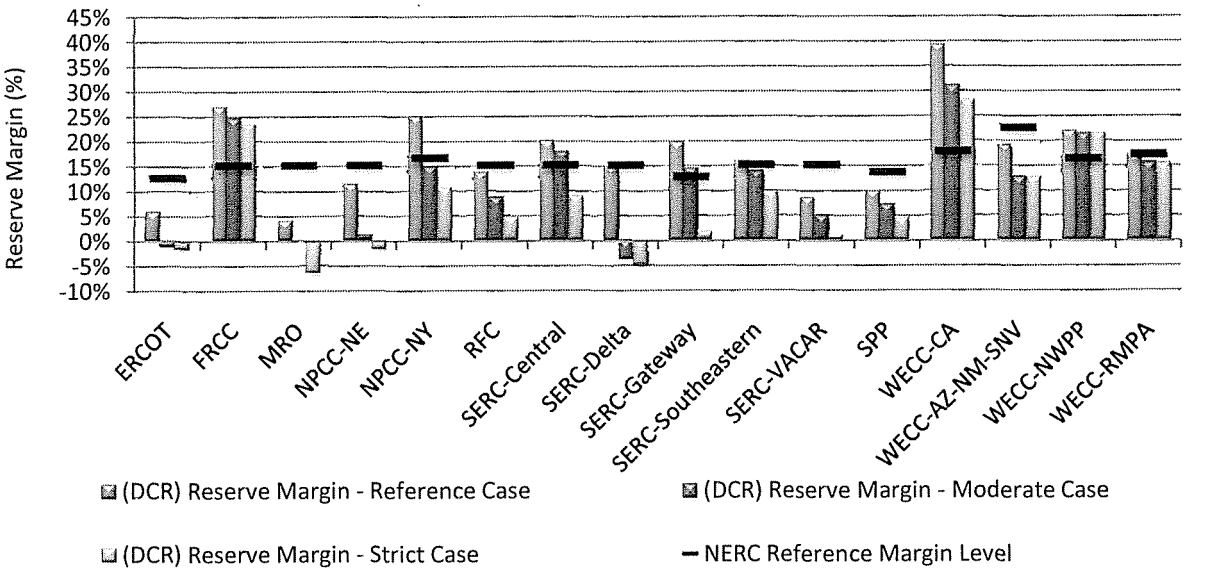


Figure 22: 2018 Summer Peak Adjusted Potential Capacity Resources (APCR) Planning Reserve Margin Impacts of Combined EPA Regulation Scenario

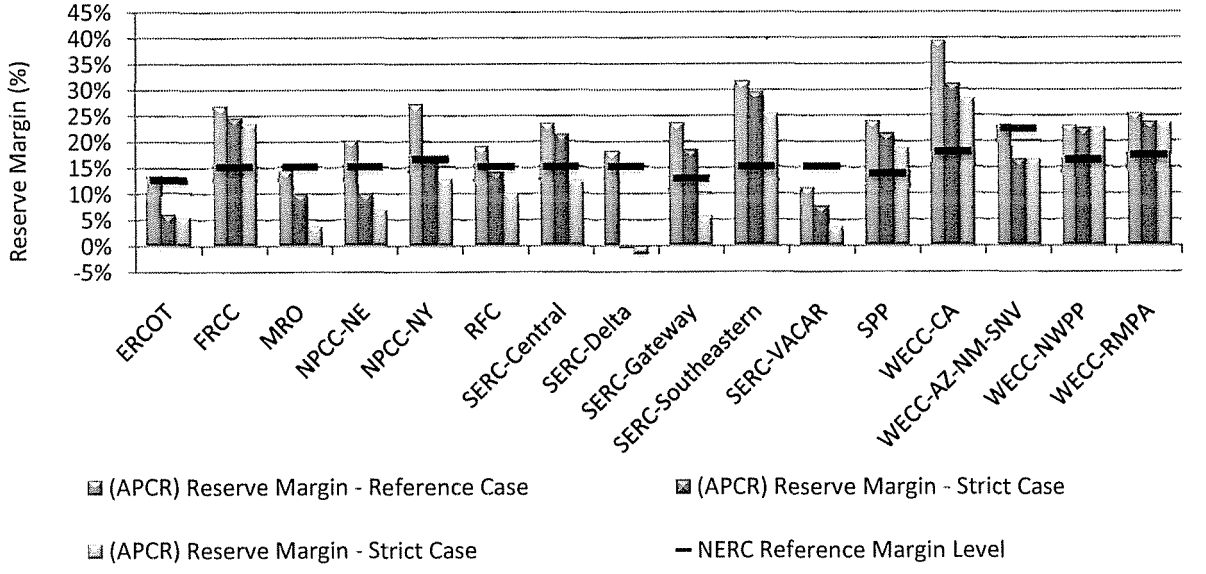


Table 14: Combined Impacts - 2018				
	Moderate Case		Strict Case	
	Resulting Reserve Margin (%) (DCR to APCR)	Percentage Point Change in Reserve Margin	Resulting Reserve Margin (%) (DCR to APCR)	Percentage Point Change in Reserve Margin
ERCOT	-1.2% – 6.0%	-7.2 – -7.2	-1.7% – 5.6%	-7.7 – -7.7
FRCC	24.6% – 24.6%	-2.3 – -2.3	23.5% – 23.5%	-3.5 – -3.5
MRO	-0.3% – 9.9%	-4.4 – -4.4	-6.5% – 3.7%	-10.6 – -10.6
NPCC-NE	1.2% – 10.0%	-10.2 – -10.2	-1.8% – 6.9%	-13.3 – -13.3
NPCC-NY	14.9% – 16.9%	-10.2 – -10.2	10.7% – 12.7%	-14.4 – -14.4
RFC	8.7% – 14.1%	-5.1 – -5.1	4.7% – 10.0%	-9.2 – -9.2
SERC-Central	18.0% – 21.3%	-2.2 – -2.2	9.0% – 12.3%	-11.2 – -11.2
SERC-Delta	-3.7% – -0.5%	-18.7 – -18.7	-4.9% – -1.7%	-19.9 – -19.9
SERC-Gateway	14.5% – 18.4%	-5.2 – -5.2	1.7% – 5.6%	-18.0 – -18.0
SERC-Southeastern	13.9% – 29.6%	-2.1 – -2.1	9.7% – 25.4%	-6.3 – -6.3
SERC-VACAR	5.0% – 7.6%	-3.5 – -3.5	0.9% – 3.4%	-7.6 – -7.6
SPP	7.4% – 21.4%	-2.6 – -2.6	4.6% – 18.7%	-5.3 – -5.3
WECC-CA	31.1% – 31.1%	-8.3 – -8.3	28.2% – 28.2%	-11.2 – -11.2
WECC-AZ-NM-SNV	12.6% – 16.6%	-6.6 – -6.6	12.6% – 16.6%	-6.6 – -6.6
WECC-NWPP	21.5% – 22.6%	-0.5 – -0.5	21.5% – 22.6%	-0.5 – -0.5
WECC-RMPA	15.7% – 23.8%	-1.6 – -1.6	15.4% – 23.5%	-1.9 – -1.9
TOTAL	11.0% – 16.5%	-5.3 – -5.3	7.6% – 13.1%	-8.8 – -8.8

Industry Actions: Tools and Solutions for Mitigating Resource Adequacy Issue

In addition to the potential for waivers or extensions, a variety of tools and solutions can help mitigate significant reliability impacts resulting from resource adequacy concerns created by this scenario assessment. They include, but are not limited to:

Advancing In-service Dates of Future or Conceptual Resources

- Generation resources may be able to advance their in-service dates where sufficient lead time is given.
- Accelerated construction may be possible.
- Existing market tools, such as forward capacity markets and reserve sharing mechanisms, can assist in signaling resource needs. Price signalling will be important in developing new resources.

Addition of New Resources Not yet Proposed

- Smaller, combustion turbines or mobile generation units can be added to maintain local reliability where additional capacity is needed.
- Additional distributed generation may also mitigate local reliability issues.

Increased Demand-Side Management and Conservation

- *Increased Energy Efficiency may offset future demand growth.*
- Increasing available Demand Response resources can provide planning and operating flexibility by reducing peak demand.

Early Action to Mitigate Severe Losses

- Planning and constructing retrofits immediately will aid in preventing the potential for construction delays and overflows, mitigating the risk of additional unit loss.
- Managing retrofit timing on a unit basis will keep capacity supply by region stable..

Increase in Transfers

- Regions\subregions that have access to a larger pool of generation may be able to increase the amount of import capacity from areas with available capacity, transfer capability is sufficient. and deliverability is confirmed.
- Additional transmission or upgrades may enable additional transactions to provide additional resources across operating boundaries.

Developing or Exploring Newer Technologies

- Other technologies exist, such as trona injection, that will allow companies to comply with EPA air regulations without installing more scrubbers.

Use of More Gas-Fired Generation

- Existing gas units may have additional power production potential, which can be expanded during off peak periods. This capacity can assist in managing plant outages during the installation of emission control systems.

Repowering of Coal-Fired Generation

- Some coal-fired generation have the potential to repower their units with combined-cycle gas turbines and reducing emmisions.

The enhancements listed are all options for consideration to offset potential reliability concerns identified in this scenario assessment. The industry should closely monitor the EPA regulation process as well as continued generator participation/early-retirement announcements.

Conclusions & Recommendations

Conclusions

The results of this assessment show a significant impact to reliability should the four potential EPA rules be implemented as assumed in this assessment. Impacts to both bulk power system planning and operations may cause serious concerns unless prompt industry action is taken. Planning Reserve Margins appear to be significantly impacted, deteriorating resource adequacy in a majority of the NERC Regions/subregions. Additionally, considerable operational challenges will exist in managing, coordinating, and scheduling an industry-wide environmental control retrofit effort.

Of the four selected EPA rules, the Section 316(b) Cooling Water Intake Structures rule individually has the greatest potential impact on Planning Reserve Margins. Implementation of this rule will apply to 252 GW (1,201 units) of coal, oil steam, and gas steam generating units across the United States resulting in total "vulnerable" capacity of 37-41 GW by 2018. Additionally, approximately 60GW of nuclear capacity may be affected. Because of this scenario, Planning Reserve Margins are decreased as much as 18 percentage points in the SERC-Delta subregion where the margin falls below zero (available generation will be unable to serve load), unless additional resources are added. Other Regions/subregions affected include NPCC-New England and New York.

The remaining three selected EPA rules assessed will mostly affect existing coal-fired capacity, ranked in descending order:

MACT

- The EPA MACT Rule alone could trigger the retirement of 2-15 GW (Moderate Case and Strict Case) of existing coal capacity by 2015. The "hard stop" 2015 compliance deadline proposed by the EPA MACT Rule makes retrofit timing a significant issue and potentially problematic.

CATR

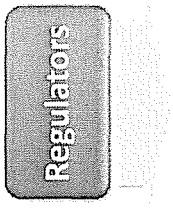
- The CATR also could have significant impacts as soon as 2015, should EPA require emission limits with no offset trading, resulting in potentially 3-7 GW of retired and derated capacity and require retrofitting of 28-576 plants with environmental controls by 2015.

CCR

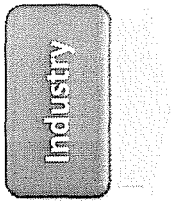
- The CCR Rule alone is projected to have the least impact, triggering the retirement of up to 12 coal units (388 MW). While the resulting impacts of the CCR scenario may not have significant impacts to capacity by itself, the associated compliance costs of CCR contribute to the Combined EPA Regulation Scenario.

Based on the assessment's assumptions, the greatest risk to Planning Reserve Margins occurs in 2015 for the Combined EPA Regulation Scenario. The overall total impact could make 46-76 GW of existing capacity "economically vulnerable" for retirement or derating by 2015. Additionally, the scenario cases assessed in this report indicate capacity reductions evident as early as 2013, resulting from the retirements of coal-fired plants and derate effects associated with plant retrofits. Impacts to Planning Reserve Margins can occur during the next four to eight years that could reduce bulk power system reliability, unless additional resources are constructed or acquired. It is essential that projected Conceptual supply resources be developed as one source of capacity replacement.

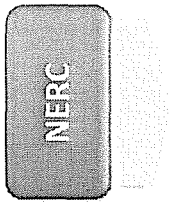
Recommendations



In the future, a variety of demands on existing infrastructure will be made to support the evolution from the current fuel mix, to one that includes generation that can meet proposed EPA regulations. The pace and aggressiveness of these environmental regulations should be adjusted to reflect and consider the overall risk to the bulk power system. EPA, FERC, DOE and state utility regulators, both together and separately, should employ the array of tools at their disposal to moderate reliability impacts, including, among other things, granting required extensions to install emission controls.



Industry participants should employ available tools to ensure Planning Reserve Margins are maintained while forthcoming EPA regulations are implemented. For example, regional wholesale competitive markets should ensure forward capacity markets are functioning effectively to support the development of new replacement capacity where needed. Similarly, stakeholders in regulated markets should work to ensure that investments are made to retrofit or replace capacity that will be affected by forthcoming EPA regulations.



NERC should further assess the implications of the EPA regulations as greater certainty or finalization emerges around industry obligations, technologies, timelines, and targets. Strategies should be communicated throughout the industry to maintain the reliability of the bulk power system. This assessment should include impacts to operating reliability and second tier impacts (e.g., deliverability, stability, localized issues, outage scheduling, operating procedures, and industry coordination) of forthcoming EPA regulations.

Appendix I: Assessment Methods

Method for This Assessment

Some studies completed by various organizations have made assumptions that environmental regulations will cause all units that meet a certain criteria to retire, for example, all units less than 230MW that have a capacity factor below 35 percent. This simplified approach does not consider other important factors:

1. Regulated versus deregulated plant (can affect the ability to finance capital improvements as well as the cost of capital)
2. Unit ownership that can affect the cost of capital
3. Regional reserve margin, *i.e.*, the need to build new capacity to replace retired capacity
4. Operating cost of the unit versus the operating cost of replacement capacity
5. Management's attitude toward fossil fuel generation
6. State specific implementation
7. Other local and unit specific issues

In developing this report, NERC used a contracted model from Energy Ventures Associates (EVA), which does not consider Reference Planning Reserve Margins commitments, reliability-must-run factors or transmission constraints. Instead, the model applied generic costs factors, related to unit size and unit location, to each unit. An economic approach is used to identify units to retire when the generic required cost of compliance with the proposed environmental regulation exceeds the cost of replacement power. For the purpose of this assessment, replacement power was considered to be gas-fired capacity. This assessment was completed in constant 2010 U.S. dollars.

EVA used its delivered natural gas and coal price forecasts. All gas prices were assessed at the point of delivery to the electric generation plant. In addition, coal supply costs were adjusted for any savings resulting from the ability to burn a different quality of coal, *e.g.*, higher BTU coal.

One deviation from this general method occurs specifically for the expected outcome of the CATR regulation, such that the model considers the surplus credits that have accumulated and allows them to be used as an offset in lieu of installing additional environmental controls.

A brief description of the method follows:

Retirement criteria: retire if (CC+FC+VC) / (1-DR) > RC, where:

CC = required compliance cost in $/MWH
FC = current fixed O&M in $/MWH
VC = variable O&M including fuel cost in $/MWH
RC = replacement cost in $/MWH
DR = derate factor that accounts for the incremental energy loss due to any new environmental controls

CC = function(incremental capital, incremental fixed O&M cost, incremental variable O&M, cost of capital, capacity factor, remaining life without new regulation)

(IC * CRF +IFOM) / (8.76*CF) + IVOM, where:

IC = Incremental capital cost ($/kW) that is plant specific for each regulation, *i.e.*, can range from zero if the plant is already in compliance to the cost of any additional capital to comply with the proposed regulation. This cost is a function of the size of the plant and its location.

CRF = Capital recovery factor = $i * (1 + i)^n / ((1 + i)^n - 1)$

i = Pre-tax cost of capital:
Deregulated IOU = 17.5%
Regulated IOU = 12.7%
Coop = 7%
Municipality = 6%

n = Remaining life in years, linear interpolation between [CF=0, n=3], and [CF=100%, n=30], *i.e.*, if CF=30% then
n = (1-30%)*3 + 30%*30 = 11.1 years

IFOM = Incremental increase in the fixed O&M cost ($/kW-yr)

CF = Capacity factor of the plant in 2008

IVOM = Incremental increase in the variable O&M cost ($/MWh)

FC = Current fixed O&M cost in $/kW-yr / (8.76*CF)[34]

	0 MW	100MW	>300 MW
Coal =	$30.00/kW-yr	$21.00/kW-yr	$18.00/kW-yr
O/G Steam =	$22.50/kW-yr	$15.75/kW-yr	$13.50/kW-yr

VC = Variable O&M cost in $/MWH

	0 MW	100MW	>300 MW
Coal =	$5.00/MWh	$4.00/MWh	$3.75/MWh
O/G Steam =	$3.33/MWh	$2.67/MWh	$2.50/MWh

Plus fuel cost
= Delivered fuel cost ($/MMBtu) * heat rate (1000 Btu/kWh)

[34] Fixed Brownfield construction costs may be lower than the Greenfield costs assumed in this assessment.

RC = Replacement cost is a function of the capacity factor, cost of new combined cycle plants, cost of new peaking capacity, and natural gas price

If CF between 10% and 90%,
RC = [(1 - (CF - 10%)/80%) * RC10 + (CF- 10%)/80% * RC90]
If CF <=10%, RC = RC10
If CF >=90%, RC = RC90

RC10 = Full capital and operating cost of a new GT unit in the NERC Region in $/MWh@ 10% CF with the capital and delivered natural gas cost varying by region

RC90 = Full capital and operating cost of a new CC unit in the NERC Region in $/MWh@ 90% CF with the capital and delivered natural gas cost varying by region

A capacity factor of 90 percent was selected for the combined cycle unit as a proxy for the practical, maximum, annual operating rate of a typical fossil fuel unit. A capacity factor of 10 percent was selected for peaking gas plants as the upper limit of what is typically observed under actual operating conditions.

New gas plant cost assumptions illustrated by Table I-1 are:

Table I-1: Model Assumptions - New Gas Plant

	Average Ten Year Outlook for NG Price				New Combined Cycle Plant			New Gas Turbine			Other Parameters	
	Combined Cycle Natural Gas Price in $/MMBtu		Gas Turbine Natural Gas Price in $/MMBtu		Capital	Fixed O&M	Var O&M	Capital	Fixed O&M	Var O&M	Pre-Tax	CRF
	2013-2022	2018-2027	2013-2023	2018-2028	$/kW	$/kW-yr	$/kWH	$/kW	$/kW-yr	$/kWH	WACC	$30.00
ERCOT	$6.35	$6.94	$6.26	$6.84	$1,200.00	$19.50	$6.00	$600.00	$7.50	$4.00	19.1%	0.192
FRCC	$7.75	$8.36	$6.78	$7.36	$1,200.00	$19.50	$6.00	$600.00	$7.50	$4.00	12.7%	0.130
MRO	$6.40	$6.98	$6.30	$6.88	$1,200.00	$19.50	$6.00	$600.00	$7.50	$4.00	12.7%	0.130
NPSS-NE	$7.10	$7.69	$6.99	$7.57	$1,200.00	$19.50	$6.00	$600.00	$7.50	$4.00	19.1%	0.192
NPCC-NY	$6.79	$7.34	$6.68	$7.22	$1,200.00	$19.50	$6.00	$600.00	$7.50	$4.00	19.1%	0.192
RFC	$6.68	$7.25	$6.39	$6.94	$1,200.00	$19.50	$6.00	$600.00	$7.50	$4.00	19.1%	0.192
SERC-Central	$6.46	$7.02	$6.29	$6.85	$1,200.00	$19.50	$6.00	$600.00	$7.50	$4.00	12.7%	0.130
SERC-Delta	$6.27	$6.85	$6.18	$6.75	$1,200.00	$19.50	$6.00	$600.00	$7.50	$4.00	12.7%	0.130
SERC-Gateway	$6.34	$6.96	$6.11	$6.73	$1,200.00	$19.50	$6.00	$600.00	$7.50	$4.00	12.7%	0.130
SERC-Southeastern	$6.65	$7.21	$6.48	$7.04	$1,200.00	$19.50	$6.00	$600.00	$7.50	$4.00	12.7%	0.130
SERC-VACAR	$6.86	$7.42	$6.59	$7.14	$1,200.00	$19.50	$6.00	$600.00	$7.50	$4.00	12.7%	0.130
SPP	$6.76	$7.32	$6.54	$7.09	$1,200.00	$19.50	$6.00	$600.00	$7.50	$4.00	12.7%	0.130
WECC-AZ-NM-SNV	$6.23	$6.80	$6.08	$6.64	$1,200.00	$19.50	$6.00	$600.00	$7.50	$4.00	19.1%	0.192
WECC-CA	$6.46	$7.06	$6.31	$6.89	$1,200.00	$19.50	$6.00	$600.00	$7.50	$4.00	19.1%	0.192
WECC-NWPP	$6.35	$6.94	$6.20	$6.77	$1,200.00	$19.50	$6.00	$600.00	$7.50	$4.00	19.1%	0.192
WECC-RMPA	$5.99	$6.54	$5.84	$6.38	$1,200.00	$19.50	$6.00	$600.00	$7.50	$4.00	12.7%	0.130

*** Constant 2010 NG Price**

WACC = Weighted Average Cost of Capital

CRF = Capital Recovery Factor

Heat Rates: 7,000 for combined cycle and 10,000 for gas turbine

Appendix II: Potential Environmental Regulations

Section 316(b) Cooling Water Intake Structures

The typical power plant uses a fuel (coal, gas or nuclear) to heat water into steam, which then turns a turbine connected to a generator, which produces electricity. The steam then condenses back into water to continue the process again. This condensation requires cooling either by water, air, or both. In open-loop cooling, (see Figure II-1), large volumes of water withdrawn from a water source (reservoir, lake or river) pass through the heat exchanger to condense steam in a single pass before the majority returns to the source. Closed-loop cooling is an alternative to open-loop cooling (see Figure II-2). Closed-loop cooling systems circulate a similar total volume of water as open-loop systems for a given plant size, but only withdraw a limited amount of water to replace evaporative loss and blow-down. There is also "dry" or air-cooling which requires little to no water and is cooled directly or indirectly via conductive heat transfer using a high flow rate of ambient air blown by fans across the condenser.

Figure II-1: Open-Loop Cooling

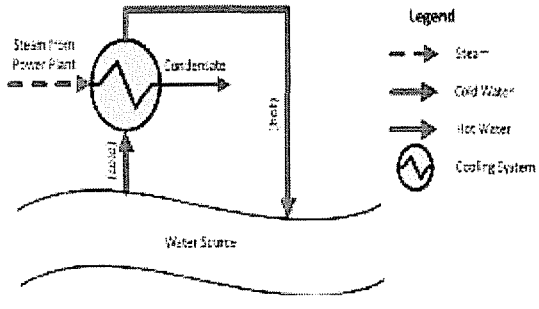
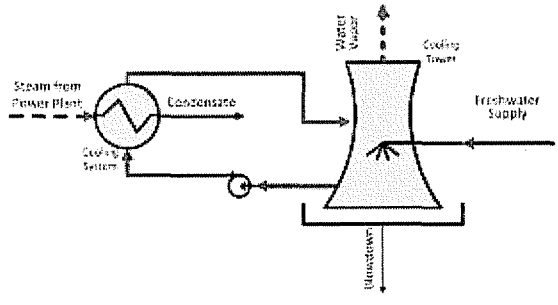


Figure II-2: Closed-Loop Cooling



Section 316(b) of the Clean Water Act regulates cooling water intake structures and requires that cooling water intake structures reflect the BTA for minimizing adverse environmental impacts. In defining BTA, EPA has, for more than 30 years, considered the cost and benefits of control alternatives. EPA originally developed the Section 316(b) rule for existing generation facilities using greater than 50 million gallons per day (mgd) in 2004-2007. However, parts of the rule were overturned in the U.S. Court of Appeals in 2007 and remanded to EPA for reconsideration. EPA is planning to issue a new draft rule for public comment by September 2010. Rule implementation is likely to start during 2014 and be fully implemented over a five-year compliance period.

This proposed water rule will likely apply to all existing and new nuclear and fossil steam generating units, which contributed over 93 percent of 2008 U.S. generation. Power sources such as combustion turbines, hydroelectric facilities, wind turbines, and solar PV panels use no cooling water and therefore will not be subject to the proposed rule. Major EPA proposed making policy issues directly affecting Planning Reserve Margins are:

- implementation period;
- applicability to existing structures and; and
- EPA BTA retrofit technology selection.

In its original 2004 existing facilities rule (overturned by the U.S. Court of Appeals in 2007), EPA set significant new national technology-based performance standards. The standards are intended to minimize adverse environmental impacts of cooling water intake structures by reducing the number of aquatic organisms lost. The performance standards prescribed ranges of reductions based on several factors and provided multiple compliance alternatives including the use of economic tests to properly implement site-specific regulatory BTA determinations.

However, EPA's expected draft replacement rule (Phase II) is expected to be substantially different due in part to the fact that the performance standards are expected to favor performance commensurate with cooling towers. In addition, despite a 2009 Supreme Court ruling that EPA has the discretion to use cost-benefit analyses when setting performance standards, EPA has signaled concerns associated with the use of cost-benefit analyses.

For example, if EPA defines BTA for cooling water systems such as recirculating cooling water systems with a reach-back provision to cover existing cooling water systems, up to 312 GW of existing steam electric power stations that use once-through cooling water systems may require additions to retrofit recirculating cooling water systems or acceleration of their retirement. For those units opting to retrofit, the stations would increase onsite electricity consumption (1-4 percent) from station loads because of increased power needs for cooling water pumping.

In its October 2008 report titled *Electricity Reliability Impacts of a Mandatory Cooling Tower Rule for Existing Steam Generating Units*, the U.S. Department of Energy (DOE) estimated that a tougher mandatory recirculating cooling water requirement, now being considered by EPA, would accelerate the retirement of 39.6 GW of existing fossil capacity and derate retrofitted control units by an additional 9.3 GW.[35] The DOE study made a simplifying assumption that existing steam units with once through cooling water systems operating at capacity factors less than 35 percent would be retired and retrofitted plant output capacity was reduced by four percent to represent increased station loads.

The 1,200 affected units with once through cooling water systems and their cooling water intake power suppliers identified rates through the U.S. Energy Information Administration (EIA) Form 923 and older Form 767 (Steam Electric Plant Operation and Design Report) data filings.[36] The affected units include 754 coal units, 405 oil/gas steam units and 42 units of nuclear capacity.

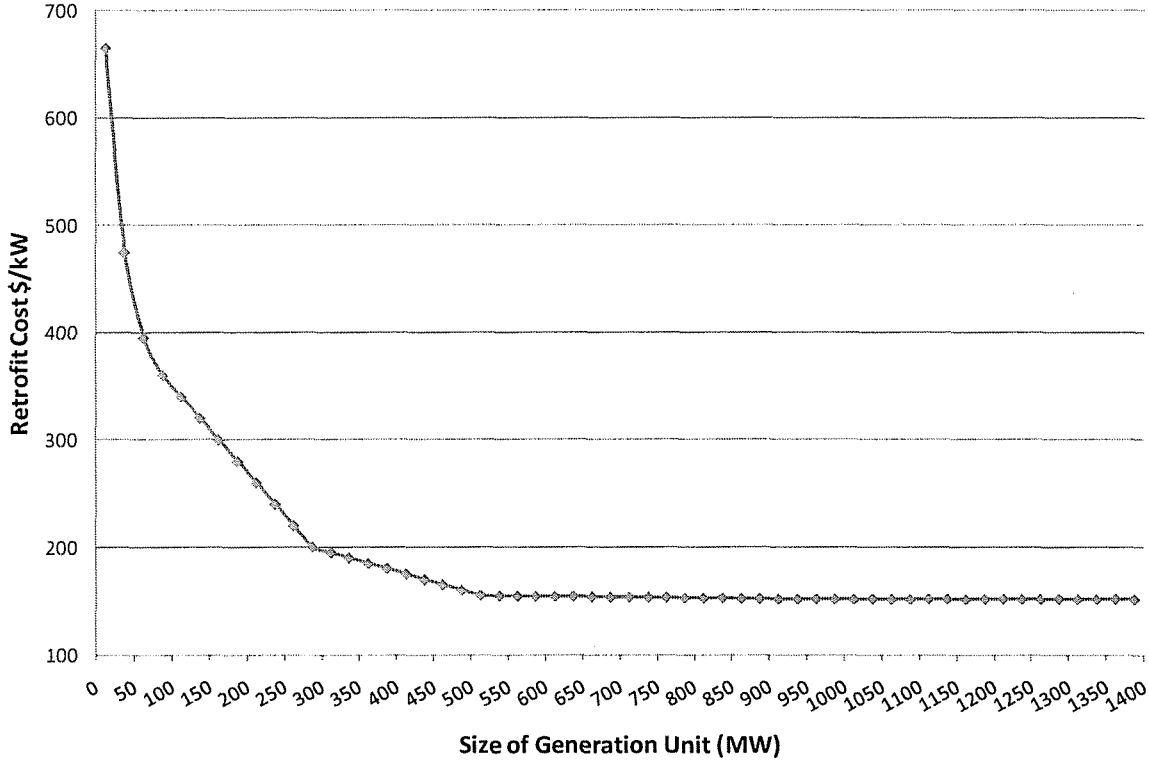
[35] http://www.oe.energy.gov/DocumentsandMedia/Cooling_Tower_Report.pdf
[36] http://www.eia.doe.gov/cneaf/electricity/page/eia906_920.html

For these units, capital cost estimates to convert from once through cooling water to recirculating cooling water systems are derived from three engineering studies and cost surveys:

- EPRI: *Issues Analysis of Retrofitting Once Through Cooled Plants with Closed Cycle Cooling* (10/07);[37]
- Maulbetsch Consulting: EPRI Survey of 50 plant estimates (7/2002); and
- Stone & Webster: Study for Utility Water Assessment Group (7/2002).

These studies found that capital conversion costs are directly tied to the once-through cooling water pumping rate and heavily influenced by site layout and local conditions. Conversion costs ranged from $170-440 (2010 dollars) / gallons per minute (gpm) with an average capital conversion cost of $240/gpm. The average conversion costs were applied for most locations, except for known urban locations having constrained site conditions for which a 25 percent higher capital cost estimate of $300/gpm (2010 dollars) was applied. The base case costs applied in this reliability assessment are shown in Figure II-3.

Figure II-3: Base Case Retrofit Cost Curve for Section 316(b)($/kW)



In addition to the capital conversion costs, the station would lose both capacity and energy due to increased power consumption from the cooling water pump. The capacity and energy losses estimated in the 2008 DOE study and applied in this assessment are shown in Table II-1.

[37] EPRI is expected to issue a new revised report that will include detailed cost information not only for installing cooling towers, but also for retrofitting plants on sensitive water bodies, and operations and maintenance costs.

Table II-1: Capacity Derating/Energy Penalties Due to Cooling Tower Conversion

NERC Regions/ Subregions	Average Energy Loss %	Capacity Derating Penalty (%)
ERCOT	0.80%	2.50%
FRCC	0.90%	2.50%
MRO	1.40%	3.10%
NPCC	1.30%	3.40%
NYPP	1.20%	3.20%
RFC	1.60%	3.40%
Entergy	0.90%	2.60%
Gateway	1.20%	3.10%
Southeastern	0.80%	2.40%
TVA	0.90%	2.60%
VACAR	1.00%	2.80%
SPP	1.00%	2.80%
AZ-NM-SNV	1.40%	2.70%
CA	0.90%	2.50%
NWPP	1.40%	3.00%
RMPA	0.00%	2.50%
Total	1.20%	2.90%

Source: DOE *Electric Reliability Impacts of a Mandatory Cooling Tower Rule for Existing Steam Generating Units*(10/2008)

However, these referenced compliance costs and reliability impacts may be underestimated for the following reasons:

- First, the published studies used to develop the average capital cost estimates are based upon surveys done in 2002 and 2007. Such conversions are rare; no historic costing data have been published. Since these surveys, environmental project construction costs have escalated rapidly.
- Second, the site-specific conditions and plant layout can have significant impacts on conversion costs that are not reflected by applying industrial average estimates. Although an adjustment was made for known constrained urban sites, several more sites likely exist that may have similar (but unknown) site constraint problems.
- Finally, given the short potential rule implementation period and the large affected power plant population, demand for labor and construction materials for conversions could be in high demand and result in real cost escalation. Such capital cost run-ups have occurred in pollution control projects.

The Strict Case provides a 25 percent real price escalation in the average conversion cost to $300/gpm at most locations and $400/gpm at known constrained urban site locations to capture these potential risks. Alternatively, EPA could consider several policy options that could reduce the rule's impact. These options include (1) narrowing the rule scope to the largest cooling water consumers (*e.g.*, EPA's original rule applied only to water intakes greater than 50 million gallons per day), and (2) applying lower cost technology options for existing cooling systems (*e.g.* retrofitting fine mesh screens per the 2004 rule). Any narrowing of the regulation scope or cost would reduce the rule's reliability impacts. These alternative EPA regulatory options were not modeled for this assessment.

National Emissions Standards for Hazardous Pollutants (NESHAP) or Maximum Achievable Control Technology (MACT)

Under Title I of the 1990 Clean Air Act, EPA is obligated to develop an emission control program for listed air toxics for sources that emit at or above prescribed threshold values, including mercury. The Clean Air Act defines MACT for existing sources as "the average emission limitation achieved by the best performing 12 percent of the existing sources." EPA is obligated under a consent decree to propose a MACT rule by March 16, 2011 and to finalize the rule by November 16, 2011. The Clean Air Act mandates a three-year compliance timeframe: 2014 or 2015.

The potential EPA MACT rule will apply to all 1,732 existing and future coal and oil fired capacity (415.2 GW of existing plus another 26 GW of new planned coal units). The only flexibility for compliance is for EPA to grant a one-year extension, granted on a case-by-case basis, and a Presidential exemption of no more than 2 years based on availability of technology and national security interests.

This assessment uses environmental control costing curves to develop unit-specific compliance cost estimates, with the increased unit production costs of new pollution controls compared to unit production costs of replacement power. EPA is expected to adopt different MACT emission rate limitations, which implies that new investments required will vary by coal type.

The Moderate Case assumes that MACT is not fully implemented until 2018, as waivers are provided, largely for reliability reasons, to units that have committed and scheduled environmental upgrade projects but which may not be completed by the 2015 deadline. Further, investments are made when equipment is not present or planned, depending on the coal type, as shown in Table II-2. If wet or dry FGD are not present, then wet FGD is added for all coal types. SCR control retrofits are added for bituminous coal only. In addition, fabric filter systems with halide-treated activated carbon injection (HACI) systems are added for all coal types, if not already present. Oil stations (109.7 GW) are assumed to meet their air toxic limits through tighter oil specifications at the refinery.

By contrast, Strict Case assumes no waivers are granted and all upgrades must be complete by January 1, 2015, or units would retire. Investment costs are also projected to increase by 25 percent in Strict Case as shown by Table II-3.

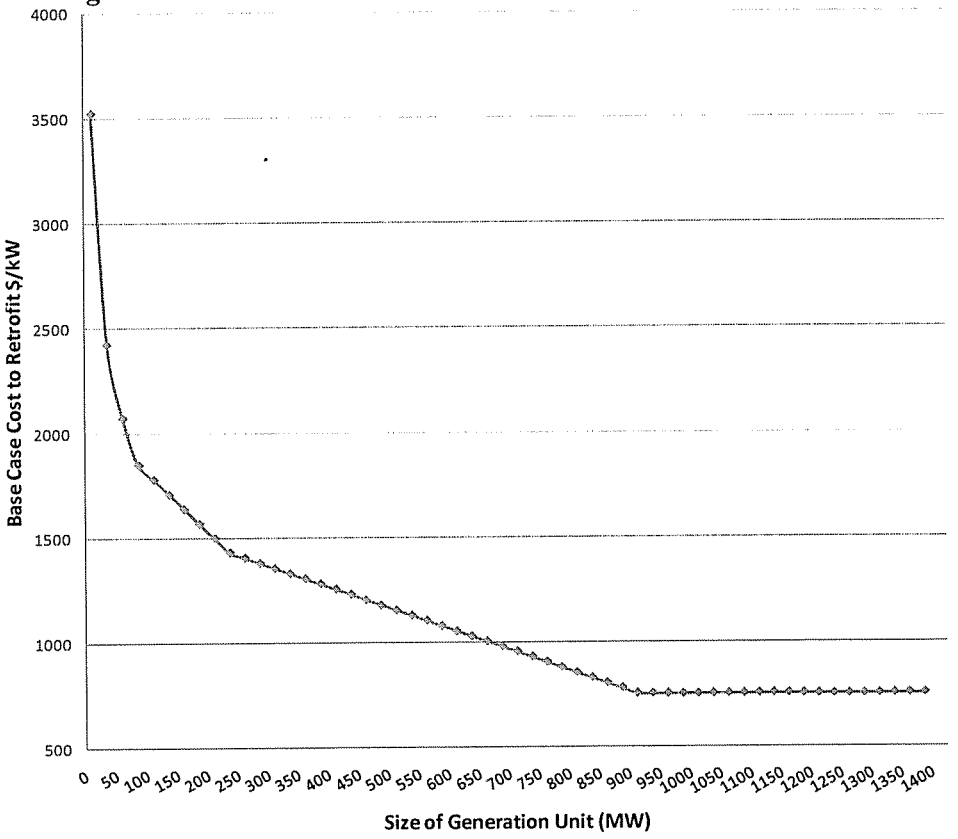
Table II-2: Moderate Case Assumptions for MACT Air Toxics (includes CAMR and Acid Gases)

	Moderate Case		
	Bituminous	Sub-bituminous	Lignite
Wet FGD	If no wet or dry FGD, add wet FGD	If no wet or dry FGD, add wet FGD	If no wet or dry FGD, add wet FGD
Dry FGD			
SCR	Add		
Activated Carbon Injection		Add	Add
Baghouse (Fabric Filter)		Add	Add

Table II-3: Strict Case Assumptions for MACT Air Toxics (includes CAMR and Acid Gases)			
	Bituminous	Sub-bituminous	Lignite
Wet FGD	25%	25%	25%
Dry FGD	25%	25%	25%
SCR	25%		
Activated Carbon Injection	+25% Add	25%	25%
Baghouse (Fabric Filter)	+25% Add	25%	25%

Representative base case costs for bituminous coal are shown in Figure II-4.

Figure II-4: Bituminous Coal Base Case Cost Curves for MACT ($/kW)



Clean Air Transport Rule (CATR)

EPA developed its Clean Air Interstate Rule (CAIR) program to address the long-range emission transport contribution to fine particulate non-attainment and to take the first compliance step by reducing contributions from major fossil combustion stationary sources. Its *original* proposed program created a new annual NO_x cap-and-trade program and modified the existing Title IV SO_2 cap-and-trade program for 28 states for which upwind out-of-state contributions to non-attainment areas were considered significant. In 2008, the U.S. Court of Appeals overturned the EPA program due to concerns that NAAQS would not be met if sources complied through an unlimited amount of emission allowance purchases.

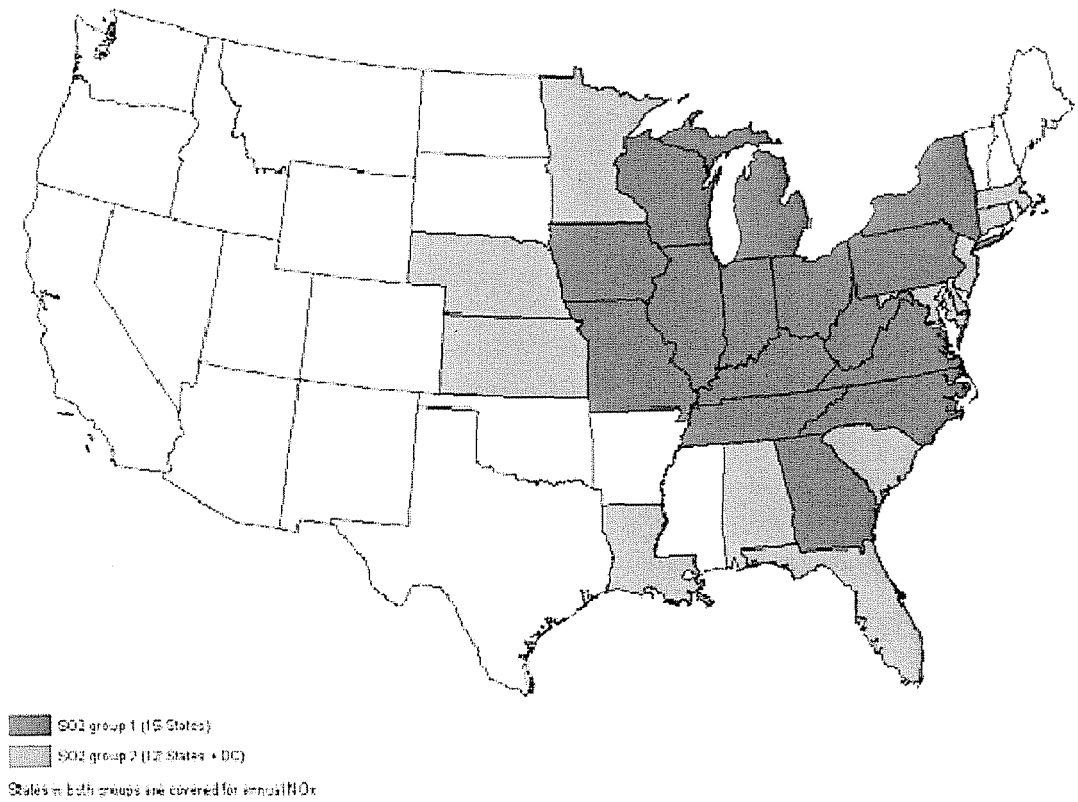
In July 2010, EPA proposed a draft CATR to control long-range transport of power plant SO_2/NO_x emissions that significantly contributed to non-attainment of fine particulate and ozone ambient air quality standards in downwind states—CATR will replace CAIR.[38] EPA anticipates issuing the final rule by March 2011. The draft program would apply only to fossil fuel electric generating units greater than 25 MW located in a designated state as shown in Figure II-5 .

Figure II-5: Clean Air Transport Rule Designated States

[38] EPA CATR Homepage: http://www.gpo.gov/fdsys/pkg/FR-2010-08-02/pdf/2010-17007.pdf#page=1 and proposed rule http://www.gpo.gov/fdsys/pkg/FR-2010-08-02/pdf/2010-17007.pdf#page=1

The potential EPA rule will regulate SO_2 and NO_x emissions under three new cap-and-trade programs (SO_2, annual NO_x and seasonal NO_x) starting January 1, 2012. EPA will set a state emissions budget cap for each pollutant, issue new allowances, and propose to significantly limit interstate allowance trading and banking after 2013. Previously banked surplus SO_2 and NO_x allowance credits and allocations created under the Acid Rain and CAIR programs cannot be used for compliance under the new program. For SO_2, affected states are organized into Group 1 or Group 2, as shown in Figure II-6.

Figure II-6: Clean Air Transport Rule Designated States



CATR applies to fossil power plant sources located within the 31 states and District of Colombia. The impact on the electric grid will vary depending on which of three EPA proposals becomes the final rule[39]:

- The EPA preferred option;
- Alternative 1 - the no interstate trading option; or
- Alternative 2 - the strict emission rate option.

EPA proposal is soliciting comments on its preferred option with limited interstate trading and intrastate trading, as well as the two alternative options. Further complicating compliance planning by electric generators, the agency recognizes that the proposed state emission budgets

[39] Described in the *Introduction* section of this report

caps are likely to change again in the near term when new fine particulate and ozone air quality standards are adopted, potentially later in 2010. These NAAQS will trigger new air quality modeling to determine the allowable pollutant loadings and allocations between contributing sources. Upon completion of this modeling, EPA will propose new state emission budget caps. The rule also gives the power industry a greater planning challenge than CAIR, since compliance must be on an aggregate state-by-state basis. In lieu of the current national emissions cap with unrestricted trading and banking, the new proposal also makes greater coordination essential between utilities within each state in order to optimize emission reductions. However, concerns over competition may limit coordination and result in less optimal compliance plans.

The new program is likely to require some electric generation units to retrofit additional FGD and selective catalytic reduction (SCR) controls by 2014, or retire. Strict emission limits that can only be met with post combustion FGD and SCR controls will directly affect 163 GW of coal-fired capacity that currently does not have FGD, or the 180 GW without post combustion NO_x controls. EPA's preferred option is summarized in Table II-4 below.

Table II-4: High Level Summary of Proposed CATR Regulation – EPA Preferred Option

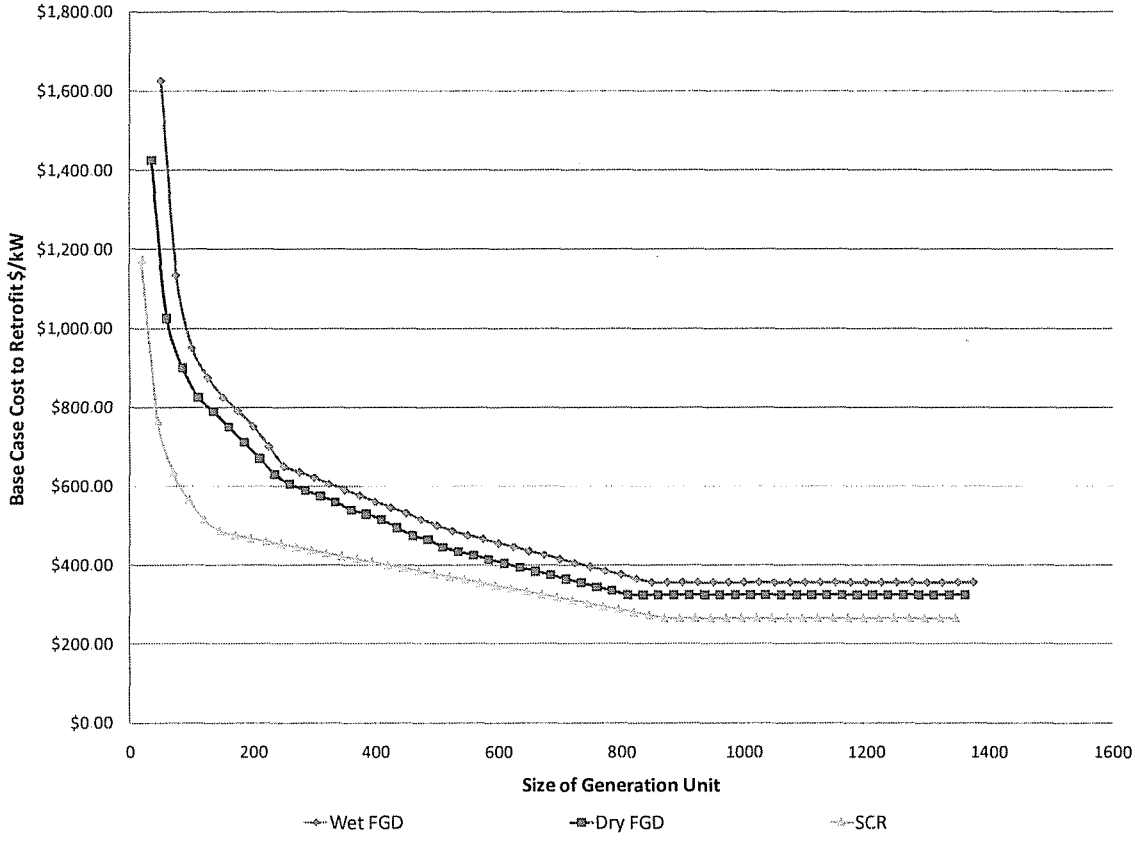
SO_2 Cap & Trade Program				
	Group 1		Group 2	
	2012 Deadline	2014 Deadline	2012 Deadline	2014 Deadline
Number of States Affected	15	15	12 & DC	12 & DC
Emissions Cap (TPY)*	3,117,288	1,723,412	776,582	776,582
Emissions Credit Trading	EPA issues new allowances and surplus acid rain allowances become worthless. Trading allowed within Group 1.	Very strict annual state emission limitations on interstate trading and use of carryover allowances.	EPA issues new allowances and surplus acid rain allowances become worthless. Trading allowed within Group 2.	Very strict annual state emission limitations on interstate trading and use of carryover allowances.

**EPA resets each state's budget at onset. State budget caps are likely to be revised once fine particulate NAAQS is implemented and modeling* is completed.

Annual NO_x Cap & Trade Program		
27 States and District of Colombia		
	2012 Deadline	2014 Deadline
Number of States Affected	28	28
Emissions Cap (TPY)	1,317,312	1,317,312
Emissions Credit Trading	EPA issues new allowances and surplus CAIR ones become worthless. Trading allowed between all states.	Very strict annual state emission limitations on interstate trading and use of carryover allowances.

The costs for retrofitting post combustion controls are shown in Figure II-7. These capital costs are from utility project engineering estimates and recent projects. They are significantly higher than EPA study estimates that rely upon much older cost data and exclude owner and financing costs.

Figure II-7: Moderate Case Average Post Combustion Control Retrofit Costs for CATR ($/kW)



This assessment examines the impacts of the EPA's preferred option – limited cap-and-trade program -- as the Moderate Case. This option increases pressure to reduce emissions beyond current plans, particularly for sources in the six states of Indiana, Kentucky, Massachusetts, Missouri, Ohio and Pennsylvania. These six states must reduce their aggregated in-state SO_2 emissions by more than 250,000 tons per year by 2014. It may prove difficult to engineer, finance, permit and construct sufficient environmental controls in less than the three years required under the draft program. This assessment examines the economic decision at current control prices. The Strict Case assumes that EPA elects to adopt their future emission rate alternative that has no provisions for any trading between units and will force more coal units to have post combustion SO_2 and NO_x controls in the selected states. The assessment evaluates the available state credits to meet the state's limits and selects generating units for retirement in 2012 and 2014 that will be required to meet the emissions cap.

Table IV-11: Combined Impacts - 2013				
	Moderate Case		Strict Case	
	Resulting Reserve Margin (%) (DCR to APCR)	Percentage Point Change in Reserve Margin	Resulting Reserve Margin (%) (DCR to APCR)	Percentage Point Change in Reserve Margin
ERCOT	16.5% – 23.9%	0.0 – 0.0	16.3% – 23.8%	-0.1 – -0.1
FRCC	28.6% – 28.6%	0.0 – 0.0	28.5% – 28.5%	0.0 – 0.0
MRO	12.9% – 22.1%	0.0 – 0.0	10.1% – 19.3%	-2.7 – -2.7
NPCC-NE	18.0% – 25.9%	-0.6 – -0.6	16.7% – 24.6%	-1.9 – -1.9
NPCC-NY	28.1% – 29.8%	0.0 – 0.0	27.3% – 29.0%	-0.8 – -0.8
RFC	19.2% – 24.0%	-0.2 – -0.2	17.6% – 22.4%	-1.9 – -1.9
SERC-Central	23.6% – 27.2%	0.0 – 0.0	22.8% – 26.4%	-0.9 – -0.9
SERC-Delta	27.5% – 30.9%	0.0 – 0.0	27.0% – 30.4%	-0.5 – -0.5
SERC-Gateway	24.0% – 28.0%	0.0 – 0.0	22.9% – 27.0%	-1.0 – -1.0
SERC-Southeastern	13.0% – 29.8%	0.0 – 0.0	12.1% – 28.9%	-0.9 – -0.9
SERC-VACAR	17.5% – 20.3%	0.0 – 0.0	15.5% – 18.3%	-1.9 – -1.9
SPP	15.9% – 30.3%	0.0 – 0.0	15.9% – 30.3%	0.0 – 0.0
WECC-CA	48.6% – 48.6%	0.0 – 0.0	48.4% – 48.4%	-0.3 – -0.3
WECC-AZ-NM-SNV	22.1% – 23.7%	0.0 – 0.0	22.1% – 23.7%	0.0 – 0.0
WECC-NWPP	29.9% – 30.1%	0.0 – 0.0	29.9% – 30.1%	0.0 – 0.0
WECC-RMPA	24.7% – 30.3%	0.0 – 0.0	24.7% – 30.3%	0.0 – 0.0
TOTAL	22.3% – 27.7%	-0.1 – -0.1	21.4% – 26.7%	-1.0 – -1.0

Table IV-12: 316(b) Impacts - 2015				
	Moderate Case		Strict Case	
	Resulting Reserve Margin (%) (DCR to APCR)	Percentage Point Change in Reserve Margin	Resulting Reserve Margin (%) (DCR to APCR)	Percentage Point Change in Reserve Margin
ERCOT	14.1% – 22.0%	-1.1 – -1.1	13.8% – 21.7%	-1.4 – -1.4
FRCC	24.7% – 24.7%	-0.3 – -0.3	24.7% – 24.7%	-0.3 – -0.3
MRO	7.6% – 17.2%	-1.7 – -1.7	7.6% – 17.1%	-1.8 – -1.8
NPCC-NE	12.0% – 21.0%	-3.5 – -3.5	12.0% – 21.0%	-3.5 – -3.5
NPCC-NY	23.5% – 25.5%	-2.9 – -2.9	23.5% – 25.5%	-2.9 – -2.9
RFC	16.2% – 21.4%	-0.9 – -0.9	16.2% – 21.4%	-0.9 – -0.9
SERC-Central	21.1% – 24.6%	-0.6 – -0.6	21.1% – 24.6%	-0.6 – -0.6
SERC-Delta	14.3% – 17.7%	-6.1 – -6.1	14.3% – 17.7%	-6.1 – -6.1
SERC-Gateway	20.0% – 24.0%	-2.7 – -2.7	20.0% – 24.0%	-2.7 – -2.7
SERC-Southeastern	11.8% – 28.5%	-0.5 – -0.5	11.9% – 28.5%	-0.5 – -0.5
SERC-VACAR	12.4% – 15.4%	-0.3 – -0.3	12.3% – 15.4%	-0.3 – -0.3
SPP	13.6% – 28.0%	-1.3 – -1.3	13.5% – 28.0%	-1.4 – -1.4
WECC-CA	48.8% – 48.8%	-1.3 – -1.3	48.8% – 48.8%	-1.3 – -1.3
WECC-AZ-NM-SNV	19.7% – 22.9%	-0.1 – -0.1	19.7% – 22.9%	-0.1 – -0.1
WECC-NWPP	26.8% – 28.0%	-0.2 – -0.2	26.8% – 28.0%	-0.2 – -0.2
WECC-RMPA	16.2% – 24.6%	-0.4 – -0.4	16.0% – 24.3%	-0.6 – -0.6
TOTAL	18.8% – 24.5%	-1.2 – -1.2	18.8% – 24.4%	-1.3 – -1.3

Table IV-13: MACT Impacts - 2015				
	Moderate Case		Strict Case	
	Resulting Reserve Margin (%) (DCR to APCR)	Percentage Point Change in Reserve Margin	Resulting Reserve Margin (%) (DCR to APCR)	Percentage Point Change in Reserve Margin
ERCOT	15.0% – 22.9%	-0.1 – -0.1	15.0% – 22.9%	-0.1 – -0.1
FRCC	25.0% – 25.0%	0.0 – 0.0	24.6% – 24.6%	-0.4 – -0.4
MRO	8.6% – 18.2%	-0.7 – -0.7	7.4% – 16.9%	-2.0 – -2.0
NPCC-NE	15.5% – 24.5%	0.0 – 0.0	13.3% – 22.3%	-2.2 – -2.2
NPCC-NY	26.3% – 28.3%	0.0 – 0.0	24.2% – 26.3%	-2.1 – -2.1
RFC	16.5% – 21.7%	-0.6 – -0.6	13.6% – 18.8%	-3.5 – -3.5
SERC-Central	21.5% – 24.9%	-0.3 – -0.3	18.8% – 22.2%	-3.0 – -3.0
SERC-Delta	20.2% – 23.5%	-0.3 – -0.3	19.9% – 23.2%	-0.5 – -0.5
SERC-Gateway	22.2% – 26.1%	-0.6 – -0.6	20.4% – 24.4%	-2.3 – -2.3
SERC-Southeastern	12.0% – 28.7%	-0.3 – -0.3	9.6% – 26.2%	-2.8 – -2.8
SERC-VACAR	12.0% – 15.0%	-0.7 – -0.7	8.4% – 11.5%	-4.2 – -4.2
SPP	14.6% – 29.1%	-0.3 – -0.3	14.5% – 28.9%	-0.4 – -0.4
WECC-CA	50.1% – 50.1%	0.0 – 0.0	50.1% – 50.1%	0.0 – 0.0
WECC-AZ-NM-SNV	19.6% – 22.9%	-0.1 – -0.1	14.9% – 18.2%	-4.8 – -4.8
WECC-NWPP	26.8% – 27.9%	-0.2 – -0.2	26.6% – 27.7%	-0.4 – -0.4
WECC-RMPA	16.5% – 24.8%	-0.1 – -0.1	15.7% – 24.0%	-0.9 – -0.9
TOTAL	19.7% – 25.4%	-0.3 – -0.3	17.9% – 23.6%	-2.1 – -2.1

Table IV-14: CATR Impacts - 2015				
	Moderate Case		Strict Case	
	Resulting Reserve Margin (%) (DCR to APCR)	Percentage Point Change in Reserve Margin	Resulting Reserve Margin (%) (DCR to APCR)	Percentage Point Change in Reserve Margin
ERCOT	15.2% – 23.0%	0.0 – 0.0	15.0% – 22.9%	-0.1 – -0.1
FRCC	25.0% – 25.0%	0.0 – 0.0	25.0% – 25.0%	0.0 – 0.0
MRO	9.3% – 18.8%	-0.1 – -0.1	6.7% – 16.2%	-2.7 – -2.7
NPCC-NE	14.9% – 23.9%	-0.5 – -0.5	14.2% – 23.2%	-1.3 – -1.3
NPCC-NY	26.3% – 28.3%	0.0 – 0.0	26.1% – 28.1%	-0.2 – -0.2
RFC	16.2% – 21.4%	-0.9 – -0.9	15.6% – 20.8%	-1.5 – -1.5
SERC-Central	21.7% – 25.2%	0.0 – 0.0	21.1% – 24.6%	-0.7 – -0.7
SERC-Delta	20.5% – 23.8%	0.0 – 0.0	19.9% – 23.3%	-0.5 – -0.5
SERC-Gateway	18.4% – 22.4%	-4.3 – -4.3	21.7% – 25.7%	-1.0 – -1.0
SERC-Southeastern	12.3% – 28.9%	-0.1 – -0.1	11.5% – 28.1%	-0.9 – -0.9
SERC-VACAR	12.6% – 15.7%	0.0 – 0.0	10.9% – 14.0%	-1.7 – -1.7
SPP	14.9% – 29.3%	0.0 – 0.0	14.2% – 28.7%	-0.7 – -0.7
WECC-CA	50.1% – 50.1%	0.0 – 0.0	50.1% – 50.1%	0.0 – 0.0
WECC-AZ-NM-SNV	19.8% – 23.0%	0.0 – 0.0	19.8% – 23.0%	0.0 – 0.0
WECC-NWPP	27.0% – 28.2%	0.0 – 0.0	27.0% – 28.2%	0.0 – 0.0
WECC-RMPA	16.6% – 25.0%	0.0 – 0.0	16.6% – 25.0%	0.0 – 0.0
TOTAL	19.7% – 25.4%	-0.3 – -0.3	19.2% – 24.8%	-0.9 – -0.9

Table IV-15: CCR Impacts - 2015				
	Moderate Case		Strict Case	
	Resulting Reserve Margin (%) (DCR to APCR)	Percentage Point Change in Reserve Margin	Resulting Reserve Margin (%) (DCR to APCR)	Percentage Point Change in Reserve Margin
ERCOT	15.2% – 23.0%	0.0 – 0.0	15.2% – 23.0%	0.0 - 0.0
FRCC	25.0% – 25.0%	0.0 – 0.0	25.0% – 25.0%	0.0 - 0.0
MRO	9.4% – 18.9%	0.0 – 0.0	9.4% – 18.9%	0.0 - 0.0
NPCC-NE	15.5% – 24.5%	0.0 – 0.0	15.5% – 24.5%	0.0 - 0.0
NPCC-NY	26.3% – 28.3%	0.0 – 0.0	26.3% – 28.3%	0.0 - 0.0
RFC	17.1% – 22.3%	0.0 – 0.0	17.1% – 22.3%	0.0 - 0.0
SERC-Central	21.8% – 25.3%	0.0 – 0.0	21.6% – 25.1%	-0.2 - -0.2
SERC-Delta	20.5% – 23.8%	0.0 – 0.0	20.5% – 23.8%	0.0 - 0.0
SERC-Gateway	22.7% – 26.7%	0.0 – 0.0	22.3% – 26.3%	-0.4 - -0.4
SERC-Southeastern	12.1% – 28.8%	-0.2 – -0.2	12.1% – 28.8%	-0.2 - -0.2
SERC-VACAR	12.6% – 15.7%	0.0 – 0.0	12.6% – 15.7%	0.0 - 0.0
SPP	14.9% – 29.3%	0.0 – 0.0	14.9% – 29.3%	0.0 - 0.0
WECC-CA	50.1% – 50.1%	0.0 – 0.0	50.1% – 50.1%	0.0 - 0.0
WECC-AZ-NM-SNV	19.8% – 23.0%	0.0 – 0.0	19.8% – 23.0%	0.0 - 0.0
WECC-NWPP	27.0% – 28.2%	0.0 – 0.0	27.0% – 28.2%	0.0 - 0.0
WECC-RMPA	16.6% – 25.0%	0.0 – 0.0	16.6% – 25.0%	0.0 - 0.0
TOTAL	20.0% – 25.7%	0.0 – 0.0	20.0% – 25.7%	0.0 - 0.0

Table IV-16: Combined Impacts - 2015				
	Moderate Case		Strict Case	
	Resulting Reserve Margin (%) (DCR to APCR)	Percentage Point Change in Reserve Margin	Resulting Reserve Margin (%) (DCR to APCR)	Percentage Point Change in Reserve Margin
ERCOT	7.5% – 15.4%	-7.7 – -7.7	6.8% – 14.7%	-8.4 – -8.4
FRCC	23.0% – 23.0%	-2.0 – -2.0	21.3% – 21.3%	-3.7 – -3.7
MRO	5.9% – 15.5%	-3.5 – -3.5	-1.7% – 7.9%	-11.0 – -11.0
NPCC-NE	7.2% – 16.2%	-8.3 – -8.3	1.8% – 10.8%	-13.6 – -13.6
NPCC-NY	17.4% – 19.5%	-8.9 – -8.9	11.5% – 13.6%	-14.8 – -14.8
RFC	14.2% – 19.4%	-2.9 – -2.9	7.2% – 12.4%	-9.9 – -9.9
SERC-Central	21.0% – 24.5%	-0.7 – -0.7	10.1% – 13.6%	-11.6 – -11.6
SERC-Delta	1.9% – 5.2%	-18.6 – -18.6	-0.2% – 3.1%	-20.6 – -20.6
SERC-Gateway	19.6% – 23.6%	-3.1 – -3.1	1.5% – 5.5%	-21.3 – -21.3
SERC-Southeastern	11.3% – 27.9%	-1.1 – -1.1	5.7% – 22.4%	-6.6 – -6.6
SERC-VACAR	11.1% – 14.2%	-1.5 – -1.5	4.6% – 7.6%	-8.0 – -8.0
SPP	12.7% – 27.1%	-2.2 – -2.2	9.3% – 23.8%	-5.5 – -5.5
WECC-CA	44.3% – 44.3%	-5.8 – -5.8	39.3% – 39.3%	-10.8 – -10.8
WECC-AZ-NM-SNV	17.3% – 20.6%	-2.4 – -2.4	12.6% – 15.9%	-7.1 – -7.1
WECC-NWPP	26.5% – 27.6%	-0.5 – -0.5	26.5% – 27.6%	-0.5 – -0.5
WECC-RMPA	14.9% – 23.2%	-1.7 – -1.7	14.6% – 22.9%	-2.1 – -2.1
TOTAL	16.1% – 21.7%	-4.0 – -4.0	10.8% – 16.4%	-9.3 – -9.3

Table IV-17: 316(b) Impacts - 2018				
	Moderate Case		Strict Case	
	Resulting Reserve Margin (%) (DCR to APCR)	Percentage Point Change in Reserve Margin	Resulting Reserve Margin (%) (DCR to APCR)	Percentage Point Change in Reserve Margin
ERCOT	-1.2% – 6.1%	-7.2 – -7.2	-1.5% – 5.8%	-7.5 – -7.5
FRCC	24.9% – 24.9%	-2.1 – -2.1	23.9% – 23.9%	-3.1 – -3.1
MRO	0.6% – 10.8%	-3.5 – -3.5	0.6% – 10.8%	-3.5 – -3.5
NPCC-NE	2.7% – 11.5%	-8.7 – -8.7	1.5% – 10.2%	-10.0 – -10.0
NPCC-NY	15.6% – 17.6%	-9.5 – -9.5	13.9% – 15.9%	-11.2 – -11.2
RFC	10.2% – 15.5%	-3.6 – -3.6	10.1% – 15.4%	-3.7 – -3.7
SERC-Central	19.1% – 22.5%	-1.0 – -1.0	19.1% – 22.5%	-1.0 – -1.0
SERC-Delta	-3.4% – -0.2%	-18.5 – -18.5	-3.4% – -0.2%	-18.5 – -18.5
SERC-Gateway	15.7% – 19.6%	-3.9 – -3.9	15.7% – 19.6%	-4.0 – -4.0
SERC-Southeastern	14.8% – 30.5%	-1.2 – -1.2	14.8% – 30.5%	-1.2 – -1.2
SERC-VACAR	7.1% – 9.6%	-1.4 – -1.4	7.1% – 9.6%	-1.5 – -1.5
SPP	7.7% – 21.8%	-2.2 – -2.2	7.6% – 21.7%	-2.3 – -2.3
WECC-CA	31.1% – 31.1%	-8.3 – -8.3	28.3% – 28.3%	-11.1 – -11.1
WECC-AZ-NM-SNV	17.1% – 21.1%	-2.1 – -2.1	17.1% – 21.1%	-2.1 – -2.1
WECC-NWPP	21.6% – 22.7%	-0.4 – -0.4	21.6% – 22.7%	-0.4 – -0.4
WECC-RMPA	15.8% – 23.9%	-1.6 – -1.6	15.8% – 23.9%	-1.6 – -1.6
TOTAL	12.0% – 17.6%	-4.3 – -4.3	11.6% – 17.1%	-4.7 – -4.7

Table IV-18: MACT Impacts - 2018				
	Moderate Case		Strict Case	
	Resulting Reserve Margin (%) (DCR to APCR)	Percentage Point Change in Reserve Margin	Resulting Reserve Margin (%) (DCR to APCR)	Percentage Point Change in Reserve Margin
ERCOT	5.9% – 13.2%	-0.1 – -0.1	5.9% – 13.2%	-0.1 – -0.1
FRCC	26.9% – 26.9%	0.0 – 0.0	26.6% – 26.6%	-0.4 – -0.4
MRO	2.3% – 12.5%	-1.8 – -1.8	2.2% – 12.4%	-1.9 – -1.9
NPCC-NE	11.3% – 20.1%	-0.1 – -0.1	9.3% – 18.1%	-2.1 – -2.1
NPCC-NY	24.9% – 26.9%	-0.2 – -0.2	23.1% – 25.1%	-2.0 – -2.0
RFC	12.2% – 17.6%	-1.6 – -1.6	10.4% – 15.7%	-3.4 – -3.4
SERC-Central	19.4% – 22.7%	-0.8 – -0.8	17.3% – 20.6%	-2.9 – -2.9
SERC-Delta	14.7% – 17.9%	-0.4 – -0.4	14.5% – 17.7%	-0.5 – -0.5
SERC-Gateway	18.8% – 22.6%	-0.9 – -0.9	17.4% – 21.3%	-2.3 – -2.3
SERC-Southeastern	15.4% – 31.1%	-0.6 – -0.6	13.3% – 29.1%	-2.6 – -2.6
SERC-VACAR	7.0% – 9.6%	-1.5 – -1.5	4.5% – 7.1%	-4.0 – -4.0
SPP	9.6% – 23.6%	-0.4 – -0.4	9.6% – 23.6%	-0.4 – -0.4
WECC-CA	39.3% – 39.3%	0.0 – 0.0	39.3% – 39.3%	0.0 – 0.0
WECC-AZ-NM-SNV	14.8% – 18.7%	-4.5 – -4.5	14.8% – 18.7%	-4.5 – -4.5
WECC-NWPP	21.6% – 22.6%	-0.4 – -0.4	21.6% – 22.6%	-0.4 – -0.4
WECC-RMPA	16.5% – 24.6%	-0.9 – -0.9	16.5% – 24.6%	-0.9 – -0.9
TOTAL	15.4% – 20.9%	-1.0 – -1.0	14.3% – 19.8%	-2.0 – -2.0

Table IV-21: Combined Impacts - 2018				
	Moderate Case		Strict Case	
	Resulting Reserve Margin (%) (DCR to APCR)	Percentage Point Change in Reserve Margin	Resulting Reserve Margin (%) (DCR to APCR)	Percentage Point Change in Reserve Margin
ERCOT	-1.2% – 6.0%	-7.2 – -7.2	-1.7% – 5.6%	-7.7 – -7.7
FRCC	24.6% – 24.6%	-2.3 – -2.3	23.5% – 23.5%	-3.5 – -3.5
MRO	-0.3% – 9.9%	-4.4 – -4.4	-6.5% – 3.7%	-10.6 – -10.6
NPCC-NE	1.2% – 10.0%	-10.2 – -10.2	-1.8% – 6.9%	-13.3 – -13.3
NPCC-NY	14.9% – 16.9%	-10.2 – -10.2	10.7% – 12.7%	-14.4 – -14.4
RFC	8.7% – 14.1%	-5.1 – -5.1	4.7% – 10.0%	-9.2 – -9.2
SERC-Central	18.0% – 21.3%	-2.2 – -2.2	9.0% – 12.3%	-11.2 – -11.2
SERC-Delta	-3.7% – -0.5%	-18.7 – -18.7	-4.9% – -1.7%	-19.9 – -19.9
SERC-Gateway	14.5% – 18.4%	-5.2 – -5.2	1.7% – 5.6%	-18.0 – -18.0
SERC-Southeastern	13.9% – 29.6%	-2.1 – -2.1	9.7% – 25.4%	-6.3 – -6.3
SERC-VACAR	5.0% – 7.6%	-3.5 – -3.5	0.9% – 3.4%	-7.6 – -7.6
SPP	7.4% – 21.4%	-2.6 – -2.6	4.6% – 18.7%	-5.3 – -5.3
WECC-CA	31.1% – 31.1%	-8.3 – -8.3	28.2% – 28.2%	-11.2 – -11.2
WECC-AZ-NM-SNV	12.6% – 16.6%	-6.6 – -6.6	12.6% – 16.6%	-6.6 – -6.6
WECC-NWPP	21.5% – 22.6%	-0.5 – -0.5	21.5% – 22.6%	-0.5 – -0.5
WECC-RMPA	15.7% – 23.8%	-1.6 – -1.6	15.4% – 23.5%	-1.9 – -1.9
TOTAL	11.0% – 16.5%	-5.3 – -5.3	7.6% – 13.1%	-8.8 – -8.8

Appendix V: Related Study Work and References

Related Study Work For 316(b)

The U.S. Senate Committee on Appropriations, Subcommittee on Energy and Water Development, requested the Office of Electricity Delivery and Energy Reliability of the Department of Energy (DOE or Department) to examine the impacts to electricity reliability of requiring generators with once-through cooling systems to be replaced with closed-cycle cooling towers.

DOE provided NERC with a list of steam generation units that would be required to retrofit to cooling towers. DOE requested NERC to model the reliability impacts of the cooling tower mandate using certain assumptions. NERC provided DOE with its results in a white paper, 2008-*2017 NERC Capacity Margins: Retrofit of Once-Through Cooling Systems at Existing Generating Facilities.*

In the white paper, NERC concluded that once the deadline for the cooling tower retrofits has passed, the generation losses resulting from the requirement would exacerbate a potential decline in electric Planning Reserve Margins needed to ensure reliable delivery of electricity. Generally, the goal for NERC Regions is to have the equivalent of between 10 and 15 percent of their peak generation demand available to meet contingencies. NERC projects overall capacity reserve margins to fall to 14.7 percent by 2015, assuming only planned generation is built. However, upon assessing the impact of a cooling tower mandate, NERC projects that, "U.S. resource margins will drop from 14.7 percent to 10.4 percent when both the retired units and auxiliary loads due to retrofitting were compared to the *Reference Case*."

The following assumptions were used for this assessment:

Assumptions specified by DOE:

- Close-loop cooling systems will be added to all nuclear units. Capacity factors can be used as a proxy for economic suitability for retrofit
- Unit Retirements/Retrofits were based on the following capacity factors from 2006:
  - Units with a capacity factor less than 35 percent are assumed to be retired.
  - Units with a capacity factor greater than or equal to 0.35 were derated by four percent of maximum rated (nameplate) capacity.
  - 60 percent of retirements/retrofits was projected to begin in 2013, 20 percent in 2014 and 20 percent in 2015.
- Plants deemed "difficult to retrofit" due to geographical limitations (*e.g.* land-locked, space and permitting constraints) could result in early retirement. This assessment does not assume their early retirement.
- No new plants are built to replace capacity lost to retired units or auxiliary loads.
- Retrofits are instantaneous, with no capacity shortfalls due to plant shutdowns.
- Plants with a zero capacity factor (inactive or not yet built) are not assessed. These plants are not included in the Region's *Reference Case*.

Assumptions specified by NERC:

- The NERC Reference Margin Level adopted the Regional/subregional Target Capacity Margin. If not available, the NERC Reference Margin Level is based on supply-side fuel: 13 percent for thermal systems and 9 percent for hydro (Capacity Margin).
- Unit Retirement/Retrofit capacity reduction comparison is based against "Adjusted Potential Resources", calculated with all Existing Capacity and probable Planned Additions, Proposed Additions, and Net Transactions.
- Units already expected to retire between 2010 and 2015 were not considered part of the capacity reduction as they are already factored into the Region's projections.

NERC reviewed the impact of either retrofitting units with existing once-through-cooling systems to closed-loop cooling systems (resulting in four percent reduction in nameplate capacity) or unit retirements (capacity factor less than 35 percent) on NERC-US and Regional capacity margins for 2008–2017. Based on a worst-case view, NERC-US Adjusted Potential Resources may be impacted up to 49,000 MW, reducing the Adjusted Potential Resource Margin by 4.3 percent and some areas may require more resources to offset capacity reductions and maintain the reliability of the bulk power system. Some subregions, such as WECC-CA, NPCC-NE, ERCOT, SERC-Central and NPCC-NY, experience significant impacts.

Table V-1: 2015 US Summer Peak Potential Retrofit/Retirement Effects

	Adjusted Potential Resources (MW)	Reduction due to Retirement (MW)	Derate due to Retrofit (MW)	NERC Reference Margin Level	Adjusted Potential Resources Margin	Margin Reduction	Reduced Margin
United States							
WECC - CA-MX US	72,293	10,137	289	13.2%	12.7%	14.7%	-2.0%
NPCC - New England	31,673	2,827	428	13.0%	10.0%	10.3%	-0.3%
ERCOT	86,436	10,919	542	11.1%	15.9%	12.9%	3.0%
NPCC US	72,750	6,481	990	13.0%	13.3%	9.9%	3.4%
WECC US	176,944	10,177	314	12.3%	11.1%	5.6%	5.5%
NPCC - New York	41,077	3,654	561	13.0%	15.9%	9.6%	6.3%
SERC - VACAR	78,182	553	1,032	13.0%	11.0%	1.8%	9.2%
WECC - RMPA	15,609	40	0	10.5%	10.2%	0.2%	10.0%
SERC - Central	54,548	0	949	13.0%	12.6%	1.5%	11.0%
SERC - Delta	41,259	4,266	466	13.0%	21.5%	10.2%	11.4%
RFC	230,062	3,339	2,863	12.8%	14.5%	2.4%	12.1%
SERC	269,599	6,054	3,307	13.0%	15.6%	3.0%	12.5%
SERC - Southeastern	66,675	675	357	13.0%	13.9%	1.4%	12.6%
MRO US	55,582	529	612	13.0%	15.1%	1.8%	13.3%
FRCC	63,170	1,267	454	13.0%	18.7%	2.3%	16.4%
WECC - NWPP	51,861	0	25	11.9%	16.9%	0.0%	16.8%
SPP	63,700	817	257	12.0%	24.1%	1.3%	22.8%
SERC - Gateway	28,935	560	502	13.0%	28.8%	2.7%	26.1%
Total-NERC US	1,018,243	39,583	9,369	13.0%	14.7%	4.3%	10.4%

In comparing the results of the prior collaborative DOE/NERC assessment to the results in this report, impacts of similar magnitudes were found. Further, the areas (Regions/subregions) of concern highlighted in the prior assessment are aligned with those identified in this assessment.

EPRI Study Work For CCR:

EPRI conducted a screening assessment of the potential impact of EPA's expected proposals for management of CCR prior to publication of the draft rule.[42] This assessment indicated that 40 to 97 GW of coal-fired capacity could be "at risk" for retirement based on the increased costs associated with such a rule. The methods for estimating compliance costs at the generating unit level are similar to methods discussed in this report, with three significant differences:

- the sample of coal-fired generating units included in the assessment;
- the definition of the term "at risk" capacity; and
- some aspects of the cost assignment logic for Subtitle C (hazardous waste) management of CCRs.

Coal-Fired Capacity Assumptions

The total capacity represented by the units included in the EPRI analysis differed from the total capacity of the units included in the NERC assessment. Included in the EPRI analysis--but excluded from NERC's--are smaller units not in the bulk power system, planned coal-fired units not currently operating but scheduled to come online during the 20-year EPRI study horizon, and units that have recently announced early retirements. Since EPRI's analysis in 2009, several utilities have announced plans to retire older coal-fired generating units. Combined, the units included in EPRI's analysis, but excluded from the NERC assessment, represent 20 GW of capacity.

Definition of "at risk" Coal Capacity

The EPRI study was a screening-level economic analysis, intended to identify individual generating units that were predicted to be no longer profitable under a Subtitle C regulation. Any unit that would no longer be profitable was defined as "at risk." "At risk" in this context means that a decision would have to be made with respect to the generating unit: early retirement, repower, purchase power, or continue operation at a loss or at higher market prices. NERC, however, starts with the premise that reliability cannot be compromised and that for many units shutdown is not an option (particularly base-load units) without major disruption to the power grid. Thus, NERC's assessment compared the cost of compliance with Subtitle C requirements to the cost of natural gas-fired replacement power in order to determine which decision would be the most economical for a generating unit; only those units where compliance costs exceeded repowering costs were considered candidates for shutdown and thus deemed "at risk" for retirement.

Subtitle C Cost Assumptions

In assessing the cost of hazardous waste regulation on power plants, EPRI considered costs that NERC did not include in its assessment. One was the cost of off-site disposal at a commercial facility. NERC's assessment assumed all power plants would locate and construct Subtitle C landfills on or near the power plant property. While some states do not currently allow establishment of hazardous waste landfills within the state, NERC assumed that provisions

[42] EPRI, 2009, Testimony at the House Subcommittee on Energy and Environment Hearing on "Drinking Water and Public Health Impacts of Coal Combustion Waste Disposal," Washington DC, December 10, 2009. http://mydocs.epri.com/docs/CorporateDocuments/SectorPages/Portfolio/Environment/Ken%20Ladwig%20Written%20Testimony%20USHouse-E%26E%2010Dec2009%20FINAL.pdf

would be made to facilitate permitting of these Subtitle C facilities. Based on current disposal patterns, interviews with several utilities, and site-specific conditions such as land availability and watershed restrictions, EPRI assumed that a percentage of plants would be forced to dispose of CCRs in off-site commercial facilities, at higher costs for both transportation and disposal. The EPRI analysis also included special handling costs at the power plant to meet Subtitle C requirements. The NERC assessment did not include any special handling costs at the plant nor engineering retrofits that may be necessary for meeting Subtitle C standards. Finally, the NERC assessment assumed continued CCR utilization at current rates; EPRI ran simulations with both continued CCR use at the same rate and no CCR use.

Follow-on Steps

In their regulatory proposal, EPA requested additional information on both off-site disposal costs and "upstream" management and storage costs associated with Subtitle C regulation. In response to the EPA's request for additional cost data, EPRI is in the process of developing detailed engineering costs for Subtitle C regulation at the power plant as well as at CCR disposal sites. EPRI will share the engineering information and cost data with NERC when it is available. EPRI will prepare a technical report with the engineering and cost data in 4Q 2010 that will be publicly available.

Terms Used in This Report

Adjusted Potential Capacity Resources — The sum of Deliverable Capacity Resources, Existing Other Resources, Future Other Resources (reduced by a confidence factor), Conceptual Resources (reduced by a confidence factor), and net provisional transactions minus all derates. (MW)

Adjusted Potential Reserve Margin (%) — The sum of Deliverable Capacity Resources, Existing Other Resources, Future Other Resources (reduced by a confidence factor), Conceptual Resources (reduced by a confidence factor), and net provisional transactions minus all derates and Net Internal Demand shown as a percent of Net Internal Demand.

Capacity Categories — *See **Existing Generation Resources, Future Generation Resources, and Conceptual Generation Resources**.*

Conceptual Generation Resources — This category includes generation resources that are not included in *Existing Generation Resources* or *Future Generation Resources*, but have been identified and/or announced on a resource planning basis through one or more of the following sources:

1. Corporate announcement
2. Entered into or is in the early stages of an approval process
3. Is in a generator interconnection (or other) queue for study
4. "Place-holder" generation for use in modeling, such as generator modeling needed to support NERC Standard TPL analysis, as well as, integrated resource planning resource studies.

Resources included in this category may be adjusted using a confidence factor (%) to reflect uncertainties associated with siting, project development or queue position.

Deliverable Capacity Resources — Existing, Certain and Net Firm Transactions plus Future, Planned capacity resources plus Expected Imports, minus Expected Exports. (MW)

Deliverable Reserve Margin (%) — Deliverable Capacity Resources minus Net Internal Demand shown as a percent of Net Internal Demand.

Demand — *See **Net Internal Demand**,* and ***Total Internal Demand***

Demand Response — Changes in electric use by demand-side resources from their normal consumption patterns in response to changes in the price of electricity, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized.

Derate (Capacity) — The amount of capacity that is expected to be unavailable on seasonal peak.

Existing, Certain (Existing Generation Resources) — Existing generation resources available to operate and deliver power within or into the Region during the period of analysis in the assessment. Resources included in this category may be reported as a portion of the full capability of the resource, plant, or unit. This category includes, but is not limited to the following:

1. contracted (or firm) or other similar resource confirmed able to serve load during the period of analysis in the assessment;
2. where organized markets exist, designated market resource[43] that is eligible to bid into a market or has been designated as a firm network resource;
3. a Network Resource[44], as that term is used for FERC *pro forma* or other regulatory approved tariffs;
4. energy-only resources[45] confirmed able to serve load during the period of analysis in the assessment and will not be curtailed;[46]
5. capacity resources that cannot be sold elsewhere; and
6. other resources not included in the above categories that have been confirmed able to serve load and not to be curtailed[47] during the period of analysis in the assessment.

Existing, Certain & Net Firm Transactions — Existing, Certain capacity resources plus Firm Imports, minus Firm Exports. (MW)

Existing, Certain and Net Firm Transactions (%) (Margin Category) – Existing, Certain and Net Firm Transactions minus Net Internal Demand shown as a percent of Net Internal Demand.

Existing Generation Resources — *See **Existing, Certain**, **Existing, Other,*** and ***Existing, but Inoperable.***

Existing, Inoperable (Existing Generation Resources) — This category contains the existing portion of generation resources that are out-of-service and cannot be brought back into service to serve load during the period of analysis in the assessment. However, this category can include inoperable resources that could return to service at some point in the future. This value may vary for future seasons and can be reported as zero. This includes all existing generation not included in categories Existing, Certain or Existing, Other, but is not limited to, the following:

1. mothballed generation (that cannot be returned to service for the period of the assessment);
2. other existing but out-of-service generation (that cannot be returned to service for the period of the assessment);
3. does not include behind-the-meter generation or non-connected emergency generators that normally do not run; and
4. does not include partially dismantled units that are not forecasted to return to service.

Existing, Other (Existing Generation Resources) — Existing generation resources that may be available to operate and deliver power within or into the Region during the period of analysis in the assessment, but may be curtailed or interrupted at any time for various reasons. This category also includes portions of intermittent generation not included in Existing, Certain. This category includes, but is not limited to the following:

1. a resource with non-firm or other similar transmission arrangements;

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[43] Curtailable demand or load that is designated as a network resource or bid into a market is not included in this category, but rather must be subtracted from the appropriate category in the demand section.

[44] Curtailable demand or load that is designated as a network resource or bid into a market is not included in this category, but rather must be subtracted from the appropriate category in the demand section.

[45] Energy Only Resources are generally generating resources that are designated as energy-only resources or have elected to be classified as energy-only resources and may include generating capacity that can be delivered within the area but may be recallable to another area (Source: 2008 EIA 411 document OMB No. 1905-0129)." Note: Other than wind and solar energy, WECC does not have energy-only resources that are counted towards capacity.

[46] Energy only resources with transmission service constraints are to be considered in category Existing, Other.

[47] Energy only resources with transmission service constraints are to be considered in category Existing, Other.

2. energy-only resources that have been confirmed able to serve load for any reason during the period of analysis in the assessment, but may be curtailed for any reason;
3. mothballed generation (that may be returned to service for the period of the assessment);
4. portions of variable generation not counted in the Existing, Certain category (*e.g.*, wind, solar, etc. that may not be available or derated during the assessment period);
5. hydro generation not counted as Existing, Certain or derated; and
6. generation resources constrained for other reasons.

Expected (Transaction Category) — A category of Purchases/Imports and Sales/Exports with the following clarification:

1. Expected implies that a contract has not been executed, but is in negotiation, projected or other. These Purchases or Sales are expected to be firm.
2. Expected Purchases and Sales should be considered in the reliability assessments.

Firm (Transaction Category) — A category of Purchases/Imports and Sales/Exports with the following clarification contract including:

1. Firm implies a contract has been signed and may be recallable.
2. Firm Purchases and Sales should be reported in the reliability assessments. The purchasing entity should count such capacity in margin calculations. Care should be taken by both entities to appropriately report the generating capacity that is subject to such Firm contract.

Future Generation Resources (*See also **Future, Planned** and **Future, Other)* — This category includes generation resources the reporting entity has a reasonable expectation of coming online during the period of the assessment. As such, to qualify in either of the Future categories, the resource must have achieved one or more of these milestones:

1. Construction has started.
2. Regulatory permits being approved, are any one of the following:
   a. site permit;
   b. construction permit; or
   c. Environmental permit.
3. Regulatory approval has been received to be in the rate base.
4. There is an approved power purchase agreement.
5. Resources is approved and/or designated as a resource by a market operator.

Future, Other (Future Generation Resources) — This category includes future generating resources that do not qualify in *Future, Planned* and are not included in the Conceptual category. This category includes, but is not limited to, generation resources during the period of analysis in the assessment that:

1. may be curtailed or interrupted at any time for any reason;
2. are energy-only resources that may not be able to serve load during the period of analysis in the assessment;
3. are variable generation not counted in the *Future, Planned* category or may not be available or is derated during the assessment period; or
4. is hydro generation not counted in category *Future, Planned* or derated.

Resources included in this category may be adjusted using a confidence factor to reflect uncertainties associated with siting, project development or queue position.

Future, Planned (Future Generation Resources) — Generation resources anticipated to be available to operate and deliver power within or into the Region during the period of analysis in the assessment. This category includes, but is not limited to, the following:

1. Contracted (or firm) or other similar resource;
2. Where organized markets exist, a designated market resource[48] that is eligible to bid into a market or has been designated as a firm network resource.
3. A Network Resource[49], as that term is used for FERC pro forma or other regulatory approved tariffs.
4. Energy-only resources confirmed able to serve load during the period of analysis in the assessment and will not be curtailed[50].
5. Where applicable, is included in an integrated resource plan under a regulatory environment that mandates resource adequacy requirements and the obligation to serve.

NERC Reference Reserve Margin Level (%) — Either the Target Reserve Margin provided by the Region/subregion or NERC assigned based on capacity mix (*e.g.*, thermal/hydro). Each Region/subregion may have their own specific margin level based on load, generation, and transmission characteristics as well as regulatory requirements. If provided in the data submittals, the Regional/subregional Target Reserve Margin level is adopted as the NERC Reference Reserve Margin Level. If not, NERC assigned a 15 percent Reserve Margin for predominately thermal systems and 10 percent for predominately hydro systems.

Net Internal Demand: Total Internal Demand reduced by the total Dispatchable, Controllable, Capacity Demand Response equaling the sum of Direct Control Load Management, Contractually Interruptible (Curtailable), Critical Peak Pricing (CPP) with Control, and Load as a Capacity Resource.

On-Peak (Capacity) — The amount of capacity that is expected to be available on seasonal peak.

Potential Capacity Resources — The sum of Deliverable Capacity Resources, Existing Other Resources, Future Other Resources, Conceptual Resources, and net provisional transactions minus all derates. (MW)

Potential Reserve Margin (%) — The sum of Deliverable Capacity Resources, Existing Other Resources, Future Other Resources, Conceptual Resources, and net provisional transactions minus all derates and Net Internal Demand shown as a percentage of Net Internal Demand.

Prospective Capacity Reserve Margin (%) — Prospective Capacity Resources minus Net Internal Demand shown as a percentage of Net Internal Demand.

Prospective Capacity Resources — Deliverable Capacity Resources plus Existing, Other capacity resources, minus all Existing, Other deratings (including derates from variable resources, energy only resources, scheduled outages for maintenance, and transmission-limited resources), plus Future, Other capacity resources (adjusted by a confidence factor), minus all Future, Other deratings. (MW)

Provisional (Transaction Category) — A category of Purchases/Imports and Sales/Exports contract including Purchases and Sales that are expected to be provisionally firm. Provisional implies

[48] Curtailable demand or load that is designated as a network resource or bid into a market is not included in this category, but rather must be subtracted from the appropriate category in the demand section.

[49] Curtailable demand or load that is designated as a network resource or bid into a market is not included in this category, but rather must be subtracted from the appropriate category in the demand section.

[50] Energy only resources with transmission service constraints are to be considered in category Future, Other.

that the transactions are under study, but negotiations have not begun. Provisional Purchases and Sales should be considered in the reliability assessments.

Reference Reserve Margin Level — *See **NERC Reference Reserve Margin Level***

Reserve Margin (%) —Roughly, Capacity minus Demand, divided by Demand or (Capacity-Demand)/Demand. Replaced *Capacity Margin(s) (%)* for NERC Assessments in 2009.

Target Reserve Margin (%) — Established target for Reserve Margin by the Region or subregion. Not all Regions report a Target Reserve Margin. The NERC Reference Reserve Margin Level is used in those cases where a Target Reserve Margin is not provided.

Transfer/Transaction (*See also **Firm, Non-Firm, Expected** and **Provisional)*** — Contracts for Capacity are defined as an agreement between two or more parties for the Purchase and Sale of generating capacity. Purchase contracts refer to imported capacity that is transmitted from an outside Region or subregion to the reporting Region or subregion. Sales contracts refer to exported capacity that is transmitted from the reporting Region or subregion to an outside Region or subregion. For example, if a resource subject to a contract is located in one Region and sold to another Region, the Region in which the resource is located reports the capacity of the resource and reports the sale of such capacity that is being sold to the outside Region. The purchasing Region reports such capacity as a purchase, but does not report the capacity of such resource. Transmission must be available for all reported Purchases and Sales.

Abbreviations Used in This Report

316(b)	Clean Water Act – Section 316(b), Cooling Water Intake Structures
APCR	Adjusted Potential Capacity Resources
AZ-NM-SNV	Arizona-New Mexico-Southern Nevada (subregion of WECC)
BTA	Best Technology Available
CA	California (subregion of WECC)
CA-MX-US	California-México (subregion of WECC)
CAIR	Clean Air Interstate Rule
CAMR	Clean Air Mercury Rule
CATR	Clean Air Transport Rule
CCB	Coal Combustion Byproducts
CCR	Coal Combustion Residuals
DOE	U.S. Department of Energy
EIA	Energy Information Agency (of DOE)
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ERCOT	Electric Reliability Council of Texas
EVA	Energy Venture Associates
FERC	U.S. Federal Energy Regulatory Commission
FGD	Flue gas desulfurization
FRCC	Florida Reliability Coordinating Council
GHG	Greenhouse Gas
gpm	Gallons per minute
GW	Gigawatt
GWh	Gigawatt hours
HACI	Halide-treated Activated Carbon Injection
HAP	Hazardous Air Pollutants
MACT	Maximum Achievable Control Technology
mgd	Million gallons per day
MRO	Midwest Reliability Organization
MW	Megawatts (millions of watts)
MWH	Megawatt hours
NAAQS	National Ambient Air Quality Standards
NERC	North American Electric Reliability Corporation
NESHAP	National Emissions Standards of Hazardous Air Pollutants
NO_x	Nitrogen Oxide
NPCC	Northeast Power Coordinating Council
NWPP	Northwest Power Pool Area (subregion of WECC)
NYPP	New York Power Pool
PV	Photovoltaic
RCRA	Resource Conservation Recovery Act
RFC	Reliability*First* Corporation
RMPA	Rocky Mountain Power Area (subregion of WECC)
RMR	Reliability Must Run
RMRG	Rocky Mountain Reserve Group
RP	Reliability Planner
SCR	Selective Catalytic Reduction
SERC	SERC Reliability Corporation
SO_2	Sulfur Dioxide
SPP	Southwest Power Pool
tpy	Tons per year
TRE	Texas Regional Entity
TVA	Tennessee Valley Authority
VACAR	Virginia and Carolinas (subregion of SERC)
WECC	Western Electricity Coordinating Council

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North American Electric Reliability Corporation Staff Roster

ensure
the reliability of the
bulk power system

BEFORE THE KENTUCKY PUBLIC SERVICE COMMISSION

Docket Nos. 2011-00161 and 2011-00162

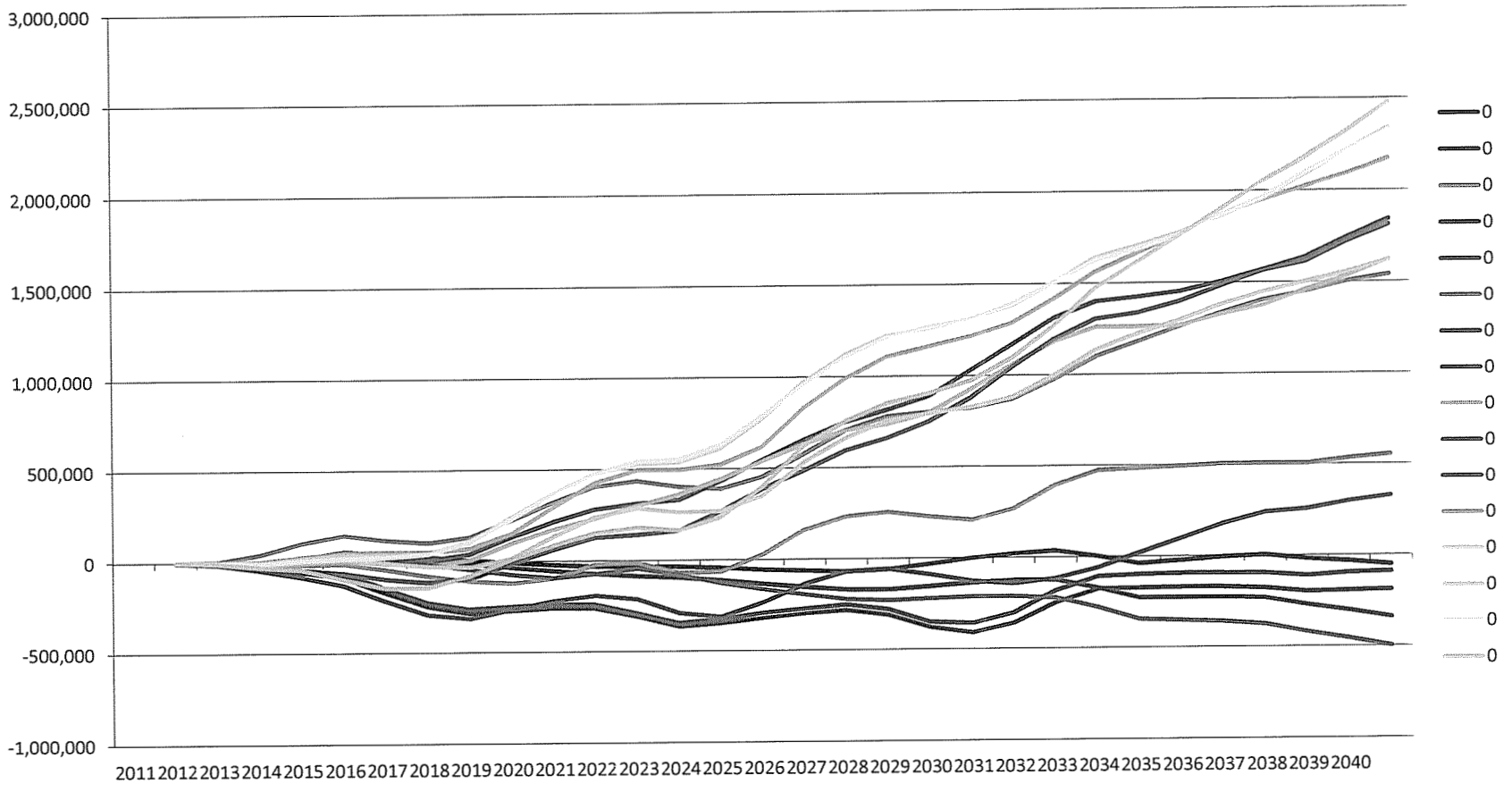
Environmental Intervenors' Responses and Supporting Attachments to September 30, 2011 Data Requests by Louisville Gas and Electric Company and Kentucky Utilities Company

Attachment in Response to Question 4B

	Delta NPVRR $M Install Controls / (Retire)
Tyrone 3	(13)
Brown 3	(104)
Cane Run 6	566
Brown 1-2	(194)
Cane Run 4-5	(55)
Green River 3-4	137
Ghent 1-4	(158)
Trimble County 1	612
Mill Creek 3-4	541
Mill Creek 1-2	(155)

Cumulative Difference in Revenue Requirements

Install Controls vs. Retire/Replace Capacity



Retirement Savings (Deltas)

	Capital	O&M	Total	
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0
	0	0	0	0

Revenue Requirement Deltas

	Prod Cost	Capital	Total	Check
	0	0	0	13
	0	0	0	104
	0	0	0	-566
	0	0	0	194
	0	0	0	55
	0	0	0	-137
	0	0	0	158
	0	0	0	-612
	0	0	0	-541
	0	0	0	155
	0	0	0	-522
	0	0	0	-746
	0	0	0	-806
	0	0	0	-513

0	0	0	0	-800
0	0	0	0	-675

		1	2	3	4	5	6	7	8	9
	Retire:									
	No Retirements	TY	TY GR3	TY GR3 BR3	TY GR3 CR4	TY GR3 CR4 CR6	TY GR3 CR4 CR6 BR1-2	TY GR3 CR	TY GR3 CR GH3	TY GR3 CR GH1
2010										
2011										
2012										
2013										
2014										
2015										
2016		3x1C(1)	2x1C(1)	3x1C(1)	3x1C(1)	3x1C(1)	3x1C(1)	3x1C(1)	3x1C(1) 2x1C(1)	3x1C(2)
2017	3x1C(1)									
2018							3x1C(1)			
2019								3x1C(1)		
2020			2x1C(1)	3x1C(1)		3x1C(1)			3x1C(1)	
2021										
2022					2x1C(1)					3x1C(1)
2023										
2024	3x1C(1)	3x1C(1)					3x1C(1)			
2025			3x1C(1)					3x1C(1)		
2026				3x1C(1)	3x1C(1)	3x1C(1)			3x1C(1)	
2027										
2028										3x1C(1)
2029										
2030	2x1C(1)	3x1C(1)								
2031			SCCT(1)				3x1C(1)	2x1C(1)		
2032					SCCT(1)					
2033			3x1C(1)	3x1C(1)		3x1C(1)			3x1C(1)	
2034					3x1C(1)					
2035	2x1C(1)									2x1C(1)
2036		2x1C(1)						2x1C(1)		
2037							SCCT(1)			

2038										
2039	SCCT(1)						SCCT(1)			
2040			SCCT(1)	SCCT(1)		SCCT(1)			SCCT(1)	SCCT(1)
30 Yr PVRR ($B)	23.6	23.7	23.8	24.7	24.2	24.8	25.5	25.3	26.6	26.6

10	11	12	13	14	15	16
TY GR CR	TY GR CR MC4	TY GR CR TC1	TY GR CR GH4	TY GR CR MC3	TY GR CR GH2	TY GR CR MC1-2
3x1C(1)	3x1C(2)	3x1C(2)	3x1C(2)	3x1C(2)	3x1C(2)	3x1C(2)
3x1C(1)						
						3x1C(1)
	3x1C(1)		3x1C(1)		3x1C(1)	
		3x1C(1)		3x1C(1)		
3x1C(1)						
						2x1C(1)
	3x1C(1)	3x1C(1)	3x1C(1)	3x1C(1)	3x1C(1)	
3x1C(1)						3x1C(1)
			3x1C(1)		3x1C(1)	
	3x1C(1)	2x1C(1)		2x1C(1)		
SCCT(1)						SCCT(1)

SCCT(1)

SCCT(1)

SCCT(1)

SCCT(1)

25.4 26.9 26.7 26.9 26.6 27.0 27.5

Breakeven RR by Year ($M)

	Year $									
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
TY	-13	-14	-15	-16	-17	-18	-19	-21	-22	-23
GR3	-104	-111	-119	-127	-135	-144	-154	-164	-175	-187
BR3	566	603	644	687	733	782	835	891	951	1,015
CR4	-194	-207	-220	-235	-251	-268	-286	-305	-325	-347
CR6	-55	-59	-63	-67	-72	-77	-82	-87	-93	-100
BR1-2	137	146	156	166	177	189	202	216	230	246
CR5	-158	-169	-180	-192	-205	-219	-233	-249	-266	-283
GH3	612	653	697	744	794	847	904	964	1,029	1,098
GH1	541	578	616	658	702	749	799	853	910	971
GR4	-155	-165	-176	-188	-201	-214	-229	-244	-261	-278
MC4	522	557	594	634	676	722	770	822	877	936
TC1	746	797	850	907	968	1,033	1,102	1,176	1,255	1,339
GH4	806	860	918	979	1,045	1,115	1,190	1,270	1,355	1,446
MC3	513	547	584	623	665	710	757	808	862	920
GH2	800	854	911	973	1,038	1,108	1,182	1,261	1,346	1,436
MC1-2	675	720	768	820	875	933	996	1,063	1,134	1,210

Breakeven Year

	Must Op Thru
BR3	2019
BR1-2	2021
GH3	2020
GH1	2021
MC4	2023
TC1	2018
GH4	2018
MC3	2021
GH2	2018
MC1-2	2024

Station	Unit		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
BR	BR1	BR1FFP 0	0	238	3,127	7,278	12,105	12,775	12,123	11,534	10,999	10,472
BR	BR1	BR1SAM 0	0	0	0	231	521	550	522	497	474	452
BR	BR2	BR2FFP 0	0	252	3,379	7,865	13,414	13,865	13,156	12,514	11,931	11,357
BR	BR2	BR2SAM 0	0	0	0	231	534	553	525	499	476	453
BR	BR3	BR3FFP 0	0	0	204	2,854	7,595	13,437	14,120	13,404	12,757	12,171
GH	GH1	GH1FFP 0	0	64	4,332	10,157	17,736	19,154	18,156	17,246	16,412	15,591
GH	GH1	GH1SAM 0	0	122	562	1,006	1,964	2,121	2,010	1,909	1,817	1,726
GH	GH2	GH2FFP 0	0	0	2,787	7,280	15,016	18,298	17,569	16,777	16,056	15,369
GH	GH2	GH2SAM 0	0	11	724	984	935	891	851	814	779	744
GH	GH3	GH3FFP 0	0	0	0	3,571	8,804	18,270	21,813	20,853	19,901	19,030
GH	GH3	GH3SAM 0	0	115	565	1,578	1,935	1,853	1,769	1,691	1,618	1,544
GH	GH4	GH4FFP 0	0	0	0	2,843	7,668	14,952	21,319	20,238	19,257	18,361
GH	GH4	GH4SAM 0	0	122	527	974	1,948	1,967	1,872	1,786	1,707	1,631
MC	MC1	MC1FGD 0	0	0	2,360	7,268	12,372	21,934	23,856	22,601	21,453	20,399
MC	MC1	MC1FFP 0	0	0	1,271	5,238	9,364	17,796	19,361	18,343	17,414	16,559
MC	MC1	MC1SAM 0	0	0	0	42	560	1,131	1,232	1,168	1,109	1,055
MC	MC2	MC2FGD 0	0	0	2,361	7,270	12,377	23,214	24,770	23,450	22,238	21,119
MC	MC2	MC2FFP 0	0	0	1,215	5,051	9,134	18,426	19,666	18,620	17,659	16,772
MC	MC2	MC2SAM 0	0	0	0	42	560	1,197	1,279	1,211	1,149	1,092
MC	MC3	MC3FGDU 0	0	0	646	3,668	6,975	9,472	9,135	8,699	8,295	7,908
MC	MC3	MC3FGDR 0	0	0	0	0	39	175	207	197	187	179
MC	MC3	MC3FFP 0	0	0	0	3,730	8,326	13,896	18,276	17,601	16,757	15,977
MC	MC3	MC3SAM 0	0	0	734	1,992	2,100	1,997	1,901	1,813	1,728	1,642
MC	MC4	MC4FGD 0	0	379	6,987	15,193	21,072	28,573	27,555	26,231	25,008	23,834
MC	MC4	MC4SCR 0	0	105	667	724	688	655	625	596	566	537
MC	MC4	MC4FFP 0	0	377	5,055	10,178	14,629	19,836	19,129	18,210	17,361	16,546
MC	MC4	MC4SAM 0	0	0	0	578	1,620	2,201	2,123	2,022	1,929	1,839
TC	TC1	TC1FFP 0	0	0	0	2,200	5,745	11,967	15,834	15,223	14,502	13,838
CR	CR4	CR4FGD 0	0	394	3,222	13,574	27,295	25,773	24,370	23,071	21,861	20,666
CR	CR4	CR4SCR 0	64	390	2,395	6,163	10,786	10,183	9,627	9,112	8,633	8,160
CR	CR4	CR4FF 0	0	280	1,715	3,329	5,526	5,216	4,930	4,666	4,421	4,178
CR	CR4	CR4PAC 0	0	0	0	235	386	365	345	327	310	293
CR	CR4	CR4LIME 0	0	0	0	259	427	403	381	361	342	323

CR	CR5	CR5FGD 0	0	359	3,311	14,658	29,304	27,663	26,148	24,742	23,429	22,132
CR	CR5	CR5SCR 0	63	388	2,719	6,475	11,557	10,908	10,308	9,752	9,234	8,721
CR	CR5	CR5FF 0	0	300	1,823	3,531	5,992	5,654	5,343	5,054	4,785	4,519
CR	CR5	CR5PAC 0	0	0	0	251	423	399	378	357	338	320
CR	CR5	CR5LIME 0	0	0	0	278	468	441	417	395	374	353
CR	CR6	CR6FGD 0	0	346	3,887	18,407	35,115	33,170	31,385	29,739	28,213	26,706
CR	CR6	CR6SCR 0	79	1,294	4,201	8,457	14,206	13,414	12,689	12,019	11,399	10,787
CR	CR6	CR6FF 0	0	394	2,364	4,540	7,252	6,848	6,477	6,136	5,819	5,507
CR	CR6	CR6PAC 0	0	0	0	352	558	527	499	473	448	424
CR	CR6	CR6LIME 0	0	0	0	391	619	585	553	525	498	471
GR	GR3	GR3SFF 0	0	0	1,323	4,035	5,553	5,254	4,983	4,739	4,516	4,297
GR	GR3	GR3PAC 0	0	0	0	112	154	145	138	131	125	119
GR	GR4	GR4SFF 0	0	0	1,885	5,750	8,517	8,050	7,626	7,237	6,881	6,529
GR	GR4	GR4PAC 0	0	0	0	160	235	223	211	200	190	181

2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
9,946	9,420	8,894	8,368	7,842	7,483	7,291	7,099	6,908	6,716	6,525	6,333	6,141
429	407	384	362	339	324	315	307	299	291	282	274	266
10,783	10,210	9,636	9,062	8,488	8,095	7,881	7,668	7,455	7,242	7,028	6,815	6,602
431	408	385	362	340	324	315	307	298	290	281	273	264
11,595	11,019	10,443	9,867	9,290	8,714	8,325	8,122	7,920	7,717	7,514	7,311	7,109
14,769	13,948	13,127	12,305	11,484	10,897	10,545	10,193	9,841	9,489	9,137	8,785	8,433
1,635	1,544	1,453	1,362	1,271	1,206	1,167	1,128	1,089	1,050	1,011	972	933
14,684	13,998	13,313	12,627	11,942	11,257	10,791	10,556	10,330	10,104	9,878	9,652	9,425
709	674	639	605	570	546	535	523	511	500	488	476	464
18,199	17,369	16,538	15,708	14,877	14,047	13,216	12,647	12,344	12,047	11,750	11,452	11,155
1,471	1,397	1,324	1,250	1,177	1,126	1,099	1,073	1,047	1,020	994	967	941
17,541	16,757	15,973	15,188	14,404	13,619	12,835	12,050	11,513	11,223	10,932	10,642	10,352
1,555	1,479	1,403	1,328	1,252	1,176	1,124	1,096	1,068	1,039	1,011	983	955
19,360	18,320	17,281	16,242	15,203	14,164	13,412	12,949	12,485	12,022	11,558	11,095	10,631
15,717	14,875	14,032	13,190	12,348	11,506	10,896	10,520	10,143	9,767	9,390	9,013	8,637
1,001	948	895	841	788	735	696	672	648	624	600	576	552
20,015	18,911	17,806	16,702	15,598	14,494	13,677	13,148	12,618	12,088	11,558	11,028	10,499
15,896	15,021	14,145	13,270	12,395	11,519	10,871	10,450	10,029	9,608	9,187	8,766	8,344
1,035	978	922	865	808	752	710	682	655	627	600	572	545
7,522	7,135	6,748	6,362	5,975	5,589	5,303	5,124	4,950	4,777	4,603	4,429	4,256
170	162	154	145	137	128	121	115	111	107	104	100	96
15,228	14,480	13,732	12,985	12,237	11,489	10,742	10,190	9,844	9,510	9,175	8,841	8,506
1,557	1,472	1,387	1,302	1,217	1,155	1,116	1,077	1,039	1,000	961	923	884
22,662	21,491	20,319	19,147	17,976	16,804	15,940	15,402	14,880	14,358	13,836	13,314	12,792
508	479	449	420	399	386	372	359	346	332	319	306	292
15,733	14,919	14,106	13,293	12,479	11,666	11,066	10,692	10,330	9,968	9,605	9,243	8,881
1,749	1,660	1,570	1,480	1,391	1,301	1,235	1,193	1,153	1,112	1,072	1,031	991
13,200	12,564	11,927	11,291	10,654	10,018	9,381	8,918	8,637	8,363	8,089	7,815	7,541
19,471	18,276	17,081	15,886	14,691	13,773	13,130	12,488	11,845	11,203	10,560	0	0
7,687	7,214	6,740	6,267	5,794	5,431	5,177	4,924	4,671	4,417	4,164	0	0
3,935	3,692	3,450	3,207	2,964	2,778	2,648	2,519	2,389	2,260	2,130	0	0
276	259	242	225	208	195	186	177	168	159	150	0	0
305	286	267	249	230	216	206	195	185	175	165	0	0

20,835	19,538	18,241	16,944	15,647	14,641	13,924	13,207	12,490	11,774	0	0	0
8,208	7,696	7,183	6,670	6,158	5,760	5,478	5,196	4,914	4,632	0	0	0
4,253	3,987	3,721	3,455	3,189	2,983	2,837	2,691	2,545	2,399	0	0	0
301	282	263	245	226	212	201	191	180	170	0	0	0
333	312	291	271	250	234	222	211	199	188	0	0	0
25,199	23,692	22,185	20,678	19,171	18,033	17,265	16,496	15,727	14,959	14,190	13,421	12,653
10,175	9,563	8,951	8,339	7,727	7,266	6,956	6,646	6,337	6,027	5,717	5,408	5,098
5,194	4,882	4,569	4,257	3,944	3,709	3,551	3,393	3,235	3,077	2,919	2,761	2,602
401	377	353	329	305	287	275	262	250	238	226	213	201
445	418	391	365	338	318	305	291	278	264	250	237	223
4,078	3,859	3,640	3,421	3,202	3,050	2,967	2,884	2,800	2,717	2,634	2,550	2,467
113	107	101	95	89	85	82	80	78	75	73	71	68
6,177	5,825	5,473	5,122	4,770	4,515	4,356	4,198	4,040	3,881	3,723	3,565	3,407
171	161	152	142	132	125	121	116	112	108	103	99	94

2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045
5,950	5,758	5,566	5,375	5,183	4,991	4,800	4,608	4,417	4,225	4,033	3,842	3,650
257	249	241	232	224	216	208	199	191	183	174	166	158
6,388	6,175	5,962	5,749	5,535	5,322	5,109	4,895	4,682	4,469	4,256	4,042	3,829
256	247	239	230	222	213	205	196	187	179	170	162	153
6,906	6,703	6,501	6,298	6,095	5,893	5,690	5,487	5,284	5,082	4,879	4,676	4,474
8,081	7,729	7,377	7,025	6,673	6,321	5,969	2,424	0	0	0	0	0
894	855	816	777	738	699	661	268	0	0	0	0	0
9,199	8,973	8,747	8,521	8,295	8,069	7,843	7,617	7,391	7,165	6,939	6,713	6,486
453	441	429	418	406	394	383	371	359	348	336	324	312
10,858	10,561	10,263	9,966	9,669	9,372	9,075	8,777	8,480	8,183	7,886	7,588	7,291
915	888	862	835	809	782	756	730	703	677	650	624	598
10,061	9,771	9,481	9,190	8,900	8,610	8,319	8,029	7,739	7,448	7,158	6,867	6,577
927	899	870	842	814	786	758	730	701	673	645	617	589
10,167	9,704	9,240	8,777	8,313	7,850	3,188	0	0	0	0	0	0
8,260	7,884	7,507	7,130	6,754	6,377	2,590	0	0	0	0	0	0
528	504	480	455	431	407	165	0	0	0	0	0	0
9,969	9,439	8,909	2,908	0	0	0	0	0	0	0	0	0
7,923	7,502	7,081	2,311	0	0	0	0	0	0	0	0	0
517	490	462	151	0	0	0	0	0	0	0	0	0
4,082	3,909	3,735	3,561	3,388	3,214	3,040	2,653	188	0	0	0	0
92	88	85	81	77	73	69	64	44	0	0	0	0
8,172	7,837	7,503	7,168	6,834	6,499	6,165	5,830	4,673	341	0	0	0
846	807	768	730	691	652	213	0	0	0	0	0	0
12,270	11,748	11,226	10,705	10,183	9,661	9,139	7,976	573	0	0	0	0
279	266	252	239	226	92	0	0	0	0	0	0	0
8,518	8,156	7,794	7,431	7,069	6,707	6,344	5,537	398	0	0	0	0
951	910	870	829	789	748	708	618	44	0	0	0	0
7,267	6,993	6,719	6,445	6,171	5,897	5,623	5,349	5,075	4,801	4,186	261	0
0	0	0	0	0	0	0	0	0	0	0	0	0
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2,384	2,300	2,217	2,134	2,050	1,967	1,884	1,800	1,717	1,634	1,550	1,467	1,384
66	64	62	59	57	55	52	50	48	45	43	41	38
3,248	3,090	2,932	2,773	2,615	0	0	0	0	0	0	0	0
90	86	81	77	73	0	0	0	0	0	0	0	0

2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058
3,458	3,267	1,327	0	0	0	0	0	0	0	0	0	0
150	141	57	0	0	0	0	0	0	0	0	0	0
3,616	1,180	0	0	0	0	0	0	0	0	0	0	0
145	47	0	0	0	0	0	0	0	0	0	0	0
4,271	4,068	3,865	3,663	3,460	1,405	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
6,260	6,034	5,808	5,582	5,356	5,130	4,904	4,678	4,452	4,226	4,000	3,489	253
301	289	277	266	254	242	231	219	207	196	0	0	0
6,994	6,697	6,400	6,102	5,805	5,508	5,211	4,152	214	0	0	0	0
571	545	518	492	465	405	21	0	0	0	0	0	0
6,287	5,996	5,706	5,416	5,125	4,835	0	0	0	0	0	0	0
561	532	504	476	117	0	0	0	0	0	0	0	0
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		2010	2011	2012	2013	2014	2015	2016	2017	2018
	Retirement Cost									
	All Units	0	0	0	0	0	0	2100	0	0
	2% Escalation Rate									
	Unit Costs ($000)									
BR	BR1		3,816	4,811	3,969	4,049	4,130	4,212	4,296	4,382
BR	BR2		6,633	7,160	7,253	7,398	7,546	7,697	7,851	8,008
BR	BR3		15,885	20,876	14,904	15,202	15,506	15,816	16,132	16,455
CR	CR4		14,372	9,218	12,029	12,269	12,515	12,765	13,020	13,281
CR	CR5		11,842	9,889	12,791	13,047	13,308	13,574	13,845	14,122
CR	CR6		10,666	11,619	10,173	10,376	10,584	10,795	11,011	11,231
GH	GH1		17,829	19,141	17,966	18,325	18,691	19,065	19,447	19,835
GH	GH2		12,225	18,498	13,429	13,698	13,972	14,251	14,536	14,827
GH	GH3		17,961	13,501	12,475	12,724	12,979	13,238	13,503	13,773
GH	GH4		11,533	13,496	12,105	12,347	12,594	12,846	13,103	13,365
GR	GR3		4,270	5,792	4,360	4,447	4,536	4,627	4,719	4,813
GR	GR4		7,338	6,924	8,633	8,805	8,982	9,161	9,344	9,531
MC	MC1		11,892	17,333	12,669	12,923	13,181	13,445	13,714	13,988
MC	MC2		16,179	11,941	15,201	15,505	15,815	16,131	16,454	16,783
MC	MC3		18,313	14,238	17,221	17,566	17,917	18,275	18,641	19,014
MC	MC4		16,531	18,981	17,245	17,590	17,942	18,300	18,666	19,040
TC	TC1		17,205	15,170	17,403	17,751	18,106	18,468	18,837	19,214
TY	TY3		410	416	418	427	435	444	453	462

2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
0	0	0	0	0	0	0	0	0	0	0	0
4,470	4,559	4,651	4,744	4,838	4,935	5,034	5,135	5,237	5,342	5,449	5,558
8,168	8,331	8,498	8,668	8,841	9,018	9,199	9,383	9,570	9,762	9,957	10,156
16,784	17,120	17,462	17,811	18,167	18,531	18,901	19,279	19,665	20,058	20,460	20,869
13,546	13,817	14,094	14,375	14,663	14,956	15,255	15,560	15,872	16,189	16,513	16,843
14,405	14,693	14,987	15,286	15,592	15,904	16,222	16,546	16,877	17,215	17,559	17,910
11,456	11,685	11,919	12,157	12,400	12,648	12,901	13,159	13,423	13,691	13,965	14,244
20,232	20,637	21,050	21,471	21,900	22,338	22,785	23,240	23,705	24,179	24,663	25,156
15,124	15,426	15,735	16,049	16,370	16,698	17,032	17,372	17,720	18,074	18,436	18,804
14,049	14,330	14,616	14,909	15,207	15,511	15,821	16,138	16,460	16,790	17,125	17,468
13,632	13,905	14,183	14,467	14,756	15,051	15,352	15,659	15,973	16,292	16,618	16,950
4,910	5,008	5,108	5,210	5,314	5,421	5,529	5,640	5,753	5,868	5,985	6,105
9,722	9,916	10,115	10,317	10,523	10,734	10,949	11,167	11,391	11,619	11,851	12,088
14,268	14,553	14,844	15,141	15,444	15,753	16,068	16,389	16,717	17,051	17,392	17,740
17,118	17,461	17,810	18,166	18,530	18,900	19,278	19,664	20,057	20,458	20,867	21,285
19,394	19,782	20,177	20,581	20,993	21,412	21,841	22,278	22,723	23,178	23,641	24,114
19,421	19,809	20,205	20,609	21,021	21,442	21,871	22,308	22,754	23,209	23,674	24,147
19,598	19,990	20,390	20,798	21,214	21,638	22,071	22,512	22,962	23,422	23,890	24,368
471	480	490	500	510	520	530	541	552	563	574	586

2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
0	0	0	0	0	0	0	0	0	0
5,669	5,782	5,898	6,016	6,136	6,259	6,384	6,512	6,642	6,775
10,359	10,566	10,778	10,993	11,213	11,437	11,666	11,899	12,137	12,380
21,286	21,712	22,146	22,589	23,041	23,502	23,972	24,451	24,940	25,439
17,180	17,524	17,874	18,232	18,596	18,968	19,347	19,734	20,129	20,532
18,269	18,634	19,007	19,387	19,775	20,170	20,573	20,985	21,405	21,833
14,529	14,820	15,116	15,418	15,727	16,041	16,362	16,689	17,023	17,364
25,659	26,172	26,696	27,230	27,774	28,330	28,897	29,474	30,064	30,665
19,181	19,564	19,955	20,355	20,762	21,177	21,600	22,032	22,473	22,923
17,817	18,174	18,537	18,908	19,286	19,672	20,065	20,466	20,876	21,293
17,289	17,635	17,988	18,347	18,714	19,089	19,470	19,860	20,257	20,662
6,227	6,351	6,478	6,608	6,740	6,875	7,012	7,153	7,296	7,442
12,330	12,576	12,828	13,084	13,346	13,613	13,885	14,163	14,446	14,735
18,095	18,457	18,826	19,202	19,586	19,978	20,378	20,785	21,201	21,625
21,710	22,145	22,587	23,039	23,500	23,970	24,449	24,938	25,437	25,946
24,596	25,088	25,590	26,102	26,624	27,156	27,699	28,253	28,818	29,395
24,630	25,123	25,625	26,138	26,660	27,194	27,737	28,292	28,858	29,435
24,855	25,352	25,859	26,377	26,904	27,442	27,991	28,551	29,122	29,704
597	609	622	634	647	660	673	686	700	714

Escalation Rate: 2% Year $: 2010

		Month	Year	Equipment	Fixed O&M $/yr	2011	2012	2013	2014	2015	2016	2017
BR	BR1	5	2014	PJFF/PAC		0	0	0	598,882	610,860	623,077	635,538
BR	BR1	5	2014	SAM Mitigation		0	0	0	78,540	137,333	140,079	142,881
BR	BR2	4	2014	PJFF/PAC		0	0	0	714,168	728,451	743,020	757,880
BR	BR2	4	2014	SAM Mitigation		0	0	0	134,640	137,333	140,079	142,881
BR	BR3	5	2015	PJFF/PAC		0	0	0	0	1,067,560	1,088,911	1,110,689
GH	GH1	5	2014	PJFF/PAC		0	0	0	1,293,082	1,318,944	1,345,322	1,372,229
GH	GH1	5	2014	SCR Turn-Down		0	0	0	0	0	0	0
GH	GH1	2	2013	SAM Mitigation		0	0	0	4,899	0	0	0
GH	GH2	11	2014	PJFF/PAC		0	0	0	777,600	1,586,304	1,618,030	1,650,391
GH	GH2	12	2012	Sorbent Injection		0	8,064	98,700	100,674	102,687	104,741	106,836
GH	GH3	10	2015	PJFF/PAC		0	0	0	0	652,436	1,330,969	1,357,589
GH	GH3	11	2013	SCR Turn-Down		0	0	0	0	0	0	0
GH	GH3	2	2013	SAM Mitigation		0	0	0	0	0	0	0
GH	GH4	12	2015	PJFF/PAC		0	0	0	0	631,870	1,289,014	1,314,795
GH	GH4	3	2014	SCR Turn-Down		0	0	0	0	0	0	0
GH	GH4	2	2013	SAM Mitigation		0	0	0	0	0	0	0
MC	MC1	5	2015	Combined 1&2 FGD		0	0	0	0	-238,642	-219,636	-200,250
MC	MC1	5	2015	PJFF/PAC		0	0	0	0	1,446,222	1,475,147	1,504,650
MC	MC1	5	2015	SAM Mitigation		0	0	0	0	22,100	38,643	39,416
MC	MC2	4	2015	Combined 1&2 FGD		0	0	0	0	186,506	205,512	224,899
MC	MC2	4	2015	PJFF/PAC		0	0	0	0	1,418,867	1,447,245	1,476,189
MC	MC2	4	2015	SAM Mitigation		0	0	0	0	25,257	38,643	39,416
MC	MC3	11	2014	FGD		0	0	0	0	0	0	0
MC	MC3	10	2015	PJFF/PAC		0	0	0	0	646,753	1,319,377	1,345,764
MC	MC3	4	2013	SAM Mitigation		0	0	24,068	36,824	37,560	38,312	39,078
MC	MC3	4	2013	SCR Turn-Down		0	0	0	0	0	0	0
MC	MC4	11	2014	FGD		0	0	0	0	0	0	0
MC	MC4	11	2014	PJFF/PAC		0	0	0	743,376	1,516,487	1,546,817	1,577,754
MC	MC4	11	2014	SAM Mitigation		0	0	0	3,095	37,885	38,643	39,416
MC	MC4	11	2014	SCR Turn-Down		0	0	0	0	0	0	0
TC	TC1	11	2015	PJFF/PAC		0	0	0	0	493,761	1,007,273	1,027,418

CR	CR4	1	2016	SCR	1,871,000	0	0	0	0	0	2,107,050	2,149,191
CR	CR4	1	2016	WFGD		0	0	0	0	0	0	0
CR	CR4	1	2016	PJFF	1,191,000	0	0	0	0	0	1,341,259	1,368,085
CR	CR4	1	2016	SAM Mitigation	174,000	0	0	0	0	0	195,952	199,871
CR	CR4	1	2016	PAC Injection	169,000	0	0	0	0	0	190,321	194,128
CR	CR5	1	2016	SCR	1,993,000	0	0	0	0	0	2,244,442	2,289,331
CR	CR5	1	2016	WFGD		0	0	0	0	0	0	0
CR	CR5	1	2016	PJFF	1,251,000	0	0	0	0	0	1,408,829	1,437,006
CR	CR5	1	2016	SAM Mitigation	177,000	0	0	0	0	0	199,331	203,317
CR	CR5	1	2016	PAC Injection	172,000	0	0	0	0	0	193,700	197,574
CR	CR6	1	2016	SCR	2,392,000	0	0	0	0	0	2,693,781	2,747,656
CR	CR6	1	2016	WFGD		0	0	0	0	0	0	0
CR	CR6	1	2016	PJFF	1,632,000	0	0	0	0	0	1,837,897	1,874,655
CR	CR6	1	2016	SAM Mitigation	198,000	0	0	0	0	0	222,980	227,440
CR	CR6	1	2016	PAC Injection	191,000	0	0	0	0	0	215,097	219,399
GR	GR3	1	2016	SCR	943,000	0	0	0	0	0	1,061,971	1,083,211
GR	GR3	1	2016	CDS-FF	3,322,000	0	0	0	0	0	3,741,112	3,815,934
GR	GR3	1	2016	PAC Injection	141,000	0	0	0	0	0	158,789	161,965
GR	GR4	1	2016	SCR	1,284,000	0	0	0	0	0	1,445,993	1,474,912
GR	GR4	1	2016	CDS-FF	4,309,000	0	0	0	0	0	4,852,634	4,949,687
GR	GR4	1	2016	PAC Injection	150,000	0	0	0	0	0	168,924	172,303

2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
648,249	661,214	674,439	687,927	701,686	715,720	730,034	744,635	759,527	774,718	790,212	806,016
145,739	148,653	151,627	154,659	157,752	160,907	164,125	167,408	170,756	174,171	177,655	181,208
773,038	788,499	804,269	820,354	836,761	853,496	870,566	887,978	905,737	923,852	942,329	961,175
145,739	148,653	151,627	154,659	157,752	160,907	164,125	167,408	170,756	174,171	177,655	181,208
1,132,903	1,155,561	1,178,672	1,202,245	1,226,290	1,250,816	1,275,832	1,301,349	1,327,376	1,353,924	1,381,002	1,408,622
1,399,673	1,427,667	1,456,220	1,485,345	1,515,052	1,545,353	1,576,260	1,607,785	1,639,941	1,672,739	1,706,194	1,740,318
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
1,683,399	1,717,067	1,751,408	1,786,436	1,822,165	1,858,608	1,895,781	1,933,696	1,972,370	2,011,817	2,052,054	2,093,095
108,973	111,152	113,375	115,643	117,956	120,315	122,721	125,175	127,679	130,232	132,837	135,494
1,384,741	1,412,435	1,440,684	1,469,498	1,498,888	1,528,865	1,559,443	1,590,632	1,622,444	1,654,893	1,687,991	1,721,751
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
1,341,091	1,367,912	1,395,271	1,423,176	1,451,640	1,480,672	1,510,286	1,540,491	1,571,301	1,602,727	1,634,782	1,667,477
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
-180,476	-160,306	-139,733	-118,749	-121,124	-123,546	-126,017	-128,537	-131,108	-133,730	-136,405	-139,133
1,534,743	1,565,438	1,596,746	1,628,681	1,661,255	1,694,480	1,728,370	1,762,937	1,798,196	1,834,160	1,870,843	1,908,260
40,204	41,008	41,828	42,665	43,518	44,388	45,276	46,182	47,105	48,047	49,008	49,989
244,673	264,842	285,415	306,400	312,528	318,778	325,154	331,657	338,290	345,056	351,957	358,996
1,505,713	1,535,828	1,566,544	1,597,875	1,629,832	1,662,429	1,695,678	1,729,591	1,764,183	1,799,467	1,835,456	1,872,165
40,204	41,008	41,828	42,665	43,518	44,388	45,276	46,182	47,105	48,047	49,008	49,989
0	0	0	0	0	0	0	0	0	0	0	0
1,372,679	1,400,133	1,428,136	1,456,698	1,485,832	1,515,549	1,545,860	1,576,777	1,608,313	1,640,479	1,673,288	1,706,754
39,859	40,657	41,470	42,299	43,145	44,008	44,888	45,786	46,702	47,636	48,588	49,560
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
1,609,309	1,641,495	1,674,325	1,707,811	1,741,967	1,776,807	1,812,343	1,848,590	1,885,562	1,923,273	1,961,738	2,000,973
40,204	41,008	41,828	42,665	43,518	44,388	45,276	46,182	47,105	48,047	49,008	49,989
0	0	0	0	0	0	0	0	0	0	0	0
1,047,966	1,068,926	1,090,304	1,112,110	1,134,353	1,157,040	1,180,180	1,203,784	1,227,860	1,252,417	1,277,465	1,303,015

2,192,175	2,236,018	2,280,739	2,326,353	2,372,880	2,420,338	2,468,745	2,518,120	2,568,482	2,619,852	2,672,249	2,725,694
0	0	0	0	0	0	0	0	0	0	0	0
1,395,446	1,423,355	1,451,822	1,480,859	1,510,476	1,540,685	1,571,499	1,602,929	1,634,988	1,667,688	1,701,041	1,735,062
203,869	207,946	212,105	216,347	220,674	225,088	229,589	234,181	238,865	243,642	248,515	253,485
198,010	201,971	206,010	210,130	214,333	218,620	222,992	227,452	232,001	236,641	241,374	246,201
2,335,117	2,381,819	2,429,456	2,478,045	2,527,606	2,578,158	2,629,721	2,682,316	2,735,962	2,790,681	2,846,495	2,903,425
0	0	0	0	0	0	0	0	0	0	0	0
1,465,746	1,495,061	1,524,962	1,555,461	1,586,570	1,618,302	1,650,668	1,683,681	1,717,355	1,751,702	1,786,736	1,822,471
207,384	211,531	215,762	220,077	224,479	228,968	233,548	238,219	242,983	247,843	252,800	257,856
201,525	205,556	209,667	213,860	218,138	222,500	226,950	231,489	236,119	240,842	245,658	250,572
2,802,609	2,858,661	2,915,835	2,974,151	3,033,634	3,094,307	3,156,193	3,219,317	3,283,703	3,349,377	3,416,365	3,484,692
0	0	0	0	0	0	0	0	0	0	0	0
1,912,148	1,950,391	1,989,399	2,029,187	2,069,771	2,111,166	2,153,389	2,196,457	2,240,386	2,285,194	2,330,898	2,377,516
231,989	236,628	241,361	246,188	251,112	256,134	261,257	266,482	271,812	277,248	282,793	288,449
223,787	228,263	232,828	237,484	242,234	247,079	252,020	257,061	262,202	267,446	272,795	278,251
1,104,875	1,126,972	1,149,512	1,172,502	1,195,952	1,219,871	1,244,268	1,269,154	1,294,537	1,320,428	1,346,836	1,373,773
3,892,252	3,970,098	4,049,499	4,130,489	4,213,099	4,297,361	4,383,308	4,470,975	4,560,394	4,651,602	4,744,634	4,839,527
165,204	168,508	171,878	175,316	178,822	182,399	186,047	189,767	193,563	197,434	201,383	205,410
1,504,411	1,534,499	1,565,189	1,596,493	1,628,422	1,660,991	1,694,211	1,728,095	1,762,657	1,797,910	1,833,868	1,870,546
5,048,680	5,149,654	5,252,647	5,357,700	5,464,854	5,574,151	5,685,634	5,799,347	5,915,334	6,033,640	6,154,313	6,277,399
175,749	179,264	182,849	186,506	190,236	194,041	197,922	201,880	205,918	210,036	214,237	218,522

2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
822,137	838,580	855,351	872,458	889,907	907,705	925,860	944,377	963,264	982,530	1,002,180
184,832	188,529	192,299	196,145	200,068	204,069	208,151	212,314	216,560	220,891	225,309
980,399	1,000,007	1,020,007	1,040,407	1,061,215	1,082,440	1,104,088	1,126,170	1,148,694	1,171,668	1,195,101
184,832	188,529	192,299	196,145	200,068	204,069	208,151	212,314	216,560	220,891	225,309
1,436,795	1,465,530	1,494,841	1,524,738	1,555,233	1,586,337	1,618,064	1,650,425	1,683,434	1,717,103	1,751,445
1,775,124	1,810,627	1,846,839	1,883,776	1,921,452	1,959,881	1,999,078	2,039,060	2,079,841	2,121,438	2,163,867
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
2,134,957	2,177,656	2,221,209	2,265,633	2,310,946	2,357,165	2,404,308	2,452,394	2,501,442	2,551,471	2,602,500
138,204	140,968	143,787	146,663	149,596	152,588	155,640	158,753	161,928	165,166	168,470
1,756,186	1,791,310	1,827,136	1,863,678	1,900,952	1,938,971	1,977,751	2,017,306	2,057,652	2,098,805	2,140,781
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
1,700,827	1,734,844	1,769,540	1,804,931	1,841,030	1,877,850	1,915,407	1,953,716	1,992,790	2,032,646	2,073,299
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
-141,916	-144,754	-147,649	-150,602	-153,614	-156,686	-159,820	-163,017	-166,277	-169,602	-172,994
1,946,425	1,985,354	2,025,061	2,065,562	2,106,873	2,149,010	2,191,991	2,235,831	2,280,547	2,326,158	2,372,681
50,988	52,008	53,048	54,109	55,191	56,295	57,421	58,570	59,741	60,936	62,155
366,176	373,499	380,969	388,589	396,361	404,288	412,374	420,621	429,033	437,614	446,366
1,909,608	1,947,801	1,986,757	2,026,492	2,067,022	2,108,362	2,150,529	2,193,540	2,237,411	2,282,159	2,327,802
50,988	52,008	53,048	54,109	55,191	56,295	57,421	58,570	59,741	60,936	62,155
0	0	0	0	0	0	0	0	0	0	0
1,740,889	1,775,707	1,811,221	1,847,446	1,884,395	1,922,083	1,960,524	1,999,735	2,039,729	2,080,524	2,122,134
50,551	51,562	52,594	53,645	54,718	55,813	56,929	58,068	59,229	60,414	61,622
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
2,040,992	2,081,812	2,123,449	2,165,918	2,209,236	2,253,421	2,298,489	2,344,459	2,391,348	2,439,175	2,487,958
50,988	52,008	53,048	54,109	55,191	56,295	57,421	58,570	59,741	60,936	62,155
0	0	0	0	0	0	0	0	0	0	0
1,329,075	1,355,656	1,382,769	1,410,425	1,438,633	1,467,406	1,496,754	1,526,689	1,557,223	1,588,367	1,620,135

2,780,208	2,835,812	2,892,528	2,950,379	3,009,386	3,069,574	3,130,965	3,193,585	3,257,456	3,322,605	3,389,058
0	0	0	0	0	0	0	0	0	0	0
1,769,763	1,805,159	1,841,262	1,878,087	1,915,649	1,953,962	1,993,041	2,032,902	2,073,560	2,115,031	2,157,332
258,555	263,726	269,000	274,380	279,868	285,465	291,175	296,998	302,938	308,997	315,177
251,125	256,148	261,271	266,496	271,826	277,262	282,808	288,464	294,233	300,118	306,120
2,961,493	3,020,723	3,081,137	3,142,760	3,205,615	3,269,728	3,335,122	3,401,825	3,469,861	3,539,258	3,610,044
0	0	0	0	0	0	0	0	0	0	0
1,858,920	1,896,099	1,934,021	1,972,701	2,012,155	2,052,398	2,093,446	2,135,315	2,178,021	2,221,582	2,266,013
263,013	268,273	273,638	279,111	284,693	290,387	296,195	302,119	308,161	314,325	320,611
255,583	260,695	265,909	271,227	276,651	282,184	287,828	293,584	299,456	305,445	311,554
3,554,386	3,625,474	3,697,983	3,771,943	3,847,382	3,924,330	4,002,816	4,082,872	4,164,530	4,247,820	4,332,777
0	0	0	0	0	0	0	0	0	0	0
2,425,066	2,473,567	2,523,039	2,573,500	2,624,970	2,677,469	2,731,018	2,785,639	2,841,352	2,898,179	2,956,142
294,218	300,102	306,104	312,226	318,471	324,840	331,337	337,964	344,723	351,617	358,650
283,816	289,492	295,282	301,188	307,212	313,356	319,623	326,015	332,536	339,186	345,970
1,401,248	1,429,273	1,457,859	1,487,016	1,516,756	1,547,091	1,578,033	1,609,594	1,641,786	1,674,622	1,708,114
4,936,317	5,035,044	5,135,744	5,238,459	5,343,229	5,450,093	5,559,095	5,670,277	5,783,682	5,899,356	6,017,343
209,519	213,709	217,983	222,343	226,790	231,325	235,952	240,671	245,484	250,394	255,402
1,907,956	1,946,116	1,985,038	2,024,739	2,065,233	2,106,538	2,148,669	2,191,642	2,235,475	2,280,185	2,325,788
6,402,947	6,531,006	6,661,626	6,794,859	6,930,756	7,069,371	7,210,759	7,354,974	7,502,073	7,652,115	7,805,157
222,892	227,350	231,897	236,535	241,266	246,091	251,013	256,033	261,154	266,377	271,704

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Station	Unit	Capacity	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
BR	BR1	101	69	164	256	346	434	520	605	689	771	852
BR	BR2	167	114	271	423	571	717	860	1,001	1,139	1,275	1,408
BR	BR3	416	285	675	1,053	1,423	1,786	2,143	2,493	2,838	3,176	3,508
CR	CR4	155	77	204	327	447	564	678	790	899	1,006	1,109
CR	CR5	168	84	221	355	485	611	735	856	975	1,090	1,202
CR	CR6	240	120	316	507	692	873	1,050	1,223	1,392	1,557	1,718
GH	GH1	475	510	1,206	1,884	2,548	3,200	3,843	4,477	5,101	5,717	6,322
GH	GH2	484	520	1,228	1,920	2,596	3,261	3,916	4,562	5,198	5,825	6,442
GH	GH3	480	516	1,218	1,904	2,575	3,234	3,883	4,524	5,155	5,777	6,389
GH	GH4	479	515	1,216	1,900	2,570	3,227	3,875	4,514	5,144	5,765	6,376
GR	GR3	68	39	96	151	205	258	309	360	410	458	506
GR	GR4	95	55	134	211	286	360	432	503	572	640	707
MC	MC1	303	309	767	1,213	1,649	2,077	2,497	2,910	3,315	3,714	4,104
MC	MC2	301	307	762	1,205	1,639	2,063	2,480	2,891	3,294	3,689	4,077
MC	MC3	391	398	989	1,565	2,128	2,680	3,222	3,755	4,278	4,792	5,296
MC	MC4	477	486	1,207	1,910	2,597	3,270	3,931	4,581	5,219	5,846	6,461
TC	TC1	383	115	270	420	567	712	855	996	1,135	1,272	1,407
TC	TC2	549	166	386	602	813	1,021	1,225	1,427	1,626	1,823	2,016
TY	TY3	71	94	233	368	499	628	754	878	999	1,118	1,234

2.50% Capital Escalation Rate

2011 CR	281	454	428	405	384	364	344	325	305	285
2012 CR		288	465	439	415	394	373	353	333	313
2013 CR			295	477	450	426	403	382	362	341
2014 CR				303	489	461	436	413	392	371
2015 CR					310	501	473	447	424	402
2016 CR						318	513	485	459	434
2017 CR							326	526	497	470
2018 CR								334	539	509
2019 CR									342	553

2020 CR										351
2021 CR										
2022 CR										
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2024 CR										
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2036 CR										
2037 CR										
2038 CR										
2039 CR										
2040 CR										
2011 MC	1,499	2,188	2,076	1,972	1,877	1,788	1,703	1,617	1,532	1,447
2012 MC		1,536	2,243	2,128	2,021	1,923	1,833	1,745	1,658	1,570
2013 MC			1,575	2,299	2,181	2,072	1,972	1,878	1,789	1,699
2014 MC				1,614	2,357	2,235	2,124	2,021	1,925	1,834
2015 MC					1,655	2,416	2,291	2,177	2,071	1,974
2016 MC						1,696	2,476	2,348	2,231	2,123
2017 MC							1,738	2,538	2,407	2,287
2018 MC								1,782	2,601	2,467
2019 MC									1,826	2,666
2020 MC										1,872
2021 MC										
2022 MC										
2023 MC										

2024 MC										
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2026 MC										
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2028 MC										
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2035 MC										
2036 MC										
2037 MC										
2038 MC										
2039 MC										
2040 MC										
2011 TC	281	368	350	333	318	304	291	278	264	251
2012 TC		288	377	358	341	326	312	298	284	271
2013 TC			295	387	367	350	334	319	305	292
2014 TC				303	396	376	359	342	327	313
2015 TC					310	406	386	368	351	336
2016 TC						318	416	396	377	360
2017 TC							326	427	405	386
2018 TC								334	437	416
2019 TC									342	448
2020 TC										351
2021 TC										
2022 TC										
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2038 TC										
2039 TC										
2040 TC										
2011 GH	2,061	2,756	2,617	2,492	2,377	2,272	2,171	2,070	1,970	1,869
2012 GH		2,113	2,825	2,683	2,554	2,436	2,328	2,225	2,122	2,019
2013 GH			2,165	2,895	2,750	2,618	2,497	2,387	2,281	2,175
2014 GH				2,219	2,968	2,819	2,683	2,560	2,446	2,338
2015 GH					2,275	3,042	2,889	2,750	2,623	2,507
2016 GH						2,332	3,118	2,961	2,819	2,689
2017 GH							2,390	3,196	3,035	2,889
2018 GH								2,450	3,276	3,111
2019 GH									2,511	3,358
2020 GH										2,574
2021 GH										
2022 GH										
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2038 GH										
2039 GH										
2040 GH										
2011 BR	468	629	595	565	538	513	489	464	440	415
2012 BR		480	645	610	579	551	526	501	476	451
2013 BR			492	661	625	594	565	539	513	488
2014 BR				504	677	641	609	579	552	526
2015 BR					517	694	657	624	594	566
2016 BR						530	712	674	639	608
2017 BR							543	729	690	655
2018 BR								557	748	708
2019 BR									571	766
2020 BR										585
2021 BR										
2022 BR										
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2036	BR									
2037	BR									
2038	BR									
2039	BR									
2040	BR									
2011	GR	94	134	127	120	114	108	103	98	92	87
2012	GR		96	137	130	123	117	111	106	100	95
2013	GR			98	141	133	126	120	114	108	103
2014	GR				101	144	136	129	123	117	111
2015	GR					103	148	140	132	126	120
2016	GR						106	151	143	136	129
2017	GR							109	155	147	139
2018	GR								111	159	150
2019	GR									114	163
2020	GR										117
2021	GR										
2022	GR										
2023	GR										
2024	GR										
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2036	GR										
2037	GR										
2038	GR										
2039	GR										

2040 GR										
2011 TY	94	137	129	122	116	111	105	99	94	88
2012 TY		96	140	132	125	119	113	108	102	96
2013 TY			98	143	136	129	122	116	110	104
2014 TY				101	147	139	132	125	119	113
2015 TY					103	151	143	135	128	122
2016 TY						106	154	146	138	131
2017 TY							109	158	150	142
2018 TY								111	162	153
2019 TY									114	166
2020 TY										117
2021 TY										
2022 TY										
2023 TY										
2024 TY										
2025 TY										
2026 TY										
2027 TY										
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2035 TY										
2036 TY										
2037 TY										
2038 TY										
2039 TY										
2040 TY										

2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
931	1,008	1,085	1,163	1,241	1,320	1,399	1,479	1,560	1,642	1,724	1,807	1,891
1,539	1,667	1,794	1,922	2,052	2,182	2,313	2,446	2,579	2,714	2,850	2,988	3,126
3,834	4,153	4,469	4,789	5,111	5,435	5,762	6,092	6,425	6,761	7,100	7,442	7,787
1,210	1,308	1,405	1,501	1,596	1,691	1,786	1,880	1,974	2,023	2,073	2,125	2,178
1,312	1,418	1,522	1,626	1,730	1,833	1,936	2,038	2,139	2,193	2,247	2,304	2,361
1,874	2,026	2,175	2,324	2,471	2,619	2,765	2,911	3,056	3,132	3,210	3,291	3,373
6,918	7,504	8,080	8,653	9,231	9,814	10,402	10,995	11,594	12,199	12,809	13,425	14,048
7,049	7,646	8,233	8,817	9,405	9,999	10,599	11,204	11,814	12,430	13,052	13,680	14,314
6,991	7,583	8,165	8,744	9,328	9,917	10,511	11,111	11,716	12,327	12,944	13,567	14,196
6,977	7,567	8,148	8,726	9,308	9,896	10,489	11,088	11,692	12,302	12,917	13,538	14,166
553	598	643	689	734	780	825	871	918	964	1,011	1,057	1,104
772	836	899	962	1,026	1,089	1,153	1,217	1,282	1,347	1,412	1,477	1,543
4,487	4,862	5,229	5,592	5,956	6,320	6,686	7,053	7,421	7,790	8,160	8,531	8,903
4,458	4,830	5,194	5,555	5,916	6,279	6,642	7,007	7,372	7,739	8,106	8,475	8,845
5,790	6,274	6,747	7,216	7,685	8,156	8,628	9,102	9,576	10,052	10,530	11,009	11,489
7,064	7,654	8,231	8,803	9,376	9,950	10,526	11,103	11,683	12,263	12,846	13,430	14,016
1,539	1,670	1,799	1,927	2,057	2,188	2,320	2,453	2,588	2,725	2,863	3,002	3,144
2,207	2,394	2,579	2,762	2,948	3,136	3,325	3,517	3,710	3,906	4,104	4,304	4,506
1,347	1,458	1,568	1,677	1,787	1,898	2,008	2,119	2,230	2,341	2,453	2,565	2,678

266	246	231	221	211	200	190	180	169	0	0	0	0
293	272	252	237	226	216	205	195	184	174	0	0	0
321	300	279	259	243	232	221	210	200	189	178	0	0
350	329	307	286	265	249	238	227	216	205	194	182	0
380	358	337	315	293	272	255	244	232	221	210	198	187
412	390	367	345	323	301	279	262	250	238	227	215	203
445	422	399	377	354	331	308	286	268	256	244	232	220
482	456	433	409	386	363	339	316	293	275	263	250	238
522	494	468	444	420	396	372	348	324	300	282	269	257

567	535	506	479	455	430	406	381	357	332	307	289	276
360	581	548	519	491	466	441	416	391	365	340	315	296
	369	595	562	532	504	478	452	426	400	375	349	323
		378	610	576	545	516	490	463	437	410	384	358
			387	625	591	559	529	502	475	448	421	394
				397	641	605	573	542	514	487	459	431
					407	657	621	587	556	527	499	470
						417	673	636	602	570	540	511
							428	690	652	617	584	554
								438	708	668	632	599
									449	725	685	648
										461	743	702
											472	762
												484

1,361	1,276	1,191	1,128	1,089	1,049	1,010	970	931	891	851	812	772
1,483	1,395	1,308	1,221	1,157	1,116	1,075	1,035	994	954	913	873	832
1,610	1,520	1,430	1,341	1,251	1,185	1,144	1,102	1,061	1,019	978	936	895
1,742	1,650	1,558	1,466	1,374	1,282	1,215	1,173	1,130	1,087	1,045	1,002	960
1,879	1,785	1,691	1,597	1,503	1,409	1,314	1,245	1,202	1,158	1,115	1,071	1,027
2,023	1,926	1,830	1,733	1,637	1,540	1,444	1,347	1,277	1,232	1,187	1,142	1,098
2,176	2,073	1,975	1,876	1,777	1,678	1,579	1,480	1,381	1,309	1,263	1,217	1,171
2,344	2,231	2,125	2,024	1,922	1,821	1,720	1,618	1,517	1,415	1,341	1,294	1,247
2,529	2,403	2,286	2,178	2,075	1,971	1,867	1,763	1,659	1,555	1,451	1,375	1,327
2,733	2,592	2,463	2,344	2,233	2,126	2,020	1,913	1,807	1,700	1,594	1,487	1,409
1,919	2,801	2,657	2,524	2,402	2,289	2,180	2,070	1,961	1,852	1,743	1,634	1,524
	1,967	2,871	2,723	2,588	2,462	2,346	2,234	2,122	2,010	1,898	1,786	1,674
		2,016	2,943	2,792	2,652	2,524	2,405	2,290	2,175	2,060	1,946	1,831

			2,066	3,017	2,861	2,719	2,587	2,465	2,347	2,230	2,112	1,994
				2,118	3,092	2,933	2,787	2,651	2,526	2,406	2,285	2,165
					2,171	3,170	3,006	2,856	2,718	2,589	2,466	2,342
						2,225	3,249	3,081	2,928	2,786	2,654	2,528
							2,281	3,330	3,158	3,001	2,855	2,721
								2,338	3,413	3,237	3,076	2,927
									2,396	3,499	3,318	3,153
										2,456	3,586	3,401
											2,518	3,676
												2,580

238	225	211	203	198	193	189	184	179	175	170	165	161
257	244	230	217	208	203	198	193	189	184	179	174	170
278	264	250	236	222	213	208	203	198	193	188	184	179
299	285	270	256	242	228	218	213	208	203	198	193	188
321	306	292	277	263	248	233	224	218	213	208	203	198
344	329	314	299	284	269	254	239	229	224	219	213	208
369	353	337	322	307	291	276	261	245	235	230	224	219
396	378	361	346	330	314	298	283	267	251	241	235	230
426	406	387	370	354	338	322	306	290	274	258	247	241
460	437	416	397	380	363	347	330	314	297	281	264	253
360	471	447	426	407	389	372	355	338	321	305	288	271
	369	483	459	437	417	399	381	364	347	329	312	295
		378	495	470	448	427	409	391	373	355	338	320
			387	507	482	459	438	419	401	383	364	346
				397	520	494	470	449	429	411	392	373
					407	533	506	482	460	440	421	402
						417	546	519	494	472	451	432

							428	560	532	507	484	463
								438	574	545	519	496
									449	588	559	532
										461	603	573
											472	618
												484
1,768	1,667	1,567	1,498	1,460	1,422	1,384	1,346	1,309	1,271	1,233	1,195	1,158
1,916	1,812	1,709	1,606	1,535	1,496	1,458	1,419	1,380	1,341	1,303	1,264	1,225
2,069	1,963	1,858	1,752	1,646	1,573	1,534	1,494	1,454	1,415	1,375	1,335	1,296
2,229	2,121	2,013	1,904	1,796	1,687	1,613	1,572	1,531	1,491	1,450	1,409	1,369
2,396	2,285	2,174	2,063	1,952	1,841	1,729	1,653	1,611	1,570	1,528	1,486	1,445
2,570	2,456	2,342	2,228	2,114	2,001	1,887	1,773	1,694	1,652	1,609	1,566	1,523
2,756	2,634	2,518	2,401	2,284	2,167	2,051	1,934	1,817	1,737	1,693	1,649	1,605
2,962	2,825	2,700	2,581	2,461	2,341	2,221	2,102	1,982	1,862	1,780	1,735	1,690
3,189	3,036	2,896	2,768	2,645	2,522	2,400	2,277	2,154	2,032	1,909	1,825	1,779
3,442	3,269	3,112	2,968	2,837	2,711	2,585	2,460	2,334	2,208	2,082	1,957	1,870
2,638	3,528	3,350	3,189	3,042	2,908	2,779	2,650	2,521	2,392	2,263	2,134	2,006
	2,704	3,616	3,434	3,269	3,119	2,981	2,848	2,716	2,584	2,452	2,320	2,188
		2,772	3,706	3,520	3,351	3,196	3,055	2,920	2,784	2,649	2,513	2,378
			2,841	3,799	3,608	3,435	3,276	3,131	2,993	2,854	2,715	2,576
				2,912	3,894	3,698	3,521	3,358	3,210	3,067	2,925	2,783
					2,985	3,991	3,791	3,609	3,442	3,290	3,144	2,998
						3,060	4,091	3,886	3,699	3,528	3,372	3,223
							3,136	4,193	3,983	3,791	3,617	3,456
								3,214	4,298	4,082	3,886	3,707
									3,295	4,406	4,184	3,983
										3,377	4,516	4,289

												3,462	4,629
													3,548
391	367	350	341	332	323	315	306	297	288	279	271	262	
426	401	376	359	350	341	332	323	313	304	295	286	277	
462	436	411	385	368	358	349	340	331	321	312	303	293	
500	474	447	421	395	377	367	358	348	339	329	320	310	
539	512	485	458	432	405	386	377	367	357	347	338	328	
580	553	525	498	470	442	415	396	386	376	366	356	346	
624	595	567	538	510	482	453	425	406	396	385	375	365	
672	639	610	581	552	523	494	465	436	416	406	395	385	
725	688	655	625	595	566	536	506	476	447	426	416	405	
785	743	706	672	641	610	580	549	519	488	458	437	426	
600	805	762	723	688	657	625	594	563	532	500	469	448	
	615	825	781	741	706	673	641	609	577	545	513	481	
		630	846	801	760	723	690	657	624	591	559	526	
			646	867	821	779	741	707	673	640	606	573	
				662	889	841	798	760	725	690	656	621	
					678	911	862	818	779	743	708	672	
						695	934	884	839	798	761	725	
							713	957	906	860	818	781	
								731	981	928	881	839	
									749	1,005	952	903	
										768	1,031	975	
											787	1,056	
												806	

81	76	72	70	68	65	63	61	58	56	54	52	49
89	83	78	74	72	69	67	65	62	60	58	55	53
97	91	86	80	76	73	71	69	66	64	61	59	57
105	99	94	88	82	78	75	73	70	68	65	63	61
114	108	102	96	90	84	80	77	75	72	70	67	65
123	117	111	104	98	92	86	82	79	77	74	71	69
132	126	120	113	107	101	94	88	84	81	78	76	73
143	135	129	123	116	110	103	97	90	86	83	80	78
154	146	139	132	126	119	112	106	99	93	88	85	82
167	158	150	142	135	129	122	115	108	102	95	90	87
120	171	162	154	146	139	132	125	118	111	104	97	92
	123	176	166	157	150	142	135	128	121	114	107	100
		126	180	170	161	153	146	139	131	124	117	110
			129	184	174	165	157	150	142	135	127	120
				132	189	179	169	161	153	146	138	130
					136	194	183	174	165	157	149	141
						139	199	188	178	169	161	153
							143	204	193	183	173	165
								146	209	197	187	178
									150	214	202	192
										154	219	207
											157	225
												161

83	77	73	71	68	66	63	61	58	56	53	51	48
90	85	79	75	72	70	67	65	62	60	57	55	52
99	93	87	81	77	74	71	69	66	64	61	59	56
107	101	95	89	83	79	76	73	71	68	65	63	60
116	110	104	97	91	85	81	78	75	72	70	67	64
125	119	112	106	100	93	87	83	80	77	74	71	69
135	128	122	115	109	102	96	89	85	82	79	76	73
145	138	131	125	118	111	105	98	92	87	84	81	78
157	149	142	135	128	121	114	107	101	94	89	86	83
171	161	153	145	138	131	124	117	110	103	96	91	88
120	175	165	157	149	141	134	127	120	113	106	99	93
	123	179	169	161	152	145	138	130	123	116	108	101
		126	184	174	165	156	149	141	134	126	119	111
			129	188	178	169	160	152	145	137	129	122
				132	193	182	173	164	156	148	140	133
					136	198	187	177	168	160	152	144
						139	203	192	182	172	164	156
							143	208	196	186	177	168
								146	213	201	191	181
									150	218	206	196
										154	224	212
											157	229
												161

2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046
1,975	2,061	2,147	2,234	2,322	2,411	2,501	2,446	2,340	2,239	2,145	2,055	1,969
3,266	3,407	3,550	3,694	3,839	3,986	4,135	4,045	3,868	3,703	3,546	3,397	3,255
8,136	8,488	8,843	9,202	9,564	9,930	10,300	10,076	9,636	9,223	8,833	8,463	8,109
2,233	2,289	2,346	2,405	2,465	2,526	2,589	2,492	2,292	2,102	1,921	1,747	1,580
2,420	2,481	2,543	2,606	2,671	2,738	2,807	2,701	2,484	2,278	2,082	1,893	1,713
3,457	3,544	3,632	3,723	3,816	3,912	4,009	3,858	3,549	3,255	2,974	2,705	2,447
14,676	15,311	15,953	16,601	17,256	17,918	18,587	18,193	17,419	16,688	15,994	15,334	14,702
14,954	15,601	16,255	16,915	17,583	18,257	18,939	18,537	17,749	17,004	16,297	15,624	14,981
14,831	15,472	16,121	16,775	17,437	18,106	18,782	18,384	17,602	16,863	16,163	15,495	14,857
14,800	15,440	16,087	16,741	17,401	18,069	18,743	18,346	17,565	16,828	16,129	15,463	14,826
1,152	1,199	1,247	1,295	1,343	1,377	1,411	1,364	1,281	1,203	1,128	1,056	988
1,609	1,675	1,742	1,809	1,876	1,923	1,971	1,906	1,790	1,680	1,575	1,476	1,380
9,277	9,651	10,027	10,278	10,535	10,798	11,068	10,698	10,020	9,375	8,758	8,166	7,598
9,216	9,588	9,961	10,210	10,465	10,727	10,995	10,627	9,954	9,313	8,700	8,112	7,548
11,971	12,455	12,940	13,263	13,595	13,934	14,283	13,805	12,931	12,097	11,301	10,538	9,805
14,604	15,194	15,786	16,180	16,585	16,999	17,424	16,841	15,775	14,758	13,787	12,856	11,962
3,286	3,431	3,577	3,725	3,875	4,026	4,180	4,093	3,927	3,771	3,623	3,483	3,349
4,711	4,918	5,127	5,339	5,554	5,771	5,991	5,866	5,629	5,405	5,193	4,992	4,801
2,790	2,904	3,017	3,092	3,170	3,249	3,330	3,217	3,011	2,815	2,629	2,451	2,281

0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
192	0	0	0	0	0	0	0	0	0	0	0	0
208	196	0	0	0	0	0	0	0	0	0	0	0
226	214	201	0	0	0	0	0	0	0	0	0	0
244	232	219	206	0	0	0	0	0	0	0	0	0

263	250	237	224	212	0	0	0	0	0	0	0	0
283	270	256	243	230	217	0	0	0	0	0	0	0
303	290	276	263	249	236	222	0	0	0	0	0	0
331	311	297	283	269	256	242	228	0	0	0	0	0
366	339	319	305	290	276	262	248	234	0	0	0	0
403	376	348	327	312	298	283	268	254	239	0	0	0
442	413	385	357	335	320	305	290	275	260	245	0	0
482	453	424	395	365	343	328	313	297	282	267	252	0
524	494	464	434	404	375	352	336	320	305	289	273	258
568	537	506	476	445	415	384	361	345	329	312	296	280
614	582	551	519	488	456	425	394	370	353	337	320	304
664	629	596	564	532	500	468	436	403	379	362	345	328
720	681	645	611	578	545	512	479	446	414	388	371	354
781	738	698	661	627	593	559	525	491	458	424	398	380
496	800	756	715	677	642	608	573	538	504	469	434	408
	508	820	775	733	694	658	623	587	552	516	481	445
		521	841	794	751	712	675	638	602	566	529	493
			534	862	814	770	730	692	654	617	580	542
				547	884	835	789	748	709	671	633	594
					561	906	855	809	766	727	688	648
						575	928	877	829	786	745	705
733	693	654	0	0	0	0	0	0	0	0	0	0
792	751	711	670	0	0	0	0	0	0	0	0	0
853	811	770	728	687	0	0	0	0	0	0	0	0
917	874	832	789	747	704	0	0	0	0	0	0	0
984	940	896	853	809	765	722	0	0	0	0	0	0
1,053	1,008	963	919	874	829	784	740	0	0	0	0	0
1,125	1,079	1,033	987	942	896	850	804	758	0	0	0	0
1,200	1,153	1,106	1,059	1,012	965	918	871	824	777	0	0	0
1,278	1,230	1,182	1,134	1,086	1,037	989	941	893	845	797	0	0
1,360	1,310	1,261	1,212	1,162	1,113	1,063	1,014	965	915	866	816	0
1,444	1,394	1,343	1,292	1,242	1,191	1,141	1,090	1,039	989	938	887	837
1,562	1,480	1,429	1,377	1,325	1,273	1,221	1,169	1,117	1,065	1,013	962	910
1,716	1,601	1,518	1,464	1,411	1,358	1,305	1,252	1,198	1,145	1,092	1,039	986

1,877	1,759	1,642	1,555	1,501	1,446	1,392	1,337	1,283	1,228	1,174	1,119	1,065
2,044	1,924	1,803	1,683	1,594	1,538	1,483	1,427	1,371	1,315	1,259	1,203	1,147
2,219	2,095	1,972	1,848	1,725	1,634	1,577	1,520	1,462	1,405	1,348	1,290	1,233
2,401	2,274	2,148	2,021	1,894	1,768	1,675	1,616	1,558	1,499	1,440	1,381	1,323
2,591	2,461	2,331	2,201	2,072	1,942	1,812	1,717	1,657	1,597	1,536	1,476	1,416
2,789	2,656	2,522	2,389	2,256	2,123	1,990	1,857	1,760	1,698	1,636	1,575	1,513
3,000	2,858	2,722	2,586	2,449	2,313	2,176	2,040	1,904	1,804	1,741	1,677	1,614
3,232	3,075	2,930	2,790	2,650	2,510	2,371	2,231	2,091	1,951	1,849	1,784	1,719
3,486	3,312	3,152	3,003	2,860	2,716	2,573	2,430	2,287	2,143	2,000	1,895	1,829
3,768	3,573	3,395	3,231	3,078	2,931	2,784	2,637	2,491	2,344	2,197	2,050	1,943
2,645	3,862	3,663	3,480	3,311	3,155	3,004	2,854	2,703	2,553	2,402	2,252	2,101
	2,711	3,958	3,754	3,567	3,394	3,234	3,080	2,925	2,771	2,617	2,462	2,308
		2,779	4,057	3,848	3,656	3,479	3,315	3,157	2,998	2,840	2,682	2,524
			2,848	4,159	3,944	3,748	3,566	3,398	3,236	3,073	2,911	2,749
				2,920	4,263	4,043	3,841	3,655	3,483	3,316	3,150	2,984
					2,993	4,369	4,144	3,937	3,746	3,570	3,399	3,229
						3,067	4,478	4,248	4,036	3,840	3,659	3,484
156	152	147	142	138	133	128	124	119	114	110	105	101
165	160	155	151	146	141	136	132	127	122	117	113	108
174	169	164	159	154	149	145	140	135	130	125	120	115
183	178	173	168	163	158	153	148	143	138	133	128	123
193	188	183	178	172	167	162	157	152	147	142	137	131
203	198	192	187	182	177	171	166	161	156	150	145	140
213	208	203	197	192	187	181	176	170	165	160	154	149
224	219	213	208	202	197	191	186	180	175	169	164	158
235	230	224	219	213	207	202	196	190	185	179	173	168
247	241	236	230	224	218	212	207	201	195	189	183	178
259	253	247	241	236	230	224	218	212	206	200	194	188
277	266	260	254	248	241	235	229	223	217	211	205	199
302	284	272	266	260	254	247	241	235	229	223	216	210
328	310	292	279	273	266	260	254	247	241	234	228	222
355	336	317	299	286	280	273	267	260	253	247	240	234
383	364	345	325	306	293	287	280	273	266	260	253	246
412	392	373	353	334	314	301	294	287	280	273	266	259

442	422	402	382	362	342	322	308	301	294	287	280	273
474	453	433	412	392	371	350	330	316	309	301	294	287
508	486	465	444	423	401	380	359	338	324	316	309	302
546	521	498	476	455	433	411	390	368	347	332	324	317
587	559	534	511	488	466	444	422	400	377	355	340	332
633	602	573	547	523	501	478	455	432	410	387	364	349
496	649	617	588	561	536	513	490	466	443	420	396	373
	508	665	632	602	575	550	526	502	478	454	430	406
		521	682	648	617	589	564	539	515	490	466	441
			534	699	664	633	604	578	553	527	502	477
				547	717	681	648	619	592	566	541	515
					561	735	698	665	634	607	580	554
						575	753	715	681	650	622	595
1,120	1,082	1,044	1,007	969	931	893	856	818	780	742	704	667
1,187	1,148	1,109	1,070	1,032	993	954	916	877	838	800	761	722
1,256	1,216	1,177	1,137	1,097	1,058	1,018	978	939	899	859	819	780
1,328	1,287	1,247	1,206	1,165	1,125	1,084	1,043	1,003	962	921	881	840
1,403	1,361	1,320	1,278	1,236	1,194	1,153	1,111	1,069	1,028	986	944	903
1,481	1,438	1,395	1,353	1,310	1,267	1,224	1,182	1,139	1,096	1,053	1,011	968
1,562	1,518	1,474	1,430	1,386	1,343	1,299	1,255	1,211	1,167	1,124	1,080	1,036
1,645	1,601	1,556	1,511	1,466	1,421	1,376	1,331	1,286	1,241	1,197	1,152	1,107
1,733	1,687	1,641	1,595	1,549	1,503	1,457	1,410	1,364	1,318	1,272	1,226	1,180
1,823	1,776	1,729	1,682	1,634	1,587	1,540	1,493	1,446	1,399	1,351	1,304	1,257
1,917	1,869	1,820	1,772	1,724	1,675	1,627	1,579	1,530	1,482	1,434	1,385	1,337
2,056	1,965	1,915	1,866	1,816	1,767	1,717	1,668	1,618	1,569	1,519	1,469	1,420
2,243	2,107	2,014	1,963	1,912	1,862	1,811	1,760	1,709	1,659	1,608	1,557	1,506
2,437	2,299	2,160	2,064	2,012	1,960	1,908	1,856	1,804	1,752	1,700	1,648	1,596
2,641	2,498	2,356	2,214	2,116	2,063	2,009	1,956	1,903	1,849	1,796	1,742	1,689
2,852	2,707	2,561	2,415	2,269	2,169	2,114	2,060	2,005	1,950	1,895	1,841	1,786
3,073	2,924	2,774	2,625	2,475	2,326	2,223	2,167	2,111	2,055	1,999	1,943	1,887
3,303	3,150	2,997	2,844	2,690	2,537	2,384	2,279	2,221	2,164	2,106	2,049	1,991
3,543	3,386	3,229	3,072	2,915	2,758	2,601	2,444	2,336	2,277	2,218	2,159	2,100
3,800	3,631	3,470	3,310	3,149	2,988	2,827	2,666	2,505	2,394	2,334	2,273	2,213
4,083	3,895	3,722	3,557	3,392	3,227	3,062	2,897	2,732	2,567	2,454	2,392	2,330

4,396	4,185	3,992	3,815	3,646	3,477	3,308	3,139	2,970	2,801	2,632	2,515	2,452
4,744	4,506	4,289	4,092	3,911	3,737	3,564	3,391	3,217	3,044	2,871	2,697	2,578
3,637	4,863	4,619	4,397	4,194	4,008	3,831	3,653	3,475	3,298	3,120	2,942	2,765
	3,728	4,984	4,734	4,507	4,299	4,109	3,927	3,744	3,562	3,380	3,198	3,016
		3,821	5,109	4,852	4,619	4,406	4,211	4,025	3,838	3,651	3,465	3,278
			3,917	5,237	4,974	4,735	4,517	4,317	4,125	3,934	3,743	3,551
				4,014	5,368	5,098	4,853	4,629	4,425	4,228	4,032	3,836
					4,115	5,502	5,226	4,974	4,745	4,535	4,334	4,133
						4,218	5,639	5,356	5,099	4,864	4,649	4,443
253	244	235	226	218	209	200	191	182	173	165	156	147
268	259	250	241	232	223	214	205	196	187	178	169	160
284	275	266	256	247	238	229	219	210	201	191	182	173
301	291	282	272	263	253	244	234	225	215	206	196	187
318	308	299	289	279	269	260	250	240	230	221	211	201
336	326	316	306	296	286	276	266	256	246	236	226	216
355	344	334	324	314	303	293	283	273	263	252	242	232
374	364	353	343	332	322	311	301	290	280	269	259	248
394	383	373	362	351	340	330	319	308	297	287	276	265
415	404	393	382	371	360	349	338	327	316	305	294	283
437	425	414	403	391	380	369	358	346	335	324	312	301
459	448	436	424	413	401	390	378	367	355	343	332	320
493	471	459	447	435	423	411	399	388	376	364	352	340
539	505	482	470	458	446	434	422	409	397	385	373	361
587	552	518	495	482	470	457	445	432	420	407	395	382
637	602	566	531	507	494	481	469	456	443	430	417	405
689	653	617	580	544	520	506	493	480	467	454	441	428
743	706	669	632	595	558	533	519	506	492	479	465	452
800	762	724	686	648	610	572	546	532	518	505	491	477
860	820	781	742	703	664	625	586	559	545	531	517	503
926	881	841	801	761	721	681	641	601	573	559	545	530
1,000	949	903	862	821	780	739	698	657	616	588	573	558
1,083	1,025	973	926	883	841	799	757	715	673	631	603	587
827	1,110	1,050	997	949	905	862	819	776	733	690	647	618
	847	1,138	1,077	1,022	973	928	884	840	795	751	707	663

		868	1,166	1,104	1,048	997	951	906	861	815	770	725
			890	1,195	1,131	1,074	1,022	975	928	882	836	789
				912	1,225	1,160	1,101	1,047	999	952	904	857
					935	1,256	1,189	1,128	1,074	1,024	975	927
						959	1,287	1,218	1,156	1,100	1,050	1,000
47	45	42	40	38	0	0	0	0	0	0	0	0
51	48	46	44	41	39	0	0	0	0	0	0	0
54	52	49	47	45	42	40	0	0	0	0	0	0
58	56	53	51	48	46	43	41	0	0	0	0	0
62	60	57	54	52	49	47	44	42	0	0	0	0
66	64	61	58	56	53	51	48	45	43	0	0	0
70	68	65	63	60	57	55	52	49	47	44	0	0
75	72	70	67	64	61	59	56	53	50	48	45	0
80	77	74	71	68	66	63	60	57	55	52	49	46
84	82	79	76	73	70	67	64	62	59	56	53	50
90	87	84	81	78	75	72	69	66	63	60	57	54
95	92	89	86	83	80	77	74	71	68	65	62	59
102	97	94	91	88	85	82	79	76	72	69	66	63
112	105	100	96	93	90	87	84	81	77	74	71	68
123	115	107	102	99	96	92	89	86	83	79	76	73
134	126	118	110	105	101	98	95	91	88	85	81	78
145	137	129	121	113	107	104	100	97	94	90	87	83
157	149	140	132	124	116	110	106	103	99	96	92	89
169	161	152	144	135	127	119	113	109	105	102	98	95
182	173	165	156	148	139	130	122	115	112	108	104	101
197	187	178	169	160	151	142	133	125	118	115	111	107
212	201	191	182	173	164	155	146	137	128	121	117	114
230	218	206	196	187	177	168	159	150	140	131	124	120
165	236	223	212	201	191	182	172	163	153	144	134	127
	169	242	229	217	206	196	186	177	167	157	147	138
		174	248	235	222	211	201	191	181	171	161	151
			178	254	240	228	217	206	196	186	175	165
				182	261	246	234	222	211	201	190	180
					187	267	253	239	228	217	206	195

						192	274	259	245	233	222	211
46	43	41	0	0	0	0	0	0	0	0	0	0
49	47	44	42	0	0	0	0	0	0	0	0	0
53	51	48	46	43	0	0	0	0	0	0	0	0
57	55	52	49	47	44	0	0	0	0	0	0	0
61	59	56	53	51	48	45	0	0	0	0	0	0
66	63	60	57	55	52	49	46	0	0	0	0	0
70	67	65	62	59	56	53	50	47	0	0	0	0
75	72	69	66	63	60	57	54	52	49	0	0	0
80	77	74	71	68	65	62	59	56	53	50	0	0
85	82	79	76	73	70	66	63	60	57	54	51	0
90	87	84	81	78	74	71	68	65	62	59	55	52
96	93	89	86	83	80	76	73	70	67	63	60	57
104	98	95	92	88	85	82	78	75	72	68	65	62
114	106	101	97	94	90	87	84	80	77	73	70	67
125	117	109	103	100	96	93	89	86	82	79	75	72
136	128	120	112	106	102	99	95	91	88	84	81	77
148	139	131	123	114	108	105	101	97	94	90	86	83
160	151	143	134	126	117	111	107	104	100	96	92	89
172	164	155	146	138	129	120	114	110	106	102	98	95
186	177	168	159	150	141	132	123	117	113	109	105	101
201	190	181	172	163	154	145	135	126	120	116	112	107
217	206	195	186	176	167	158	148	139	129	123	118	114
235	222	211	200	190	181	171	161	152	142	133	126	121
165	241	228	216	205	195	185	175	165	156	146	136	129
	169	247	234	221	210	200	190	180	170	160	149	139
		174	253	239	227	215	205	195	184	174	164	153
			178	259	245	233	221	210	199	189	178	168
				182	266	252	238	226	215	204	194	183
					187	273	258	244	232	221	210	198
						192	279	264	250	238	226	215

2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059
1,867	1,770	1,678	1,591	1,510	1,434	1,361	1,290	1,219	1,149	1,080	1,013	946
3,087	2,926	2,774	2,631	2,496	2,371	2,251	2,132	2,015	1,900	1,787	1,675	1,564
7,689	7,289	6,910	6,553	6,218	5,906	5,607	5,312	5,021	4,733	4,450	4,171	3,897
1,421	1,269	1,125	988	859	738	623	511	402	297	194	95	0
1,540	1,375	1,219	1,071	931	800	675	554	436	322	211	103	0
2,200	1,965	1,741	1,529	1,330	1,143	965	792	623	459	301	148	0
14,098	13,375	12,686	12,033	11,415	10,834	10,291	9,770	9,256	8,749	8,249	7,755	7,269
14,365	13,628	12,927	12,261	11,631	11,039	10,486	9,956	9,432	8,915	8,405	7,902	7,407
14,246	13,516	12,820	12,159	11,535	10,948	10,399	9,873	9,354	8,841	8,336	7,837	7,346
14,217	13,488	12,793	12,134	11,511	10,925	10,378	9,853	9,334	8,823	8,318	7,821	7,331
922	860	801	745	692	643	595	549	504	459	415	373	331
1,288	1,201	1,118	1,040	967	898	832	767	704	641	580	521	462
7,053	6,531	6,033	5,559	5,110	4,687	4,290	3,910	3,538	3,173	2,817	2,468	2,128
7,007	6,488	5,993	5,523	5,077	4,656	4,262	3,884	3,515	3,152	2,798	2,452	2,114
9,102	8,428	7,785	7,174	6,595	6,048	5,536	5,046	4,565	4,095	3,635	3,185	2,746
11,104	10,282	9,498	8,752	8,045	7,379	6,754	6,156	5,570	4,996	4,434	3,886	3,350
3,222	3,101	2,986	2,878	2,777	2,652	2,536	2,425	2,315	2,206	2,099	1,993	1,888
4,618	4,445	4,280	4,125	3,980	3,802	3,636	3,476	3,319	3,163	3,009	2,857	2,706
2,117	1,962	1,814	1,675	1,543	1,420	1,303	1,187	1,074	964	855	749	646
0	0	0	0	0	0	0	0	0	0	0	0	0
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264	0	0	0	0	0	0	0	0	0	0	0	0
287	271	0	0	0	0	0	0	0	0	0	0	0
311	294	278	0	0	0	0	0	0	0	0	0	0
336	319	302	285	0	0	0	0	0	0	0	0	0
363	345	327	309	292	0	0	0	0	0	0	0	0
390	372	353	335	317	299	0	0	0	0	0	0	0
418	400	381	362	344	325	306	0	0	0	0	0	0
456	429	410	390	371	352	333	314	0	0	0	0	0
505	468	439	420	400	381	361	342	322	0	0	0	0
556	518	480	450	430	410	390	370	350	330	0	0	0
609	570	531	492	462	441	421	400	379	359	338	0	0
665	624	584	544	504	473	452	431	410	389	368	347	0
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0	0	0	0	0	0	0	0	0	0	0	0	0
858	0	0	0	0	0	0	0	0	0	0	0	0
932	879	0	0	0	0	0	0	0	0	0	0	0

1,010	956	901	0	0	0	0	0	0	0	0	0	0
1,091	1,035	980	924	0	0	0	0	0	0	0	0	0
1,176	1,119	1,061	1,004	947	0	0	0	0	0	0	0	0
1,264	1,205	1,147	1,088	1,029	970	0	0	0	0	0	0	0
1,356	1,296	1,235	1,175	1,115	1,055	995	0	0	0	0	0	0
1,451	1,390	1,328	1,266	1,205	1,143	1,081	1,020	0	0	0	0	0
1,551	1,488	1,424	1,361	1,298	1,235	1,172	1,108	1,045	0	0	0	0
1,655	1,590	1,525	1,460	1,395	1,330	1,266	1,201	1,136	1,071	0	0	0
1,762	1,696	1,629	1,563	1,497	1,430	1,364	1,297	1,231	1,164	1,098	0	0
1,874	1,806	1,738	1,670	1,602	1,534	1,466	1,398	1,330	1,262	1,194	1,125	0
1,991	1,921	1,852	1,782	1,712	1,642	1,572	1,503	1,433	1,363	1,293	1,223	1,154
2,154	2,041	1,969	1,898	1,826	1,755	1,683	1,612	1,540	1,469	1,397	1,325	1,254
2,366	2,208	2,092	2,019	1,945	1,872	1,799	1,725	1,652	1,579	1,505	1,432	1,359
2,587	2,425	2,263	2,144	2,069	1,994	1,919	1,844	1,768	1,693	1,618	1,543	1,468
2,818	2,652	2,486	2,319	2,198	2,121	2,044	1,967	1,890	1,813	1,736	1,659	1,581
3,059	2,888	2,718	2,548	2,377	2,253	2,174	2,095	2,016	1,937	1,858	1,779	1,700
3,310	3,135	2,961	2,786	2,611	2,437	2,309	2,228	2,147	2,066	1,985	1,904	1,823
96	91	87	82	77	0	0	0	0	0	0	0	0
103	98	94	89	84	79	0	0	0	0	0	0	0
111	106	101	96	91	86	81	0	0	0	0	0	0
118	113	108	103	98	93	88	83	0	0	0	0	0
126	121	116	111	106	101	96	91	85	0	0	0	0
135	130	124	119	114	109	103	98	93	88	0	0	0
144	138	133	127	122	117	111	106	101	95	90	0	0
153	147	142	136	131	125	120	114	109	103	98	92	0
162	156	151	145	139	134	128	123	117	111	106	100	94
172	166	160	155	149	143	137	131	126	120	114	108	102
182	176	170	164	158	152	147	141	135	129	123	117	111
193	187	181	175	168	162	156	150	144	138	132	126	120
204	198	191	185	179	173	166	160	154	148	141	135	129
215	209	203	196	190	183	177	171	164	158	151	145	139
227	221	214	208	201	194	188	181	175	168	162	155	149
240	233	226	219	213	206	199	193	186	179	173	166	159
253	246	239	232	225	218	211	204	197	191	184	177	170

266	259	252	245	238	231	224	217	209	202	195	188	181
280	273	265	258	251	244	236	229	222	215	207	200	193
294	287	279	272	265	257	250	242	235	227	220	213	205
309	302	294	286	279	271	264	256	248	241	233	226	218
325	317	309	301	293	286	278	270	262	255	247	239	231
341	333	325	317	309	301	293	285	277	269	261	253	245
357	349	341	333	325	317	308	300	292	284	276	267	259
382	366	358	350	341	333	324	316	308	299	291	283	274
417	392	376	367	358	350	341	333	324	315	307	298	290
452	427	402	385	376	367	358	350	341	332	323	314	306
489	463	438	412	395	385	376	367	358	349	340	331	322
528	501	475	449	422	404	395	386	377	367	358	349	340
568	541	514	487	460	433	414	405	396	386	377	367	358
629	0	0	0	0	0	0	0	0	0	0	0	0
683	645	0	0	0	0	0	0	0	0	0	0	0
740	700	661	0	0	0	0	0	0	0	0	0	0
799	759	718	677	0	0	0	0	0	0	0	0	0
861	819	778	736	694	0	0	0	0	0	0	0	0
925	882	840	797	754	712	0	0	0	0	0	0	0
992	948	905	861	817	773	729	0	0	0	0	0	0
1,062	1,017	972	927	882	837	792	748	0	0	0	0	0
1,134	1,088	1,042	996	950	904	858	812	766	0	0	0	0
1,210	1,163	1,116	1,068	1,021	974	927	880	833	785	0	0	0
1,289	1,240	1,192	1,143	1,095	1,047	998	950	902	853	805	0	0
1,370	1,321	1,271	1,222	1,172	1,123	1,073	1,023	974	924	875	825	0
1,455	1,405	1,354	1,303	1,252	1,201	1,151	1,100	1,049	998	947	897	846
1,544	1,492	1,440	1,388	1,336	1,283	1,231	1,179	1,127	1,075	1,023	971	919
1,636	1,582	1,529	1,476	1,422	1,369	1,316	1,262	1,209	1,155	1,102	1,049	995
1,731	1,677	1,622	1,567	1,513	1,458	1,403	1,348	1,294	1,239	1,184	1,130	1,075
1,831	1,775	1,719	1,662	1,606	1,550	1,494	1,438	1,382	1,326	1,270	1,214	1,158
1,934	1,876	1,819	1,762	1,704	1,647	1,589	1,532	1,474	1,417	1,359	1,302	1,244
2,041	1,982	1,923	1,864	1,806	1,747	1,688	1,629	1,570	1,511	1,452	1,393	1,334
2,153	2,092	2,032	1,971	1,911	1,851	1,790	1,730	1,670	1,609	1,549	1,488	1,428
2,268	2,206	2,144	2,083	2,021	1,959	1,897	1,835	1,773	1,711	1,649	1,588	1,526

2,388	2,325	2,262	2,198	2,135	2,071	2,008	1,944	1,881	1,818	1,754	1,691	1,627
2,513	2,448	2,383	2,318	2,253	2,188	2,123	2,058	1,993	1,928	1,863	1,798	1,733
2,643	2,576	2,509	2,443	2,376	2,309	2,243	2,176	2,109	2,043	1,976	1,910	1,843
2,834	2,709	2,640	2,572	2,504	2,435	2,367	2,299	2,231	2,162	2,094	2,026	1,957
3,091	2,905	2,776	2,706	2,636	2,566	2,496	2,426	2,356	2,286	2,216	2,146	2,076
3,360	3,169	2,977	2,846	2,774	2,702	2,630	2,559	2,487	2,415	2,343	2,272	2,200
3,640	3,444	3,248	3,052	2,917	2,843	2,770	2,696	2,623	2,549	2,476	2,402	2,328
3,932	3,731	3,530	3,329	3,128	2,990	2,914	2,839	2,764	2,688	2,613	2,537	2,462
4,236	4,030	3,824	3,618	3,412	3,206	3,065	2,987	2,910	2,833	2,755	2,678	2,601
0	0	0	0	0	0	0	0	0	0	0	0	0
151	0	0	0	0	0	0	0	0	0	0	0	0
164	154	0	0	0	0	0	0	0	0	0	0	0
177	168	158	0	0	0	0	0	0	0	0	0	0
191	182	172	162	0	0	0	0	0	0	0	0	0
206	196	186	176	166	0	0	0	0	0	0	0	0
222	211	201	191	181	170	0	0	0	0	0	0	0
238	227	217	206	196	185	175	0	0	0	0	0	0
254	244	233	222	211	201	190	179	0	0	0	0	0
272	261	250	239	228	217	206	195	183	0	0	0	0
290	278	267	256	245	233	222	211	199	188	0	0	0
309	297	285	274	262	251	239	228	216	204	193	0	0
328	316	304	293	281	269	257	245	233	221	209	198	0
349	336	324	312	300	288	276	263	251	239	227	215	203
370	357	345	332	320	307	295	282	270	257	245	233	220
392	379	366	353	341	328	315	302	290	277	264	251	238
415	402	388	375	362	349	336	323	310	297	284	271	257
438	425	412	398	385	371	358	344	331	318	304	291	277
463	449	436	422	408	394	381	367	353	339	326	312	298
489	475	461	447	432	418	404	390	376	362	348	334	320
516	501	487	472	458	443	429	414	400	385	371	356	342
543	529	514	499	484	469	454	440	425	410	395	380	365
572	557	542	527	511	496	481	466	451	435	420	405	390
602	586	571	555	540	524	509	493	477	462	446	431	415
633	617	601	585	569	553	537	521	505	489	473	457	441

680	649	632	616	600	583	567	551	534	518	502	485	469
743	697	665	648	632	615	598	581	564	548	531	514	497
809	762	714	682	664	647	630	613	596	579	561	544	527
878	829	781	732	699	681	663	646	628	611	593	575	558
950	900	850	800	750	716	698	680	662	644	626	608	590
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51	48	0	0	0	0	0	0	0	0	0	0	0
56	53	50	0	0	0	0	0	0	0	0	0	0
60	57	54	51	0	0	0	0	0	0	0	0	0
65	62	59	55	52	0	0	0	0	0	0	0	0
70	66	63	60	57	54	0	0	0	0	0	0	0
75	71	68	65	61	58	55	0	0	0	0	0	0
80	77	73	70	66	63	60	56	0	0	0	0	0
86	82	79	75	72	68	65	61	58	0	0	0	0
91	88	84	81	77	73	70	66	63	59	0	0	0
97	93	90	86	83	79	75	72	68	64	61	0	0
103	100	96	92	88	85	81	77	73	70	66	62	0
110	106	102	98	94	91	87	83	79	75	71	67	64
116	113	109	105	101	97	93	89	85	81	77	73	69
123	119	115	111	107	103	99	95	91	87	83	79	75
131	126	122	118	114	110	106	102	98	93	89	85	81
141	134	130	125	121	117	113	108	104	100	96	91	87
155	145	137	133	129	124	120	115	111	107	102	98	94
169	159	148	141	136	132	127	123	118	114	109	105	101
184	173	163	152	144	140	135	130	126	121	117	112	108

200	189	178	167	156	148	143	138	134	129	124	120	115
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58	55	0	0	0	0	0	0	0	0	0	0	0
63	60	56	0	0	0	0	0	0	0	0	0	0
68	65	61	58	0	0	0	0	0	0	0	0	0
73	70	66	63	59	0	0	0	0	0	0	0	0
79	75	72	68	64	61	0	0	0	0	0	0	0
85	81	77	73	70	66	62	0	0	0	0	0	0
91	87	83	79	75	71	68	64	0	0	0	0	0
97	93	89	85	81	77	73	69	65	0	0	0	0
103	99	95	91	87	83	79	75	71	67	0	0	0
110	106	102	98	94	89	85	81	77	73	69	0	0
117	113	109	104	100	96	92	87	83	79	75	70	0
124	120	116	111	107	103	98	94	90	85	81	76	72
132	128	123	119	114	110	105	101	96	92	87	83	78
143	135	131	126	122	117	112	108	103	99	94	89	85
157	146	139	134	129	125	120	115	111	106	101	96	92
172	161	150	142	137	133	128	123	118	113	108	104	99
187	176	165	154	146	141	136	131	126	121	116	111	106
203	192	180	169	158	149	144	139	134	129	124	119	114

			$000									
Station	Unit	Capacity	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
BR	BR1	101	0	0	0	0	0	441	454	590	616	785
BR	BR2	167	0	0	0	0	0	729	751	975	1,018	1,299
BR	BR3	416	0	0	0	0	0	1,816	1,870	2,430	2,536	3,235
CR	CR4	155	258	840	1,124	1,095	1,216	1,960	1,949	1,644	1,927	2,572
CR	CR5	168	279	910	1,219	1,187	1,318	2,124	2,112	1,782	2,089	2,788
CR	CR6	240	399	1,300	1,741	1,696	1,882	5,221	5,152	4,566	4,899	5,799
GH	GH1	475	0	0	0	0	0	5,620	5,988	6,566	7,371	8,085
GH	GH2	484	0	0	0	0	0	5,727	6,101	6,691	7,510	8,238
GH	GH3	480	0	0	0	0	0	5,680	6,051	6,635	7,448	8,170
GH	GH4	479	0	0	0	0	0	5,668	6,038	6,622	7,433	8,153
GR	GR3	68										
GR	GR4	95										
MC	MC1	303										
MC	MC2	301										
MC	MC3	391										
MC	MC4	477										
TC	TC1	383	0	0	0	0	0	1,965	2,066	2,172	2,216	2,260
TC	TC2	549	0	0	0	0	0	2,817	2,961	3,114	3,176	3,240
TY	TY3	71										

BR Landfill Phase 2 Savings	0	0	0	0	0	0	0	828	908	1,960
BR Landfill Phase 3 Savings	0	0	0	0	0	0	0	0	0	0
BR Landfill O&M Savings	0	0	0	0	0	2,985	3,075	3,167	3,262	3,360
CR Landfill Capital Savings	936	3,049	4,083	3,979	4,416	4,938	4,772	3,579	4,464	6,617
CR Landfill O&M Savings	0	0	0	0	0	2,181	2,307	2,393	2,537	2,726
CR6 Stator Rewind Savings	0	0	0	0	0	2,187	2,135	2,020	1,914	1,816
GH Landfill Capital Savings	0	0	0	0	0	61	188	1,083	2,805	4,044
GH Landfill O&M Savings	0	0	0	0	0	22,633	23,991	25,431	26,957	28,601
TC Landfill Capital Savings	0	0	0	0	0	0	0	0	0	0
TC Landfill O&M Savings	0	0	0	0	0	4,782	5,027	5,286	5,392	5,500

2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
787	789	1,035	1,054	1,357	1,337	1,319	1,301	1,285	1,267	1,122	410	385
1,301	1,305	1,711	1,743	2,245	2,211	2,180	2,151	2,124	2,095	1,855	678	636
3,242	3,252	4,261	4,342	5,591	5,508	5,431	5,359	5,291	5,219	4,620	1,688	1,585
2,560	2,096	2,059	2,073	1,531	1,768	1,810	1,869	1,932	2,000	1,861	1,810	1,778
2,774	2,272	2,232	2,247	1,659	1,916	1,962	2,025	2,094	2,168	2,017	1,962	1,927
5,682	4,867	4,712	4,637	3,700	3,969	3,960	4,000	4,047	4,101	3,833	3,704	3,602
8,761	9,219	9,707	10,790	12,508	14,281	15,439	15,604	16,273	16,860	17,332	17,856	18,548
8,927	9,394	9,891	10,994	12,745	14,551	15,732	15,900	16,581	17,180	17,660	18,195	18,899
8,854	9,316	9,809	10,904	12,640	14,431	15,602	15,769	16,444	17,038	17,514	18,044	18,743
8,835	9,297	9,789	10,881	12,614	14,401	15,569	15,736	16,410	17,002	17,478	18,007	18,704

2,305	2,351	2,398	2,446	2,495	2,545	2,596	2,648	5,363	8,239	8,294	12,354	12,003
3,304	3,371	3,438	3,507	3,577	3,648	3,721	3,796	7,687	11,809	11,888	17,709	17,206

1,870	1,782	1,697	1,613	1,531	1,451	1,372	1,294	1,215	1,123	156	138	120
0	0	1,638	1,745	3,767	3,594	3,426	3,261	3,101	2,943	2,789	2,638	2,487
3,461	3,564	3,671	3,781	3,895	4,012	4,132	4,256	4,384	4,515	4,651		
6,353	4,493	4,170	4,023	1,844	2,496	2,513	2,483	2,455	2,429	1,631	1,345	1,123
2,944	3,121	3,308	3,507	3,717	3,925	4,061	4,305	4,563	4,837	5,128	5,230	5,335
1,719	1,621	1,524	1,427	1,329	1,232	1,158	1,106	1,055	1,004	952	901	850
4,399	4,388	4,387	6,672	11,397	16,206	18,397	18,341	18,358	17,892	16,784	15,709	15,118
30,979	32,838	34,808	36,897	39,110	41,457	43,944	44,668	47,348	50,189	53,201	56,393	59,776
0	0	0	0	0	0	0	0	6,478	13,344	13,344	23,088	22,094
5,610	5,722	5,836	5,953	6,072	6,194	6,318	6,444	6,573	6,704	6,838	6,975	7,115

2034	2035	2036	2037	2038	2039	2040
360	331	54	46	38	30	23
595	547	89	76	63	50	39
1,482	1,363	222	189	157	124	97
1,748	1,719	1,692	1,708	1,727	1,747	1,771
1,895	1,864	1,834	1,851	1,872	1,894	1,919
2,777	2,662	2,620	2,645	2,674	2,705	2,742
19,372	20,254	21,186	21,692	2,492	1,854	1,700
19,739	20,637	21,587	22,103	2,539	1,889	1,733
19,576	20,467	21,409	21,921	2,518	1,874	1,718
19,535	20,424	21,364	21,875	2,513	1,870	1,715
11,666	11,343	11,031	10,731	10,442	10,162	9,886
16,723	16,259	15,812	15,382	14,967	14,567	14,170
101	83	64	46	28	9	0
2,336	2,158	301	265	230	194	159
908	695	485	430	384	338	303
5,441	5,550	5,661	5,774	5,890	6,008	6,128
70	0	0	0	0	0	0
14,860	14,617	14,352	12,126	9,906	7,329	6,705
63,363	67,165	71,194	75,466	155	158	161
21,132	20,199	19,293	18,412	17,554	16,717	15,883
7,257	7,402	7,550	7,701	7,855	8,012	8,172

			$000									
Station	Unit	Capacity	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
BR	BR1	101	0	0	0	553	743	703	668	635	606	577
BR	BR2	167	0	0	0	915	1,228	1,163	1,104	1,050	1,002	954
BR	BR3	416	0	0	0	2,279	3,060	2,897	2,749	2,616	2,496	2,377
CR	CR4	155	0	0	0	980	1,582	1,494	1,413	1,339	1,269	1,201
CR	CR5	168	0	0	0	1,062	1,715	1,619	1,532	1,451	1,376	1,302
CR	CR6	240	0	0	0	1,518	2,449	2,313	2,188	2,073	1,966	1,860
GH	GH1	475	0	0	0	1,462	1,954	1,856	1,767	1,686	1,611	1,540
GH	GH2	484	0	0	0	1,489	1,991	1,891	1,800	1,718	1,642	1,569
GH	GH3	480	0	0	0	1,477	1,975	1,876	1,786	1,703	1,628	1,556
GH	GH4	479	0	0	0	1,474	1,971	1,872	1,782	1,700	1,625	1,553
GR	GR3	68	0	0	0	586	837	792	751	713	679	645
GR	GR4	95	0	0	0	819	1,169	1,106	1,049	996	948	901
MC	MC1	303	0	0	0	1,215	1,774	1,682	1,598	1,521	1,449	1,380
MC	MC2	301	0	0	0	1,207	1,762	1,671	1,588	1,511	1,440	1,371
MC	MC3	391	0	0	0	1,568	2,289	2,171	2,063	1,963	1,870	1,781
MC	MC4	477	0	0	0	1,913	2,792	2,648	2,516	2,394	2,281	2,172
TC	TC1	383	0	0	0	770	1,008	958	912	871	833	797
TC	TC2	549	0	0	0	1,104	1,445	1,373	1,307	1,248	1,194	1,142
TY	TY3	71	0	0	0	586	837	792	751	713	679	645
		BRWATER	0	0	0	3,747	5,032	4,763	4,521	4,302	4,104	3,908
		CRWATER	0	0	0	3,560	5,746	5,427	5,134	4,863	4,611	4,362
		MCWATER	0	0	0	5,902	8,617	8,173	7,765	7,389	7,040	6,704
		TCWATER	0	0	0	1,874	2,453	2,331	2,220	2,119	2,026	1,938
		GHWATER	0	0	0	5,902	7,892	7,495	7,135	6,806	6,505	6,217
		GRWATER	0	0	0	1,405	2,006	1,898	1,799	1,709	1,627	1,546

2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
548	519	491	462	433	413	403	393	382	372	361	351	340
907	859	811	764	716	684	666	649	632	615	597	580	563
2,258	2,140	2,021	1,902	1,784	1,703	1,660	1,617	1,574	1,531	1,488	1,445	1,402
1,132	1,064	996	927	859	806	770	735	699	663	627	591	0
1,227	1,153	1,079	1,005	931	874	835	796	757	718	679	640	0
1,754	1,647	1,541	1,435	1,329	1,249	1,193	1,137	1,082	1,026	970	915	0
1,468	1,397	1,325	1,254	1,183	1,111	1,062	1,035	1,008	982	955	928	901
1,496	1,423	1,350	1,278	1,205	1,132	1,082	1,055	1,028	1,000	973	946	918
1,484	1,411	1,339	1,267	1,195	1,123	1,073	1,046	1,019	992	965	938	911
1,481	1,409	1,337	1,265	1,193	1,121	1,071	1,044	1,017	990	963	936	909
611	577	544	510	476	452	438	423	409	395	380	366	352
854	807	759	712	665	631	611	591	571	551	531	511	491
1,311	1,242	1,173	1,103	1,034	965	915	882	850	818	786	754	722
1,302	1,234	1,165	1,096	1,027	959	908	877	845	813	781	749	717
1,692	1,602	1,513	1,424	1,335	1,245	1,180	1,139	1,097	1,056	1,015	973	932
2,064	1,955	1,846	1,737	1,628	1,519	1,440	1,389	1,339	1,288	1,238	1,187	1,137
760	724	688	652	616	579	555	542	529	517	504	491	479
1,090	1,038	986	934	882	830	795	777	759	741	723	704	686
611	577	544	510	476	452	438	423	409	395	380	366	352

3,713	3,518	3,323	3,128	2,933	2,800	2,729	2,659	2,588	2,517	2,447	2,376	2,305
4,113	3,865	3,616	3,367	3,118	2,929	2,798	2,668	2,537	2,407	2,277	2,146	0
6,368	6,032	5,696	5,361	5,025	4,689	4,443	4,287	4,131	3,976	3,820	3,664	3,508
1,850	1,762	1,674	1,586	1,498	1,410	1,350	1,319	1,288	1,258	1,227	1,196	1,165
5,928	5,640	5,352	5,063	4,775	4,487	4,288	4,180	4,072	3,964	3,856	3,748	3,640
1,465	1,384	1,303	1,222	1,141	1,083	1,049	1,015	980	946	912	877	843

2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046
330	320	309	299	288	278	267	257	247	236	226	215	205
546	528	511	494	477	459	442	425	408	390	373	356	339
1,359	1,316	1,273	1,230	1,187	1,144	1,101	1,058	1,016	973	930	887	844
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
875	848	821	794	767	741	714	687	660	634	607	580	553
891	864	837	809	782	755	727	700	673	646	618	591	564
884	857	830	803	776	748	721	694	667	640	613	586	559
882	855	828	801	774	747	720	693	666	639	612	585	558
337	323	309	294	280	266	251	237	0	0	0	0	0
471	451	431	411	391	371	351	331	0	0	0	0	0
690	658	626	594	562	530	0	0	0	0	0	0	0
686	654	622	590	558	526	0	0	0	0	0	0	0
891	849	808	766	725	684	0	0	0	0	0	0	0
1,086	1,036	986	935	885	834	0	0	0	0	0	0	0
466	453	441	428	415	403	390	377	364	352	339	326	314
668	650	632	613	595	577	559	541	522	504	486	468	450
337	323	309	294	280	266	251	237	0	0	0	0	0

2,235	2,164	2,094	2,023	1,952	1,882	1,811	1,740	1,670	1,599	1,529	1,458	1,387
0	0	0	0	0	0	0	0	0	0	0	0	0
3,353	3,197	3,041	2,886	2,730	2,574	0	0	0	0	0	0	0
1,134	1,103	1,072	1,041	1,010	979	949	918	887	856	825	794	763
3,531	3,423	3,315	3,207	3,099	2,991	2,883	2,774	2,666	2,558	2,450	2,342	2,234
809	774	740	706	671	637	603	568	0	0	0	0	0

2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059
194	184	174	0	0	0	0	0	0	0	0	0	0
321	304	287	0	0	0	0	0	0	0	0	0	0
801	758	715	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
526	500	473	446	0	0	0	0	0	0	0	0	0
536	509	482	454	0	0	0	0	0	0	0	0	0
532	505	478	451	0	0	0	0	0	0	0	0	0
531	504	477	450	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
301	288	276	263	250	237	225	212	0	0	0	0	0
431	413	395	377	359	340	322	304	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
1,317	1,246	1,175	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
732	701	670	640	609	578	547	516	0	0	0	0	0
2,125	2,017	1,909	1,801	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0