BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

AMEREN ENERGY RESOURCES,	)	
	)	
Petitioner,	)	PCB 12-126
	)	(Variance - Air)
v.	)	
	)	
ILLINOIS ENVIRONMENTAL PROTECTION AGENCY,	)	
	)	
	)	
Respondent.	)	

NOTICE OF FILING

To: Attached Service List

PLEASE TAKE NOTICE that I have today electronically filed with the Clerk of the Illinois Pollution Control Board **Comments of Environment Illinois, the Environmental Law & Policy Center, Natural Resources Defense Council, Respiratory Health Association, and Sierra Club**, a copy of which is attached hereto and herewith served upon you.

Respectfully submitted,

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ATTACHMENT 30

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Petitioner,	)	PCB 12-126
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COMMENTS OF ENVIRONMENT ILLINOIS, THE ENVIRONMENTAL LAW & POLICY CENTER, NATURAL RESOURCES DEFENSE COUNCIL, RESPIRATORY HEALTH ASSOCIATION, AND SIERRA CLUB

Pursuant to 35 Ill. Adm. Code 104.224(d), Environment Illinois, the Environmental Law & Policy Center, Natural Resources Defense Council, Respiratory Health Association, and Sierra Club (collectively, "Citizens Groups") submit the following comments on the Petition for Variance ("Petition") filed by Ameren Energy Resources ("AER") with the Illinois Pollution Control Board ("Board") on May 3, 2012. Since filing its Petition, AER has had the opportunity to submit written responses to two sets of questions from the Board and present testimony at the Board's August 1, 2012 public hearing. Nevertheless, AER continues to fall far short of meeting its heavy burden in justifying a variance from Illinois' Multi-Pollutant Standard ("MPS"). Among the defects in AER's proposal:

- AER has refused to commit to a definite compliance plan with the MPS' sulfur dioxide ("SO_2") emission limits, but instead states only that it will complete its Newton flue gas desulfurization ("FGD") project as it deems economic conditions to permit.
- In arguing that the variance is necessary to avoid an arbitrary or unreasonable hardship, AER still has failed to explore all of the options available to it for reducing

its fleet's SO_2 emissions other than the Newton FGD project—including emissions controls it indicates that it will use in the near future to comply with a reinstated Cross-State Air Pollution Rule ("CSAPR").

- Any hardship faced by AER from compliance with the MPS is self-imposed, because AER and its parent company made business decisions to propose, agree to, and opt into the MPS and to operate their generating plants through a deregulated entity instead of keeping them within their regulated distributing company, and benefited handsomely from their decisions for many years.
- AER has not presented an honest appraisal of the environmental impact of its proposed variance, but instead has understated the emissions it would allow and failed to acknowledge the harmful effects those increased emissions would have.

In short, AER has failed to present a sufficient basis for the Board to upset the standard described by the then-Director of the Illinois Environmental Protection Agency ("IEPA") as "one of the most important environmental and public health advances in Illinois in recent decades.[1] The Board should deny AER's Petition. In the alternative, the Board should only grant AER's Petition with strict conditions and on a markedly shorter time frame.

I. AER's Proposed Variance is Illegal Because It Lacks a Definite Compliance Plan.

AER's proposal continues to lack a legally sufficient, definite compliance plan. A central principle of Illinois' variance process is that the purpose of a variance is for temporary, not permanent, relief from a Board regulation. *Monsanto Co. v. IPCB*, 67 Ill. 2d 276, 286 (1977)

[1] *Oversight: Environmental Protection Agency's Clean Air Regulations – One Year after the CAIR and CAMR Federal Court Decisions: Hearing Before the S. Subcomm. On Clean Air and Nuclear Safety of the S. Comm. On Environment and Public Works*, 111th Cong. 2 (2009) (written statement of Douglas P. Scott, Director, Illinois Environmental Protection Agency), *available at* http://epw.senate.gov/public/index.cfm?FuseAction=Files.View&FileStore_id=fc4c5288-525a-47d6-812c-809d000c617b ("Scott Test.") (attached hereto as Ex. 1).

("[T]he concept of a variance which permanently liberates a polluter from the dictates of a board regulation is wholly inconsistent with the purposes of the Environmental Protection Act."); *City of Mendota v. IPCB*, 161 Ill. App. 3d 203, 212-13 (3d Dist. 1987). Thus, to ensure that a proposed variance is not, in effect, permanent relief, a petitioner for a variance must include a "detailed description of the compliance plan." 35 Ill. Adm. Code 104.204(f). To ensure that a proposed variance provides only time for compliance to be achieved, and not permanent relief, the Board should deny a petition that lacks a "definite compliance plan." *Ecko Glaco Corp. v. IEPA*, 186 Ill. App. 3d 141, 150-51 (1st Dist. 1989); *Container Corp. of America v. IEPA*, PCB 87-183 (July 27, 1989). Here, AER's proposed compliance plan is not definite, continues to lack necessary details, and does not ensure that the variance would provide only temporary relief from Board requirements. For those reasons, the Board should deny AER's Petition.

AER's compliance plan is not definite because it is relies on a recovery in electric generation prices, a recovery that AER itself acknowledges is uncertain. If a compliance plan is reliant on market conditions improving and affected facilities returning to profitability, then the compliance plan is not definite, and the variance containing it should be denied. *Container Corp.*, PCB 87-183 (July 27, 1989), at 6. In its Petition, AER argued that completion of its Newton FGD project would be prohibitively uneconomical[2] unless and until power prices rise sufficiently.[3] AER contends that its merchant generation business, unlike a regulated utility, must rely on higher prices and the investor confidence they bring in order to finance significant capital improvements like the Newton scrubbers.[4] At the public hearing, AER witnesses

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[2] *See, e.g.,* Petition at 7 ("AER seeks the variance... because eroding financial conditions make compliance with those requirements untenable.").
[3] *See, e.g.,* Petition at 9 ("Assuming power prices rebound..."); Petition at 21-22 ("unless and until power price market conditions improve . . .").
[4] *See* Petition, Ex. 5, Rygh Aff. at ¶ 11 ("Unlike their regulated utility peers, unregulated power companies do not enjoy the benefits of recovery assurance for prudently incurred costs and investments. Instead, [they] can only turn to the markets to generate margins.").

continued to focus on higher power prices as the key means of one day complying with the MPS SO_2 requirements.[5] According to AER, it will eventually comply with the MPS by constructing and operating scrubbers at its Newton facility. But it will only finish that FGD project if power prices rise and AER can access third-party financing.

In fact, AER itself acknowledges there is little certainty as to if or when power prices might rise sufficiently for completion of the Newton FGD project. Under questioning from the Board and its technical staff, Ameren Services Company's Vice President of Environmental Services, Michael L. Menne, could provide no time frame or assurances as to when power prices might recover:

> Q. In Ameren's response to the July 6, 2012 hearing, question No. 4 regarding conditions for the variance, Ameren indicated, "In the event completion of the FGD system becomes infeasible, AER agrees to advise the Board and the Agency of alternative plans for compliance during the remaining term of the variance." Is there a last possible date at which point AER will know if it will not be able to complete the FGD before the proposed January 15, 2020 compliance date?
>
> A. Well, if I understand what your question is, as far as knowing when we cannot complete the scrubber -- are you talking about ultimately and then for the '20 timeframe?
>
> Q. Yes.
>
> A. No. I can't give you a date because things are just changing so much every year that we don't know what position we will be in going forward. *I mean, our assumption is that markets will recover. We'll be in shape to construct that unit at that time, but beyond that, we really just don't know at this point in time.*[6]

[5] *See* Rygh Test. Tr. 49:10-14 ("This means AER needs time to realize the effects of returning to a more sustainable market economy before it will once again have access to the capital necessary to complete the Newton FGD project."). All citations to the transcript of the Board's August 1, 2012 hearing are referenced as "[Witness] Test. Tr. at [page]:[line]".

[6] Menne Test. Tr. at 37:9-38:8 (emphasis added).

AER's expert financial witness, Gary M. Rygh, could provide no time frame or assurances as to improvement in AER's financial health and, to the contrary, expressed certainty that AER's financial difficulties are unlikely to go away in the years ahead:

> AER and its subsidiaries have been some of the worst performing companies in their sector due to high reliance on coal fired generation and lack of fuel and market diversification. . . . Moody's also said recently *"The ongoing shift in natural gas prices reflects a permanent change across the US energy sector, and will make it more difficult for coal to compete with natural gas as a power source in the future. A rise in gas-fired power generation will not be strong enough to raise natural gas prices on a sustained basis."* - *April 2012.*[7]

Both neutral market analysts and even AER's in-state competitors also have acknowledged an uncertain and weak future for power generation prices. As recently as March 2012, the Standard & Poor's ratings agency predicted that future power prices are at best uncertain and quite possibly will remain low, noting the "prolonged weakness of the power markets" and the "flattening of the forward [price] curve."[8] The Moody's rating agency conditions an improvement in AER's cash flow on a "recovery in power prices, which may not occur."[9] In a news story on this variance, AER's chief merchant generation competitor in downstate Illinois, Dynegy Midwest Generation, even acknowledged that power prices may not recover from their current lows.[10] Given all of this uncertainty over improving power prices and AER's financial health, and the dependence of the compliance plan on these factors, the Board must deny AER's Petition for lack of a definite compliance plan that assures compliance, unless AER can demonstrate that it has a plan through which it will definitely achieve compliance.

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[7] Petition, Ex. 5, Rygh Aff. at ¶ 7. Elsewhere in his Affidavit, Mr. Rygh also stated, "The business conditions for the US unregulated power sector are poor with little expectation for near-term improvement." Id. at ¶ 13.
[8] *Id.* at ¶ 15 (citing Standard & Poor's).
[9] *Id.*
[10] *See* Kari Lydersen, *Ameren wants more time to clean up Illinois emissions*, MIDWEST ENERGY NEWS (Aug. 6, 2012), http://www.midwestenergynews.com/2012/08/06/ameren-wants-more-time-to-clean-up-illinois-emissions/ ("[A Dynegy spokesman] noted that Ameren's variance request 'assumes some future power market recovery to justify the necessary investment' to comply with the state limits in the future, but there is no guarantee that recovery will ever happen.").

AER's reliance on a hoped-for upswing in power prices that may never well occur renders its compliance plan wholly lacking the "detailed" and "definite" description of the compliance plan required by the Board's rules. 35 Ill. Adm. Code 104.204(f). The compliance plan must contain a "time schedule for the implementation of all phases of the control program from initiation of design to program completion." 35 Ill. Adm. Code 104.204(f)(2). Although Ameren at the hearing referenced time frames for ongoing construction activities during the variance period, it failed to provide a time schedule for the most important phases of its FGD construction program.[11] Mr. Menne and the compliance plan promise no more than annual updates on activities, updates that at some uncertain date will become "better defined as we go on."[12] Such a vague time schedule does not meet the legal standard of a "detailed compliance plan" and, thus, the Board must deny the variance.

Other factors cited by AER in support of its variance request may likewise prove permanent features of AER's economic picture, as well, such that any relief granted based on these factors would not be temporary as required by law. *Monsanto Co.*, 67 Ill. 2d at 286. These factors include the age of AER's uncontrolled Illinois power plants and the Ameren Corporation parent company's refusal to support AER. Should these factors not change in the near term—and Ameren can offer no basis to conclude that they will—there is a very real possibility that the Board and Illinois residents could be subjected to a revolving door of variance requests. In fact, just three years ago, AER received a delay to the date it must meet the most stringent SO_2 limits under the MPS.[13] In an argument strongly parallel to the Petition now before the Board, AER's

[11] Menne Test. Tr. at 32:12-33:6.
[12] Tr. at 33:2-6.
[13] *See Ameren Energy Generating Co. et al. v. IEPA*, PCB 09-21 (Oct. 1, 2008) ("2008 Petition for Variance"). Relief was eventually granted through a rulemaking. *See In the Matter of: Proposed Amendments to 35 Ill. Adm. Code 225: Control of Emissions From Large Combustion Sources (Mercury Monitoring)*, R09-10 (June 18, 2009).

2008 Petition likewise noted that emission control investments depend on the trajectory of market prices, which is "highly uncertain due to conditions in the capital and commodity markets."[14] Just a few years later, AER is back in front of the Board, still unable to present a definite and detailed compliance plan. The Citizens Groups are aware of and acknowledge the severity of the economic downturn that hit Illinois and the United States beginning in 2008. But it would frustrate entirely the goals of environmental regulation in Illinois if agreed-to provisions designed to benefit public health could be put on indefinite hold during and after any period of market uncertainty or economic weakness. The Board must deny AER's Petition.

II. AER Has Failed to Prove That Compliance With the MPS Would Impose an Arbitrary or Unreasonable Hardship.

The Illinois Environmental Protection Act ("Act") places the burden on a petitioner to prove that its proposed variance is necessary to avoid an arbitrary or unreasonable hardship. 415 ILCS 5/35, 37. In this case, AER has failed to show any cognizable hardship because it has not explored all feasible alternatives for lowering its SO_2 emissions, and because any hardship AER now faces was self-imposed by AER and the Ameren Corporation's own business decisions to opt into the MPS[15] and to operate their Illinois generating plants through a deregulated entity instead of keeping them within their regulated distributing company.

A. AER Bears a "Heavy" Burden In Demonstrating That Complying With the MPS Would Cause an Arbitrary or Unreasonable Hardship.

The Act provides that the Board may grant a variance when it finds "that compliance with any rule or regulation, requirement or order of the Board would impose an arbitrary or unreasonable hardship." 415 ILCS 5/35(a). In order to determine whether a hardship would be

[14] 2008 Petition for Variance at 10.

[15] For purposes of convenience and readability, we refer to "AER's" participation in the MPS rulemaking proceedings. The official Ameren Corporation affiliates in those proceedings were three AER subsidiaries, Ameren Energy Generating Co., Ameren Energy Resources Generating Co., and Electric Energy Incorporated (which is 80 percent owned by Ameren Energy Generating).

"arbitrary or unreasonable," the Board must balance the extent of the individual hardship against the environmental impact of granting the variance. *Monsanto Co. v. IPCB*, 67 Ill. 2d 276, 292 (1977).

A petitioner for a variance bears a "heavy" burden. *Willowbrook Motel P'ship v. IPCB.*, 135 Ill. App. 3d 343, 349 (1st Dist. 1985). The petitioner must show "that a variance *is necessary* to avoid arbitrary or unreasonable hardship." *Id.* (emphasis added). In doing so, the petitioner must show that all alternatives for compliance with the standard are infeasible. *See Allaert Rendering, Inc. v. IPCB*, 91 Ill. App. 3d 160, 162 (3d Dist. 1980).

Additionally, the Board has discounted an impending hardship when it has been "self-imposed by the petitioner's inactivity or decision making." *Marathon Oil Co v. IEPA*, PCB 94-27 (May 16, 1996), at 10. In *Ekco Glaco v. IEPA*, PCB 87-41 (Dec. 17, 1987), at 4, *aff'd* 186 Ill. App. 3d 141 (1st Dist. 1989), the Board denied a variance because:

> [The petitioner's] problems arise from the delay caused by decisions it has made in attempting to secure compliance and its failure to commit to a particular compliance option. The Board cannot find that those problems constitute an arbitrary or unreasonable hardship, especially when the potential for environmental harm and lack of a firm compliance plan are considered . . . .

The Board concluded: "any hardship in complying with the . . . regulations is largely self-imposed, in that it results from prior business decisions." *Id.* at 6. *See also Willowbrook Motel P'ship*, 135 Ill. App. 3d at 344; *Allaert Rendering*, 91 Ill. App. 3d at 162.

B. AER Has Not Shown a Hardship Because It Has Ignored Feasible Compliance Alternatives.

AER's Petition incorrectly suggests that there are only two options for the company: either obtain a variance or shutter multiple generating stations. *See, e.g.*, Petition at 2 ("Absent such stability and the improvement of power prices, AER will be left with no choice but to cease operations at additional energy centers as its only other viable compliance alternative.").

However, as became clear in AER's responses to Board questions and in testimony at the hearing, AER failed to meaningfully scrutinize other compliance or mitigation options. Before a variance can be granted, these other compliance options need to be fully explored and demonstrated not to be viable alternatives. *Allaert Rendering*, 91 Ill. App. 3d at 162 (upholding Board finding that petitioner had not shown hardship because it had not demonstrated that all compliance alternatives were economically infeasible); *Willowbrook Motel P'ship,* 135 Ill. App. 3d at 349 (variance must be "*necessary* to avoid arbitrary or unreasonable hardship") (emphasis added).

Thus, the variance should be denied due to AER's failure to demonstrate a hardship that cannot be alleviated by a means other than the variance. In the alternative, given the evidence in the record that AER can and will achieve greater levels of SO_2 emissions reductions than the minimal reductions promised to IEPA, it should be required to meet those lower emission levels as a condition of any variance.

1. AER's Scope of Analysis and Criteria for Evaluating Identified Alternative Compliance Strategies Were Improperly Narrow.

Although AER addressed two additional compliance alternatives—curtailing power production at unscrubbed units and use of dry sorbent injection ("DSI")—when pressed to do so by the Board, its evaluation of those alternatives was based on inappropriately narrow criteria.[16] AER looked at these potential compliance strategies in a fashion that was both rigid and piecemeal: each was reviewed only in isolation, and then only to determine whether it would achieve 100% compliance with the MPS. In so doing, AER failed to demonstrate that a *combination* of strategies would not work, or that such a combination of strategies—including

[16] *See* AER's Responses to the Illinois Pollution Control Board Technical Unit's Questions at 2-3 (July 30, 2012) ("First AER Response"); AER's Responses to the Illinois Pollution Control Board Technical Unit's Second Set of Questions at 2 (July 30, 2012) ("Second AER Response").

additional strategies that it failed to evaluate at all, as discussed in subsection 3, *infra*—would not at least bring AER closer to the MPS requirements so as to further reduce emissions during any variance period. Indeed, AER has effectively admitted that it can do better than the limited reductions it has consented to in connection with its variance request, because AER has admitted that it can and will do more when necessary in order to meet CSAPR requirements.[17]

With respect to curtailment of production, AER informed the Board that meeting the MPS solely by curtailing production at the unscrubbed units would require drastic operational reductions, and therefore would be uneconomical.[18] However, this scenario is a straw man. It presents no reason why a lesser level of curtailment of production at the unscrubbed units would be infeasible, or what would happen if such lesser curtailment were effectuated together with other strategies.

Similarly, with respect to DSI, AER failed to investigate the possibility of installing and implementing DSI at a rate short of what is needed to comply with the MPS, and to do so in combination with other methods of emission reduction.[19] It is entirely possible that DSI could be implemented at a rate that would not overburden the existing ESPs, as AER complained,[20] but would still effectuate significant emission reductions.

Thus, AER's meticulously narrow approach to answering the Board's questions failed to assess whether a combination of approaches and methods—including both those specifically addressed by the Board and others known to be available to it, as discussed in subsection 3

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[17] Menne Test. Tr. at 41:19-42:23.
[18] *See, e.g.*, AER First Response at 3 ("*[I]n order to comply with the proposed MPS SO_2 emission rates*, AER would need to lower capacity factors on such units to between 22% and 38%. . . . The result is negative cash flow and an inability to fund ongoing operations. . . . Operation curtailment . . . is simply not a viable compliance alternative.") (emphasis added).
[19] *See, e.g.*, AER Second Response at 2 ("More importantly, *to comply with the MPS via sorbent injection* would entail installation of such controls (and baghouses) at virtually all of AER's uncontrolled units across the system. The cost of such alternative would exceed the cost to complete the Newton Scrubber.") (emphasis added).
[20] See subsection 2, *infra*.

infra—could approach or meet the MPS requirement. AER should be required to conduct a thorough analysis to determine whether a suite of control options—including, *inter alia*, varying degrees of curtailment, varying degrees of DSI implementation, use of ultra low sulfur coal (*see infra*), maximizing/optimizing existing scrubbers, maximizing operations and capacity at units with scrubbers, and/or natural gas conversions (see *infra*)—would obviate AER's purported "hardship," and hence limit the need for a blanket variance. It is possible that using these options together, but more minimally than if each was used alone, would achieve sufficient results.

Indeed, even in the absence of the analysis that AER should have done, it is clear that it could do better than the anemic reduction to 0.35-0.38 lb/mmBtu it has promised to achieve in connection with the variance. The company concedes as much in acknowledging that it can and will do more in the way of SO_2 control to meet CSAPR requirements. Mr. Menne testified:

> Obviously, since we have been struggling to figure out how we would come up with a best way to present to you as an alternative to the MPS, we've also been looking at what else we could possibly do when CSAPR gets reinstated. . . . On the SO_2 side, we will still have to be able to take some additional measures, and we're looking at possibly reducing, bringing in more low sulfur coal or lower sulfur coal. If we have to do some sort of additional sorbent injection, it wouldn't be enough to get us to these MPS rates but we might have to enhance it some.[21]

Further, this admission undercuts AER's claim that there are only two options before the company, either obtain a variance or shutter one or more of its generating stations.[22] As AER openly concedes, there is a third option of doing more than they are doing under the variance, that is, what they suggest they will do to meet CSAPR requirements, but doing it now, pursuant to a variance or the MPS, instead of later under CSAPR.

[21] Menne Test. Tr. at 41:19-42:23.
[22] *See, e.g.*, Petition at 2.

2. AER's Evaluation of the Feasibility of DSI was Inadequate.

As noted above, AER rejected the compliance alternative of DSI. AER's dismissal of DSI[23] is based upon three claims: variable removal rates, overburdening existing electrostatic precipitators ("ESPs"), and cost.[24] Nonetheless, all of these claims are negated by (1) AER's report of DSI pilot testing at its Joppa plant, attached hereto as Exhibit 2; and (2) its earlier commitment to use DSI as documented in Ameren Corporation SEC filings.

Perhaps most informative is AER's actual experience with the DSI test program at Joppa.[25] The two types of sorbent used for the test were Sodium Bicarbonate ("SBC," a product made from Trona) and Trona, the same sorbent that is the focus of Kimberly Gray's comments in this proceeding, attached hereto as Exhibit 3.[26]

First, in terms of variability, AER dismissed the feasibility of DSI, by stating, "AER's evaluation of sorbent injection reflects removal levels of 10 to 90%. Such variability in removal efficiencies reduces the effectiveness of this technology as a compliance alternative."[27] Nonetheless, the Joppa test results indicate that the variability of SO_2 removal was well within control of the operators (or testers, in this case). To be clear, the variability in removal efficiency was a result of the testers varying the testing parameters including type of sorbent, injection location, and injection rate.[28] Otherwise, the removal efficiency remained consistent.[29] Even with these variations, when injection rate was controlled with a goal of 50% SO_2 removal, the removal rate was much more consistent and in the range of 42% to 67%, not the 10% to 90%

[23] In his testimony, AER witness Michael Menne referred to dry sorbent injection as simply "sorbent injection." Menne Test. Tr. at 41:19-42:23.
[24] AER Second Response at 2.
[25] *See* Ex. 2, The Shaw Group, *EEI Joppa Generating Station Dry Sorbent Injection Test Program, Final Report* (Sept. 24, 2010) ("Joppa Report").
[26] *See* Ex. 2 at 6; Ex. 3, Gray Comments at 5-15.
[27] AER Second Response at 2.
[28] Ex. 2, Joppa Report, at 15-28.
[29] *Id.* at 28.

suggested by AER in this proceeding.[30] Further, the Joppa Report identified the exact parameters needed to achieve a 50% SO_2 removal rate: "When using SBC for 50% SO_2 removal, a utilization rate of about 0.12 lbs SO_2 removed per lb of SBC is needed (8.3 tons of SBC/ton of SO_2 removed) with injection after the air heater and a significantly greater utilization rate . . . if injection is before the air heater."[31]

Additionally, AER's claim that variable removal rates preclude the use of sorbent injection is belied by Ameren Corporation's earlier commitments in SEC filings to do sorbent injection to meet MPS requirements:

> To comply with the MPS, Genco and AERG are installing equipment designed to reduce mercury, NO_x, and SO_2 emissions. . . . Currently, Genco's and AERG's compliance strategies and resulting estimated environmental capital expenditures also include precipitator upgrades at Genco's Joppa energy center and the inclusion of a baghouse and *dry sorbent injection SO_2 reduction technology at AERG's E.D. Edwards energy center*. Genco and AERG may also need to install additional, or optimize existing, pollution control equipment to meet new emission reduction requirements under the MPS, CSAPR, or the proposed federal MACT standard as they become effective.[32]
>
> * * *
>
> To comply with the MPS, Genco and AERG are installing equipment designed to reduce mercury, NO_x, and SO_2 emissions. . . . Genco's estimated environmental capital expenditures assume the use of *dry sorbent injection SO_2 reduction technology on all coal-fired units at EEI's Joppa plant*, but Genco is also reviewing other options.[33]

Thus, Ameren Corporation's own SEC filings indicate that DSI is a technologically feasible and financially viable control technology.

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[30] *Id.*; AER Second Response at 2.
[31] Ex. 2, Joppa Report, at 30.
[32] Ameren Corp., Quarterly Report (Form 10-Q) (May 10, 2011) at 42 (emphasis added), available at http://www.sec.gov/Archives/edgar/data/18654/000119312511134059/d10q.htm.

[33] Ameren Corp., Quarterly Report (Form 10-Q) (Aug. 9, 2011) at 48, *available at* http://www.sec.gov/Archives/edgar/data/18654/000119312511216568/d10q.htm.

The conclusion that variable removal rates are not a legitimate concern is further supported by Kimberly Gray's comments. As Ms. Gray indicated, a DSI system's SO_2 removal rate is within the control of the operator:

> DSI systems do not require major capital investment and are very robust and flexible in design. SO_2 reductions in the range of 50-80% can be achieved and reductions of as high as 95% have been documented. *Further, simply by adjusting the dry sorbent feed rate, removal rates can be tuned to changes in operating conditions (i.e., changes in fuels, loads, regulations, etc.).*[34]

Thus, removal rates vary as a result of operator choice—not because of any inherent unreliability in the technology.

Second, in terms of ESPs, AER rejects DSI additionally on the ground that its implementation would require baghouses (also called "fabric filters") at all units. The company asserts, "More importantly, to comply with the MPS via sorbent injection would entail installation of such controls (and baghouses) at virtually all of AER's uncontrolled units across the system."[35] Nevertheless, AER failed to investigate whether DSI would in fact require a baghouse at every unit. Without such a conclusive finding, it is impossible to determine what exactly the costs associated with DSI would be and whether DSI is in fact financially feasible. Once again, the Joppa Report also contradicts AER's claim that DSI would impair its ESPs and require baghouses at every unit. The report compares particulate emissions during baseline with particulate emissions during SBC injection.[36] Contrary to AER's claims regarding impairment, there was an improvement in ESP functioning with the injection of the dry sorbent.[37] The collection efficiency was 98.88% during baseline, but was 99.01% during SBC injection with an

[34] Ex. 3, Gray Comments, at 1 (emphasis added).
[35] AER Second Response at 2.
[36] Ex. 2, Joppa Report, at 31-32.
[37] *Id.* at 31.

increase in efficiency of 0.13%.[38] Perhaps the most significant statement in the whole report is the conclusion that dry sorbent injection did not impact operations of the ESP:

> It should be noted that with the addition of dry sorbent, no impacts on the operation of the ESP or opacity were observed when firing Jacobs Ranch coal. The Opacity and ESP performance (i.e., spark rates, secondary current, etc.) did change with SBC injection when firing the Belle Ayr coal with an increase in opacity of several percent. This increase did not cause the plant any issues with meeting the plant's opacity limits.[39]

This directly refutes AER's testimony that dry sorbent injection overburdens their ESPs.

Furthermore, Ameren Corporation SEC filings contradict AER's claim regarding the sweeping requirement for baghouses and instead suggest that no baghouse is in fact needed to do sorbent injection at Joppa.

> To comply with the MPS, Genco and AERG are installing equipment designed to reduce mercury, NO_x, and SO_2 emissions. . . . Genco's estimated environmental capital expenditures assume the use of *dry sorbent injection SO_2 reduction technology on all coal-fired units at EEI's Joppa plant*, but Genco is also reviewing other options.[40]

The absence of any mention of the capital expenditure needed for a baghouse at Joppa when assuming the use of dry sorbent injection suggests that no such baghouse is needed. This is consistent with the Joppa Report, discussed above, and with current operating experiences with DSI. DSI has in fact been installed at existing plants without requiring a baghouse and simply with upgrades to existing ESPs.[41] Under those circumstances, it has in fact improved ESP performance.[42]

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[38] *Id.*
[39] *Id.* at 32.
[40] Ameren Corp., Quarterly Report (Form 10-Q) at 42 (Aug. 9, 2011), *available at* http://www.sec.gov/Archives/edgar/data/18654/000119312511216568/d10q.htm.

[41] Ex. 3, Gray Comments, at 11 ("Enhancements to ESPs at existing plants appear sufficient to address the addition of a Trona system without the conversion to a fabric filter.").
[42] *Id.* ("With the use of trona, the control efficiency of ESPs improves.").

Finally, AER suggests, without documentation, that the cost of DSI is prohibitive, stating that "[t]he cost of such alternative would exceed the cost to complete the Newton Scrubber."[43] This statement does not give a full and complete picture of the relative costs of DSI and scrubbers. As stated in an Ameren Corporation SEC filing, "[c]apital requirements for some of these technologies, such as dry sorbent injection, would be lower than for scrubbers."[44] Indeed, the fact that AER considered DSI at length over many months, as documented in multiple SEC filings, suggests that it is financially feasible.[45] Ms. Gray likewise noted, "Nonetheless, perhaps the biggest advantage of DSI is lower cost compared to wet FGD with DSI averaging 10-25% of the cost of wet FGD."[46]

Together, the Joppa Report and Ameren Corporation's SEC filings, with the added insights from Ms. Gray's comments, undercut AER's claims of variability and ESP impairment and cost, and demonstrate the viability of this alternative which AER failed to sufficiently investigate. AER's Petition must be denied because it has not demonstrated there are no feasible compliance alternatives.

3. AER Failed to Consider Ultra Low Sulfur Coal and Natural Gas Conversion as Compliance Options

Not only did AER fail to adequately evaluate the compliance options identified by the Board, but it neglected entirely to consider and analyze two additional potential strategies for SO_2 emission reduction: ultra low sulfur coal ("ULSC") and natural gas conversion. Either or both of these, in combination with other strategies, could achieve significant progress toward or compliance with the MPS.

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[43] AER Second Response at 2.
[44] Ameren Corp., Quarterly Report (Form 10-Q) at 42 (Aug. 9, 2011), *available at* http://www.sec.gov/Archives/edgar/data/18654/000119312511216568/d10q.htm.
[45] *See, e.g.*, Ameren Corp., Quarterly Report (Form 10-Q) at 47 (May 10, 2011); Ameren Corp., Quarterly Report (Form 10-Q) at 42 (Aug. 9, 2011).
[46] Ex. 3, Gray Comments, at 3.

With respect to ULSC, Mr. Menne specifically identified lower-sulfur coal as a potential strategy for meeting CSAPR requirements.[47] Indeed, Ameren Corporation already is using that strategy extensively in Missouri—in combination with other strategies—to meet emission requirements. Ameren Missouri announced in 2011 that it would purchase 91 million tons of such coal from Peabody Energy through 2017 as part of a package of strategies to meet federal SO_2 reduction requirements while holding rates down.[48] In making this announcement, Ameren Missouri made clear repeatedly that ULSC was both feasible and economical as part of a larger set of emission reduction strategies. One official stated as follows:

> Buying regular coal, instead of the "ultra low sulfur coal" would have required Ameren to buy more of the expensive emission-fighting technology sooner, Baxter said. In any given year, Ameren typically burns about 20 million to 22 million tons of coal.
>
> "This contract will allow us to avoid significant levels of environmental expenditures by 2014 as well as defer the installation of costly clean air filtration equipment well beyond 2017 to meet the federal government new stringent standards for sulfur dioxide emissions reductions," Baxter said. "This strategy will avoid rate increases that would have been necessary just to meet the SO2 reduction requirements. Those would have been in the range of 15 to 20 percent by 2017 for our customers.[49]

Another Ameren official similarly commented that use of ultra low sulfur coal from Peabody "will help the company minimize its environmental expenditures, defer installation of costly clean air filtration equipment, meet sulfur dioxide emission reductions and avoid rate increases."[50] And Michael Menne, the Ameren Services Company Vice President of

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[47] Menne Test. Tr. at 41:19-42:23.

[48] Press Release, Ameren Missouri, "AER Missouri Announces Proactive, Cost-Effective Environmental Compliance Strategy," (August 4, 2011), *available at* http://ameren.mediaroom.com/index.php?s=43&item=969.

[49] Kelsey Volkmann, *Ameren, Peabody Energy ink their largest coal deal ever*, ST. LOUIS BUS. J., Aug. 4, 2011, *available at* http://www.bizjournals.com/stlouis/news/2011/08/04/ameren-peabody-energy-ink-coal-deal.html?page=all.

[50] "Compliance & Standards Briefing: Ultra-Low Sulfur Coal, Water and LEED, PV and WEEE," *Environmental Leader*, August 9, 2011, *available at* http://www.environmentalleader.com/2011/08/09/compliance-standards-briefing-ultra-low-sulfur-coal-water-and-leed-pv-and-weee/ (last accessed August 8, 2012).

Environmental Services who provided testimony in support of AER's variance petition, commented to the press a few weeks ago, "We believe the measures we've incorporated in our pollution control strategy will comply with all current and new EPA standards . . . These measures include installation of the SO_2 scrubber at our Sioux Energy Center, the use of ultra-low sulfur coal and enhanced particulate and mercury controls at our other energy centers in Missouri."[51]

With respect to natural gas, once again an Ameren affiliate itself acknowledged that natural gas conversion is a possibility. "Electric Energy [Joppa] does produce a small amount of power from natural gas, but [Bill] Sheppard [President of Electric Energy, Inc.] says if . . . prices [of energy from coal power] don't pick up, the company may need to do a major renovation and completely switch over."[52] This suggestion is consistent with the national picture of fuel-switching at existing coal-fired power plants. "Aging fossil stations are gaining new leases on life through gas turbine repowering projects that typically add capacity, lower emissions and increase efficiency."[53] In 2004, when the article was written, more than a dozen coal plants had been repowered in North America and two dozen more were planned. The viability of this option has only increased over recent years as natural gas prices have dropped. For instance, Alliant Energy has undertaken fuel-switching efforts from coal to natural gas.[54] Alliant

> acknowledged that the lure of abundant and cheap natural gas has had an influence over the company's long-term strategy. The domestic gas boom, fueled by the wide-scale expansion of hydraulic fracturing of gas wells, is expected by some

[51] Don Corrigan, *Residents Protest Smokestack Pollution at Regional Meeting*, WEBSTER-KIRKWOOD TIMES, July 6, 2012, http://www.websterkirkwoodtimes.com/Articles-News-i-2012-07-06-181215.114137-Residents-Protest-Smokestack-Pollution-At-Regional-Meeting.html.
[52] Fanna Haile-Selassie and Ben Jeffords. *Electric Energy Inc. Lays Off 44 Employees*, WSIL TV (June 13, 2012), http://www.wsiltv.com/news/local/Electric-Energy-Inc-Lays-Off-44-Employees-158958295.html.
[53] Robert Swanekamp, *Old dog . . . New tricks: Gas turbine repowering rejuvenates aging fossil stations*, POWER ENGINEERING, Oct. 1, 2004, http://www.power-eng.com/articles/print/volume-108/issue-10/features/old-dognew-tricks.html.
[54] Daniel Cusack, *Alliant to build gas-fired plant on site once reserved for coal*, CLIMATEWIRE, Aug. 6, 2012, http://www.eenews.net/climatewire/2012/08/06/5.

> analysts to continue to the end of the decade or longer if there are no major changes in wellhead production or regulations governing the practice . . . . Such forecasts are prompting dozens of utilities, including those once bullish on coal, to reconsider whether to continue investing billions of dollars in pollution controls for coal . . . .[55]

Together, these trends show the viability of this alternative which, again, AER failed to explore. AER's Petition must be denied because it has not demonstrated there are no feasible compliance alternatives.

C. Any Hardship AER Faces is Self-Imposed and Therefore Not Arbitrary or Unreasonable.

As explained above, the Board may only grant a variance when it finds that "compliance with any rule or regulation, requirement or order of the Board would impose an arbitrary or unreasonable hardship." 415 ILCS 5/35(a). The Board has made clear on numerous occasions that a self-imposed hardship is neither arbitrary nor unreasonable, and thus that no variance may be granted where the petitioner's hardship is self-imposed. *See Marathon Oil Co. v. IEPA*, PCB 94-27 (May 16, 1996), at 10-11 (variance denied even if entire refinery had to be shut down because that result "was a hardship Marathon brought on itself"); *Ekco Glaco v. IEPA*, PCB 87-41 (Dec. 17, 1987) (variance denied when petitioner's own business decisions led to noncompliance); *Allaert Rendering, Inc. v. IPCB*, 91 Ill. App. 3d 160, 162 (3d Dist. 1980) (upholding denial of variance when Board found that "any hardship visited upon [the petitioner] is largely self-imposed"). Here, AER's claimed hardships should be discounted for two reasons: i) AER willingly opted into the MPS, and ii) Ameren Corporation chose to operate its generating plants through a deregulated entity instead of keeping them within its regulated Illinois utilities, and benefited handsomely from this business decision for many years.

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[55] *Id.*

1. AER Agreed to, and Benefited From, Its Participation in the MPS.

AER proposed, negotiated, opted into, and benefited from the standards it now seeks to undermine. As a result, any hardship AER may face in complying with the MPS is self-imposed. Because, under enduring Board jurisprudence, a self-imposed hardship is neither arbitrary nor unreasonable, the Board must deny AER's Petition.

a. AER's Claimed Hardships from MPS Compliance Were Foreseeable When It Opted into the MPS, So They Are Not Arbitrary or Unreasonable.

Longstanding Board precedent has established that a self-imposed hardship includes a hardship that is foreseeable at the time a petitioner subjects itself to regulation. *See Willowbrook Motel P'ship v. IPCB*, 135 Ill. App. 343, 345 (1st Dist. 1985) (upholding Board's denial of a variance after Board found that petitioners' acquisition of property near sewage system on restricted status was "a gamble on its ability to obtain permits" to develop that property); *IEPA v. Lindgren Foundry Co.*, PCB 70-1 (Sept. 25, 1970), at 8-13 (hardship self-imposed, and variance denied, when the petitioners purchased foundry with "full knowledge, or with reason to know, that they could not operate the foundry without complying with the air pollution laws or obtaining a variance, and variances have never been a matter of right"). Thus, where the hardship borne by a petitioner is foreseeable at the time a petitioner subjects itself to regulation, that hardship is neither arbitrary nor unreasonable. In such circumstances, a request for variance must be denied. *See Willowbrook Motel P'ship*, 135 Ill. App. at 345; *Lindgren Foundry*, PCB 70-1 (Sept. 25, 1970) at 8-13; *see also Rufo v. Inmates of Suffolk County Jail*, 502 U.S. 367, 385 ("ordinarily. . . modification[s to consent decrees] should not be granted where a party relies upon events that actually were anticipated at the time it entered into a decree").

Likewise, in the present case, AER's Petition must be denied because any hardships AER faces were foreseeable in 2006, 2007, and 2009, when—as both AER and IEPA acknowledge[56]—Ameren proposed, negotiated, re-negotiated, and agreed to subject itself to the MPS. AER now complains that recent modulations in power prices and market conditions, AER's difficulty in obtaining financing, "regulatory uncertainty," the possibility that plants might need to be shut down if the variance is denied, and the MPS' SO_2 limits themselves render compliance with the MPS an arbitrary and unreasonable hardship.[57] Specifically, AER argues that "the impact of a CSAPR stay . . . coupled with the drastic changes in power prices and market conditions in the span of several months preceding this variance request make compliance with the emission rates at issue an arbitrary and unreasonable hardship."[58] AER further the MPS includes SO_2 reduction requirements more stringent than those required by federal law.[59]

AER is wrong as a matter of law. To begin with, "changes in power prices and market conditions" were entirely foreseeable when AER proposed, negotiated, and opted into the MPS in 2006-07. Natural gas prices, for example, have been volatile for many years, and certainly were volatile prior to 2006.[60] Indeed, AER recognized the shifting, unpredictable nature of energy markets and fuel prices long before it agreed to comply with the MPS,[61] and continues to

[56] Petition at 6, 12, and Ex. 4 (Ameren letter opting in to MPS); IEPA Recommendation at 5.
[57] Petition at 10-22.
[58] *Id.* at 15. At the public hearing on this matter, AER elaborated on this argument, claiming that "the MPS . . . was premised on the expectation that the power market would continue to support" the costs of installation of pollution controls. Menne Test. Tr. 19:16-24.
[59] *Id.* at 15-17.
[60] *See Table 6.8 Natural Gas Prices by Sector, Selected Years, 1967-2010*, U.S. ENERGY INFORMATION ADMINISTRATION (2010), *available at* http://www.eia.gov/totalenergy/data/annual/pdf/sec6_19.pdf (last visited Aug. 10, 2012).

[61] *See Ameren Q4 2007 Earnings Call Transcript* (Feb. 14, 2008), *available at*

recognize it today.[62] AER also knew long before proposing the MPS that operating in Illinois' deregulated market, in which electricity generators are "entirely dependent on the power price market,"[63] posed the risk of "lower revenues, reduced profit margins, and increased costs of capital and operations expense."[64]

For instance, AER's witnesses testified at the hearing that the MPS was "premised on the expectation that the power market would continue to support costly installation of pollution control equipment over the schedule of the MPS."[65] This claim is wholly unsupported. Energy forecasts at the time projected near-term *declines* in power prices.[66] In short, when AER made the business decisions to propose, negotiate, re-negotiate, and opt into the MPS, it did so fully aware that energy markets and power prices would vary—possibly in ways detrimental to the

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http://seekingalpha.com/article/64704-AER-corp-q4-2007-earnings-call-transcript?part=single (Statement of Warner L. Baxter, Executive Vice President and Chief Financial Officer, that AER's investor guidance is "subject to....energy market and economic conditions....and other risks and uncertainties...");
Ameren Energy Generating Co., Quarterly Report (Form 10-Q) at 7-8 (Mar. 9, 2005), *available at* http://www.sec.gov/Archives/edgar/data/18651/000100291005000168/amerenform10-k.htm. In the filing, Ameren warns that: "Statements in this report not based on historical facts are considered 'forward-looking' and, accordingly, involve risks and uncertainties that could cause actual results to differ materially from those discussed.... The following factors... could cause actual results to differ materially from management expectations...

- prices for power in the Midwest;
- business and economic conditions, including their impact on interest rates; . . .
- changes in the energy markets, environmental laws or regulations, interest rates, or other factors that could adversely affect assumptions in connection with the CILCORP and IP acquisitions."

[62] *See* Petition, Ex. 5, Rygh Aff., at 2-3 ("AER's gross margin is subject to fluctuations in highly volatile wholesale energy prices..."); Petition, Ex. 6, Martin Aff., at 2-3 ("the revenues and profit margins of AER... are based primarily on dynamic and competitive market-driven commodity prices for, among other things, power and fuel, which can be highly volatile.")
[63] Petition at 12.
[64] AMEREN CORP., AMEREN 2001 ANNUAL REPORT: MANAGEMENT'S DISCUSSION AND ANALYSIS OF FINANCIAL CONDITION AND RESULTS OF OPERATIONS 24 (2002), *available at* http://media.corporate-ir.net/media_files/nys/aee/reports/ar_01/Financials/02MDA.pdf (last visited Aug. 10, 2012).
[65] Menne Test. Tr. at 19:16-24.
[66] U.S. ENERGY INFORMATION ADMINISTRATION, DOE/EIA-0383, ANNUAL ENERGY OUTLOOK 2006: WITH PROJECTIONS TO 2030 4 (2006), *available at* http://www.eia.gov/oiaf/archive/aeo06/pdf/0383(2006).pdf. ("average delivered electricity prices are projected to decline from 7.6 cents per kilowatt hour (2004 dollars) in 2004 to a low of 7.1 cents per kilowatthour in 2015 as a result of declines in natural gas prices and, to a lesser extent, coal prices.").

company—and it did not make compliance with the MPS contingent on a robust power market. AER's hardship is, as such, self-imposed, and is thus neither arbitrary nor unreasonable.

AER's argument that changing prices and market volatility constitute an arbitrary and unreasonable hardship is even more untenable when viewed through the lens of Illinois law on agreements. Illinois courts adjudicating contract disputes have made clear that changes in prices and market conditions are *always foreseeable*, and do not excuse an entity from performance of a contract it has entered into. *See Northern Ill. Gas Co. v. Energy Coop., Inc.*, 122 Ill. App. 3d 940, 952-53 (3d Dist. 1984) (commercial frustration defense to contractual performance does not apply to financial distress resulting from changed natural gas prices); *YPI 180 N. LaSalle Owner, LLC*, 403 Ill. App. 3d 1 (impossibility of performance doctrine does not excuse nonperformance due to financial distress); *see also Bank of America, N.A. v. Shelbourne Development Group, LLC*, No. 09 C 4963, 2011 U.S. Dist. Lexis 21258, *14-15 (N.D. Ill. Mar. 3, 2011). As the court in *Northern Ill. Gas Co.* eloquently explained, "as any trader knows, the only certainty of the market is that prices will change. Changing and shifting markets and prices from multitudinous causes is endemic to the economy in which we live." 122 Ill. App. 3d at 952.

Here, AER's agreement with the State and other parties to enter into and abide by the MPS is the functional equivalent of a contract. As AER acknowledges, the company itself approached IEPA to develop the MPS and chose to opt in to that standard.[67] Moreover, as discussed elsewhere in the following section, AER received significant benefits in return for its agreement to comply with the MPS, which is best evidenced by AER's voluntary business decision to opt in to those standards. Because AER's agreement to comply with the MPS is tantamount to a contract, the Board should act consistently with our courts' decisions in contract cases and hold that changing prices and market conditions are foreseeable and, as such, do not

[67] Petition at 12.

excuse AER from fulfilling its commitment to IEPA and others to meet the MPS' SO_2 emission limits by 2015 and 2017.

AER's argument that "regulatory uncertainty" creates an arbitrary and unreasonable hardship likewise suffers from major flaws. Illinois courts and the Board have made clear that, in general, regulatory instability does not create sufficient hardship to warrant the granting of a variance. *See Citizens Utility Co. v IPCB*, 134 Ill. App. 3d 111, 115 (June 17, 1985) (affirming Board's denial of variance extension because, "[i]f the speculative prospect of future changes in the law were to constitute an arbitrary and unreasonable hardship, then the law itself would be emasculated with variances, as there is always a prospect for future change"); *ExxonMobil Oil Corp v. IEPA*, PCB 11-86; 12-46 (Dec. 1, 2011), at 30 (it is a "generally true proposition" that "regulatory uncertainty cannot support [a] grant of variance.")

The Board recently made clear in its *ExxonMobil* decision that a variance may be granted based, in part, on regulatory uncertainty only in "unique" circumstances where uncertainty is "unprecedented." *Id.* In that case, ExxonMobil sought a variance from requirements obligating it to install NO_x pollution control equipment by 2014, requesting that instead it be permitted to wait until its plant "turnaround" in 2019 to install that equipment. *Id.* at 1. The Board granted the variance on the grounds that, among other things, (i) the state's NO_x control requirements were intended to implement, but not be more stringent than, federal ozone requirements, and the earliest those requirements would need to be attained was 2019; (ii) there was "unprecedented uncertainty" concerning the "status and timing of any tightening of the ozone standard" after President Obama requested in September 2011 that the draft ozone standard issued by EPA be withdrawn, and that the ozone standard be revisited in 2013; and (iii) ExxonMobil would only be required, under federal law, to install and operate the pollution controls at issue if the RACT

program so requires, and "[i]t is unclear what the future ozone standard will be, whether RACT will be required under that standard, and if so, when it will be required to be implemented at sources." *Id.* at 14, 30-31.

Here, any regulatory uncertainty AER faces is not remotely comparable to the unique, unprecedented uncertainty at issue in the *ExxonMobil* proceeding. In fact, it is not clear that there is *any* material uncertainty about the rules AER is or will be subject to. Unlike in *ExxonMobil*, where the state NO_x rule was intended to implement federal law but not go beyond it, the MPS was designed to be more stringent than the federal regulations (CAIR) in place when it was finalized.[68] The obligations AER agreed to were not contingent on federal law remaining the same, and thus any subsequent changes in federal requirements create no uncertainty affecting those obligations.

Mr. Menne acknowledged that CSAPR, or some form of that rule, will go into effect in the next few years, and that AER will need to take measures to comply with it.[69] Unlike in *ExxonMobil*, where it was uncertain that the company would ever be obligated by federal law to make additional NO_x reductions, it is and has been clear to AER that CSAPR is coming soon and that AER will need to reduce its SO_2 to comply with it. Thus, federal regulatory requirements are, in fact, substantially certain.

AER's argument that compliance with the MPS is an arbitrary and unreasonable hardship because the MPS includes SO_2 reduction requirements more stringent than those required by federal law also cannot be credited. As noted above, at the time AER and IEPA agreed to the

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[68] *See In the Matter of Proposed New Ill. Admin. Code 225 Control of Emissions from Large Combustion Sources,* R06-25 (Sept. 20, 2006) (IEPA Post Hearing Comments) (". . . emission reduction requirements for SO_2 in the MPS [are] more stringent than the reductions required under CAIR.").

[69] *See* Menne Test. Tr.40:8-41:23 ("But if you believe that CSAPR is going to come back, *which most people do*, that it will come back into effect in '14 or '15 . . . . we've also been looking at what else we could possibly do *when CSAPR gets reinstated.*") (emphasis added); *see also* Petition at 15 ("AER believes that either CASPR [sic] or a regulatory replacement will be in place before the expiration of the requested variance term.").

MPS, it was clear that the MPS would be more stringent than the CAIR regulations in place at the time. Thus, it was entirely foreseeable that AER would have to make additional SO_2 reductions above those required of generators operating in other states. AER could have made the decision not to opt in to the MPS, knowing that the standard was more stringent than CAIR and did not depend on the continued viability of CAIR, but it did not do so. In short, AER knew full well upon agreeing to the MPS that it would be obligated to comply with those standards regardless of what rules were in place at the federal level. As such, any hardship AER may bear[70] stemming from its duty to comply with the MPS while generators in other states face lesser restrictions was entirely foreseeable and is not, thus, arbitrary or unreasonable. Accordingly, the Board must deny AER's petition.[71]

b. Any Hardship AER Faces From MPS Compliance Is Outweighed By the Benefits AER Gained By Opting Into the Standard.

AER received significant benefits from its negotiated agreement to the MPS obligations. The variance proposal is an unjustified effort to keep hold of those benefits while dispensing with the associated obligations.

[70] AER admits that with CSAPR, "AER may…be competing on a more equal footing in the market place." Petition at 15-16. CSAPR, the replacement for CAIR which AER recognizes will be reinstated (Menne Test. Tr. 40:8-41:23), is more stringent than CAIR—placing generators subject to CSAPR in a position more like that of AER than they were when AER agreed to the MPS.

[71] Finally, the Board should not give credence to AER's claim that, in the absence of a variance, it would have to shut down two or more plants to comply with the MPS. As an initial point, as discussed in Section II.B, *supra*, AER has not met its burden of establishing there are not any other feasible compliance alternatives. But even if shutdowns were necessary for compliance, Board precedent holds that, where a party's hardship is self-imposed—as AER's is here, for all the reasons discussed herein—even a full plant shutdown does not represent an arbitrary and unreasonable hardship warranting a variance. *See Marathon Oil Co.*, PCB 94-27 at 10-11. Here, shutdowns were contemplated by AER at the time it agreed to and opted into the MPS. In fact, the MPS provides for shutdowns to be used as a mechanism to comply with the standard. *See* 35 Ill. Adm. Code 225.233(f)(3) (regarding trade or sale or provisions resulting from over-compliance, "whether such over-compliance results from control equipment, fuel changes, changes in the method of operation, *unit shut downs*, or other reasons.") (emphasis added). As such, shutdowns were both foreseeable and foreseen when the MPS was finalized, and thus do not constitute an arbitrary and unreasonable hardship. AER's request for a variance must, therefore, be denied.

AER expressly acknowledged these substantial benefits in the 2006 rulemaking proceeding that culminated in the MPS. In that proceeding, AER explicitly laid out for the Board the business planning and economic benefits it expected to achieve by agreeing to the MPS. AER's witness Dr. Anne Smith, an expert on the costs and benefits of air emission control in the electric generating sector, testified as follows concerning the benefits to AER:

> The [MPS] provision is more costly, and those added costs are borne by Ameren. However, there would be other important financial and operational benefits to Ameren in making use of the [MPS] provision. The IL Rule, with or without the [MPS], will require Ameren (and the other Illinois generators) to make major new capital investments in control equipment . . . . There are substantial benefits to companies if they can spread the capital investment costs over a longer period of time. (There are perhaps equally important benefits if companies can spread out the associated demands on construction project management . . . .).[72]

Dr. Smith concluded that the bargained-for standard "represents a prudent trade-off for Ameren to make from the perspective of corporate financial stability, corporate management of construction projects (with associated operational stability), and the creation of opportunities to achieve these environmental benefits at lower ultimate total cost."[73] Similarly, Mr. Menne, also serving as Ameren Services Company's Vice President for Environment, Safety, and Health at that time, concluded that the MPS "balances the environmental goal of effective controls across pollutants and, at the same time, supports the goal for industry of a more stable and certain regulatory framework."[74] AER referenced and relied upon Dr. Smith's testimony in its post-hearing comments recommending implementation of the MPS.[75]

Additionally, Douglas P. Scott, then-Director of IEPA, testified before the U.S. Senate Committee on Environment and Public Works, Subcommittee on Clean Air and Nuclear Safety

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[72] *See In the Matter of Proposed New Ill. Admin. Code 225 Control of Emissions from Large Combustion Sources,* R06-25 ("R06-25") (July 28, 2006) (Testimony of Anne Smith), at 10.
[73] *Id.* at 13.
[74] *Id.* (Testimony of Michael Menne), at 6.
[75] R06-26 (Sept. 26, 2006) (Ameren Post-Hearing Comments), at 9.

("EPW"), as follows, concerning the benefits to industry of Illinois' multi-pollutant approach to regulation:

> The Illinois mercury rule provides substantial flexibility in order to reduce the costs of compliance and risk of noncompliance for power plants. This flexibility includes the ability to meet either a 90% reduction or an output based standard of 0.0080 pounds mercury/GWh, phasing in standards over a period of 3 ½ years with a less restrictive standard in phase one, compliance by averaging of emissions, and the avoidance of installing controls on units that will be shutdown in the near future provided companies make an enforceable commitment to shutdown those units by a date certain.
>
> Additional flexibility is provided via a "Temporary Technology Based Standard" (TTBS) that provides relief for units that install appropriate mercury controls but do not achieve full compliance. Eligible units only need to operate the mercury controls in an optimal manner to comply. This provision is available through June 2015 and can be used by up to 25% of a company's generating capacity.
>
> Companies may choose to voluntarily comply with the MPS or CPS as an alternative to the otherwise applicable requirements of the mercury rule. These provisions provide additional flexibility in regards to mercury control in return for companies achieving significant reductions in the emissions of SO_2 and NO_x.[76]

As described by Director Scott, AER and other companies who opted in to the MPS were afforded the substantial benefit of a flexible phased schedule for compliance with mercury requirements, which they would have been required to meet immediately had they not accepted the MPS bargain. Director Scott concluded, "The result has been a tremendous win-win-win for the environment, public health and the regulated community."[77]

In view of the substantial benefit of flexibility reaped by AER and the other Illinois companies who took advantage of the MPS, IEPA strongly emphasized to the Board in 2006 the importance of the "once-in, always in" provision of the MPS regulations—*i.e.*, the requirement that plant units opting into the MPS comply with it for the lifetime of those units. Without such a requirement, IEPA warned, regulated entities could take advantage of the flexibility benefits of

[76] Ex. 1, Scott Test. at 6.
[77] *Id.* at 14.

the rule without the concomitant control requirements for other pollutants. This point was made clear in post-hearing comments submitted by IEPA, and signed by IEPA's present Interim Director, John J. Kim:

> Once a company opts-in to the MPS, it is required to comply with the MPS for the lifetime of the affected units, i.e., the MPS is a "once-in, always-in" provision. This provision is necessary to ensure that Illinois and its citizens continue to receive the benefits of the MPS if a company elects to use this alternative to the otherwise applicable standards of the Illinois mercury rule. *Otherwise a company might elect to opt-in to the MPS, receive the benefits of mercury control flexibility, and then opt-out of the MPS and comply with the otherwise applicable requirements of the proposed mercury rule absent the additional emissions reduction requirements for NO_x and SO_2.*[78]

AER, in requesting a variance from the SO_2 requirements of the MPS after taking advantage of the flexibility it afforded with mercury compliance, is attempting exactly what Interim Director Kim stated clearly six years ago must be prohibited.

2. AER's Hardship is a Self-Imposed Consequence of Accepting the Benefits of Deregulation.

As discussed above, AER is not entitled to a variance if the hardship of which it complains is self-imposed. An essential element of the hardship of which AER complains is the financial burden of deregulation. Deregulation does not constitute a hardship that entitles AER to a variance, however, because AER's predecessor entities sought deregulation, and Ameren Corporation aggressively took advantage of its perceived benefits by choosing to enter into the deregulated market. Any "hardship" from that turn of events is simply the result of a business decision whose benefits and risks AER fully understood. And in the end, the financial burdens of deregulation are outweighed by the many years of benefits that AER received under deregulation.

[78] R06-25 (Sept. 20, 2006) (IEPA Post-Hearing Comments), at 47-48 (emphasis added).

a. AER's Predecessors Sought Deregulation.

At the Board's August 1, 2012 public hearing, the Citizens Groups presented the testimony of Robert Kelter. Mr. Kelter has more than 20 years of experience working on regulatory issues related to energy and electricity. Mr. Kelter was Director of Litigation for Illinois Citizens Utility Board ("CUB"). During Mr. Kelter's tenure at CUB, he represented CUB on legislative issues in Springfield, including drafting of legislation and negotiations to restructure the electric industry ("deregulation") and represented Illinois citizens in electric, gas, and telecommunications cases before the Illinois Commerce Commission. In his testimony, Mr. Kelter summarized the concept of deregulation as follows:

> Under the traditional regulatory framework, utilities built power plants and recovered the costs of the plant and earned a return on the investment. If the plants need updating or repairs, customers paid those costs. However, the traditional structure also meant that customers received all of the benefits from the plants. For example, if a power plant had extra capacity that was not needed to serve the utility customers, then the proceeds of the sale of that power flowed back to the regulated customers—not utility shareholders.[79]

In 1997, Illinois implemented deregulation through the Illinois Electric Service Customer Choice and Rate Relief Law. Ameren Corporation (AER's parent company) (referred to as "Ameren" within this section) both sought this deregulation legislation—through its predecessors—and also benefited immensely from it. Indeed, the deregulation legislation facilitated Ameren's creation, when, in December 1997, CIPSCO Incorporated and Union Electric merged.[80] These predecessor companies that joined to form Ameren both participated in the negotiations that led to deregulation legislation, specifically seeking deregulation.[81]

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[79] Kelter Test. Tr. at 69:8-19.
[80] *See* Ameren Corporate Fact Sheet, *available at* http://www.ameren.com/AboutAmeren/Documents/AmerenCorporateFactSheet.pdf (last visited Aug. 10, 2012).
[81] *See* Ill. Gen. Assemb., H.R., Floor Deb., 90th Assemb. May 30, 1997 at pp. 15-16, *available at* http://www.ilga.gov/house/transcripts/htrans90/t053097.pdf. (CIPSCO and Illinois Power worked out a compromise

Following deregulation, Ameren still had the option of continuing to maintain its generating assets within the distribution company, so as to be entitled to rate recovery. However, Ameren chose to both move its generating assets to a new, unregulated, subsidiary, and also to acquire additional generating assets. On May 1, 2000, it transferred its electric generating assets and liabilities (including its coal plants) at historical net book value, to a newly-created unregulated company, Ameren Energy Generating Company ("AERG"), in exchange for a $600 million promissory note and AERG stock.[82] The assets transferred included the five coal-fired electric generating stations located in Newton, Coffeen, Meredosia, Grand Tower, and Hutsonville, Illinois, along with other assets and liabilities related to the generation of electricity by AmerenCIPS.[83]

As Mr. Kelter explained, Ameren was in no way compelled by the deregulation legislation to effectuate this transfer:

> Section 16-111(g) of the new law allowed, but certainly did not require Ameren to change its structure and spin off the plants to its unregulated affiliate Ameren Generation, stating, "During the mandatory transition period, an electric utility may, without obtaining any approval of the Commission . . . sell, assign, lease or otherwise transfer assets to an affiliated or unaffiliated entity . . . ." 220 ILCS 116-111(g).
>
> The operative word here is "may." In fact, Ameren carefully weighed its options, and decided to take a calculated risk that shareholders would benefit more from moving the plants to an unregulated affiliate, than it would from keeping them with the regulated utility. Otherwise, the move never would have been made.

Kelter Test. Tr. at 69:20-70:11.

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as to how rate relief would be provided.). *See also* Jay Nies, *U.E. Favors Gradual Move to Open Electric Competition*, ST. LOUIS BUS. J., May 18, 1997, http://www.bizjournals.com/stlouis/stories/1997/05/19/focus4.html?page=all, ("Union Electric is part of an Illinois coalition that drafted and supports a bill pending in the Illinois legislature to phase in choice for industrial customers by 2000, and for all customers by 2005.").

[82] Cent. Ill. Pub. Serv. Co., Quarterly Report (Form 10-Q) at 5, 10 (May 15, 2000), *available at* http://www.sec.gov/Archives/edgar/data/18654/0001002910-00-000040.txt.

[83] Cent. Ill. Pub. Serv. Co., Quarterly Report (Form 10-Q) at 2 (May 15, 2001), *available at* http://www.sec.gov/Archives/edgar/data/18654/000001865401500012/cips10q2.txt.

Similarly, Ameren Corporation acquired generating assets after the deregulation legislation was passed. Again, this was at Ameren's own initiative, presumably because Ameren perceived such acquisitions to be financially beneficial to the company. "In 2003, Ameren grew with the acquisition of CILCORP, parent of Central Illinois Light Company, ..."[84] As a part of the purchase of CILCORP, Ameren acquired the E.D. Edwards and Duck Creek generating stations.[85]

Despite seeking the deregulation legislation, Ameren acknowledged the inherent risks of the legislation:

> The provisions of the Law could also result in lower revenues, reduced profit margins and increased costs of capital and operations expense. At this time, the Registrant is unable to determine the impact of the Law on its future financial condition, results of operations or liquidity.[86]

b. Ameren benefitted from deregulation

Even though there are inherent risks in deregulation and Ameren was aware of those risks, Ameren's bet on deregulation paid off extremely well. Ameren's success in the deregulated market was aided by the lack of competition that resulted from massive consolidation of the market into three main generating companies upon initiation of deregulation, including the newly-formed Ameren.[87] The three large generators consisted of Exelon (parent of Commonwealth Edison), Midwest Generation, and Ameren (parent of Illinois Power and CILCO). The Citizens Utility Board ("CUB") pointed out that these few suppliers were in a position to compel "substantial rate increases through their regulated electrical delivery sister

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[84] Ameren Corporate Fact Sheet, http://www.ameren.com/AboutAmeren/Documents/Ameren CorporateFactSheet.pdf (last visited Aug. 10, 2012).
[85] Ameren Corp., Quarterly Report (Form 10-Q) at 52 (Nov. 14, 2003), *available at* http://www.sec.gov/Archives/edgar/data/18651/000100291003000354/amc10-qcomb093003.txt.
[86] Cent. Ill. Pub. Serv. Co., Annual Report (Form 10-K) at 26 (Feb. 11, 1999), *available at* http://www.sec.gov/Archives/edgar/data/18654/0001002910-99-000020.txt.
[87] Mike Kroll, *The Chair Was Pulled Out From Under Cohen*, THE ZEPHYR (Nov. 17, 2005), *available at* http://www.thezephyr.com/cubcohen.htm ("Kroll Article").

companies."[88] Without genuine competition, the generating companies had captive customers at its sister distributing company and could sell its electric supply at higher rates. Again, CUB pointed this out: "'It is essentially Ameren selling to Ameren," [Executive Director of Citizens Utility Board, Dave] Kolata said. "(The auction) was set up to create the illusion of competition without the reality of competition."[89]

Not surprisingly, the deregulated but non-competitive market provided extraordinary profit for the newly-consolidated companies, including Ameren.[90] Since the passage of deregulation, Ameren's investors have received returns far above the S&P 500.[91] CUB quantified these returns to be $2.1 billion more than Ameren investors would have received from investing in other utility companies.[92] As late as 2006, Ameren was still well-positioned to continue to increase its earnings at similar rates. CUB noted that, even if Illinois rates remained at 2006 levels, Ameren's return on equity from its generation business was 28% and still increasing.[93]

As Mr. Kelter testified, "By transferring plants to unregulated affiliates Ameren was able to reap benefits from the plants that it could have never earned under traditional regulation, and customers were subject to market prices when the rate freeze ended. For many years Ameren's decision paid off handsomely."[94] The point of deregulation was to allow utilities to compete within the free market—with the lack of actual competition being an additional benefit. The free market has both risks and rewards, and Ameren should not be allowed to reap the rewards while

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[88] *Id.*
[89] *Ameren customers in Illinois brace for a rate hike*, ST. LOUIS POST-DISPATCH (Sep. 16, 2006), *available at* http://www.citizensutilityboard.org/pdfs/CUBInTheNews/20060915_STPD_AERRateHike.pdf.
[90] Kroll Article ("[T]he parent companies of these utilities experienced record profits during this period.").
[91] *See* Citizens Utility Board, *Ameren Corporation's Performance Under the Illinois Electric Service Customer Choice and Rate Relief Law of 1997* (Feb. 2006) ("CUB Report") (attached hereto as Ex. 4).
[92] *Id.*
[93] *Id.*
[94] Kelter Test. Tr. at 71:1-6.

dodging the risks. Mr. Kelter correctly observed, "Market prices go up and they go down. Nowhere in the Petition does Ameren give any kind of balanced view of the profits and losses the plants have generated over the last decade."[95]

Ameren would have us believe that the point of deregulation was to allow utilities to earn unlimited returns while still placing the burden of the risk squarely on the taxpayers. Nonetheless, Ameren chose to transfer their plants to the unregulated side of their business, and for many years Ameren shareholders benefitted from this transaction. Ameren wanted the benefits of the power plants being under the control of AER when market prices were high, environmental controls were minimal, and they were generating big profits but does not want to bear the associated risk. "Traditional regulations shielded Ameren from this type of risk, and the Company chose to give up that protection."[96]

In summary, any hardship that AER now faces in operating as part of a deregulated market was self-imposed, and counter-balanced by the substantial benefits afforded to it over many years. AER's Petition, therefore, must be denied because AER has not and cannot demonstrate that deregulation is a hardship of the type that entitles them to a variance.

3. AER's Hardship is a Self-Imposed Consequence Resulting From Its Business Decisions Made After Deregulation.

AER has claimed that it cannot obtain financing for the pollution controls at Newton from its parent corporation, Ameren Corporation.[97] (As discussed *supra*, these entities were separated from each other and created as a result of the deregulation legislation.) However, the inability of the generating company to access financing from the parent corporation is a self-imposed hardship.

[95] Kelter Test. Tr. at 72:19-22.
[96] Kelter Test. Tr. at 73:17-19.
[97] Petition at 22.

AER has not demonstrated that it *cannot* obtain financing from its parent, but rather that the parent *does not want to* provide financing. Notwithstanding the implication in the Petition that funding from Ameren Corporation is *per se* impossible[98], Ameren Corporation's statements elsewhere more plausibly indicate that it could in principle finance its subsidiary, but has chosen not to for business reasons.

As stated during an Ameren Corporation quarterly earnings call,

> Q: And just a follow-up on an earlier question, I guess the cash flow question on the Merchant segment, a lot of things can change going forward but is it in your tool box to use any cash from the corporate segment to fund any shortfalls at the Merchant segment, is that part of the potential equation?
>
> A: Yeah, I mean it's in the toolbox. It's something that we could use to do. But as we've said repeatedly *our goal is for the Merchant segment and for Genco to work to provide for their own cash need.* So that remains our focus.[99]

Ameren Corporation made similar statements in a recent SEC filing: "The Merchant Generation segment and Genco *seek to* fund their operations internally and therefore seek not to rely on financing from Ameren or external, third-party sources."[100] Finally, AER's own finance expert provided similar quotes from credit agencies in his affidavit:

> the reduction of environmental capital spending also suggests management's lack of confidence in the longer-term economic sustainability of GenCo's business model. This reinforces our view that Ameren's support for GenCo is limited and that it expects GenCo to cover its cash needs as a stand-alone business even over the short term. (S&P March 2012).[101]

These statements taken together make it clear that it is the *preference* of Ameren Corporation not to not provide financing to AER, not that there is any inherent *prohibition* on such financing.

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[98] Petition at 22-23.
[99] Ameren Corp., Q4 2011 Earnings Call (Feb. 23, 2012 10:00 AM ET), (transcript available at http://seekingalpha.com/article/388891-AER-s-ceo-discusses-q4-2011-results-earnings-call-transcript?part=single) (emphasis added). The question was asked by Reza Hitucki, of Decade Capital, and answered by Martin Lyons, SVP and CFO of AER Corporation.
[100] Ameren Corp., Quarterly Report (Form 10-Q) at 56 (May 10, 2012) (emphasis added), *available at* http://www.sec.gov/Archives/edgar/data/18654/000119312512224293/d328507d10q.htm.
[101] Petition, Ex. 5, Rygh Aff. at 10.

The preference of Ameren Corporation is a self-imposed hardship that, once again, does not rise to the level of the necessary demonstration of hardship that entitles a petitioner to a variance.

In this regard, AER has made other business decisions over the years—most notably the almost complete reliance on coal that it has now come to regret—that have contributed to the creation of the "hardship" of which it now complains. Ameren's own witness so conceded in stating, "AER and its subsidiaries have been some of the worst performing companies in their sector *due to high reliance on coal fired generation and lack of fuel and market diversification.*"[102] The Ameren entities are not entitled under the law to label the consequences of their business decisions and misjudgments over the years a "hardship" and expect the Board to bail them out.

III. AER's Proposed Variance Would Injure Public Health and the Environment by Allowing AER to Emit Significantly More Harmful SO_2.

The Board also must deny AER's Petition because AER has failed to present an honest appraisal of its proposed variance's negative environmental impact. AER contends that the variance would allow *less* SO_2 emissions than the MPS, mainly due to "offsetting" emission reductions AER claims because of its shutdown of the Meredosia and Hutsonville Energy Centers at the end of 2011. AER argues in this proceeding that these reductions should be recognized as a benefit of the variance, because AER would voluntarily commit not to operate the plants during the variance's term.[103] Elsewhere, though, AER has acknowledged that the shutdowns already are part of AER's compliance plan for *the MPS itself.*[104] Therefore, any

[102] Petitioner, Ex. 5, Rygh Aff. ¶ 7.
[103] AER contends: "The Hutsonville and Meredosia Energy Centers are fully permitted and AER may lawfully reopen them. However . . . AER would agree not to operate the facilities during the pendency of the variance period as a condition of the relief granted." Second AER Response at 7.
[104] *See* Ameren Corp., Quarterly Report (Form 10-Q) at 50 (Nov. 8, 2011), *available at* http://www.sec.gov/Archives/edgar/data/18654/000119312511302027/d238905d10q.htm (stating that AER's compliance plan with the MPS "includes the closure of the Meredosia and Hutsonville energy centers at the end of December 2011.").

emission reductions resulting from the shutdowns are not in excess of AER's MPS responsibilities, but rather a direct result of them, and will occur whether or not this variance is granted.

Properly evaluated, the proposed variance would permit AER's fleet to emit much more harmful SO_2—over 32,000 tons more for the period of 2012 to 2019, over 87,000 tons more for 2015 to 2019 alone, and over 15,000 tons more annually for each year between 2015 and 2019. (*See* Table 1, *infra*.) AER has refused to address the negative public health impacts of these excess emissions, and therefore failed to meet its burden to justify its proposed variance.

A. AER Is Required to Present Evidence of Both the Amount of Emissions That Would Be Allowed Under Its Proposed Variance, As Well As the Environmental Impact Those Emissions Would Have.

In evaluating whether AER's proposed variance is necessary to avoid an "arbitrary or unreasonable hardship," 415 ILCS 5/35, the Board must balance individual hardship against environmental impact. *Monsanto Co. v. IPCB*, 67 Ill. 2d 276, 292 (1977). AER bears the burden of demonstrating that "the hardship resulting from a denial of the variance outweighs any injury to the public or the environment from a grant of the variance." *Marathon Oil Co. v. IEPA*, 242 Ill. App. 3d 200, 206 (5th Dist. 1993).

The Board's regulations require a petitioner for a variance to submit two types of evidence regarding the variance's environmental impact. First, the petitioner must describe "the nature and amount of emissions, discharges, or releases of the constituent in question if the variance is granted, compared to those that would result if immediate compliance were required." 35 Ill. Adm. Code 104.204(g)(1). Second, the petitioner must include a "qualitative and quantitative description of the impact of petitioner's activity on human health and the

environment if the requested variance is granted, compared to the impact of petitioner's activity if immediate compliance is required." 35 Ill. Adm. Code 104.204(g)(2).

A petitioner fails to meet its burden to show an arbitrary or unreasonable hardship if it fails to present evidence of the variance's environmental impact. *City of Mendota v. IPCB*, 161 Ill. App. 3d 203, 209 (3d Dist. 1987). Conclusory assertions, unsupported by data and analysis, are not sufficient to meet a petitioner's burden of proof. *IEPA v. IPCB*, 95 Ill. App. 3d 400, 405-06 (3d Dist. 1981); *City of Mendota*, 161 Ill. App. 3d at 208; *Plexus Scientific Corp. v. IEPA*, PCB 01-120 (Apr. 5, 2001), at 3.

B. AER Significantly Understates the Amount of SO_2 Emissions That Would Be Allowed By its Proposed Variance.

AER's Petition should be denied because AER has failed to present credible evidence regarding either the amount of excess SO_s emissions that would be allowed under its proposed variance, 35 Ill. Adm. Code 104.204(g)(1), or the environmental impacts of those emissions. 35 Ill. Adm. Code 104.204(g)(2). Instead, AER's description of the variance's environmental impact rests entirely on a false premise: that the overall SO_2 emissions from AER's fleet would be lower under the variance than under the current MPS.[105]

Table 1, *infra*, demonstrates why AER's claim is false. The table compares the emissions that would be allowed from the beginning of the variance in 2012 through the end of the variance in 2020, using a consistent heat input for the emission rates of the MPS and the proposed variance. This is precisely the analysis requested by the questions posed in the Hearing Officer's orders of July 5 and July 25, 2012. What the analysis below eliminates, compared to the perplexing and error-laden charts submitted in AER's Petition and its responses to the Board's questions, are two elements completely unrelated to the proposed variance: i) emission

[105] Petition at 26. Illinois EPA also relied on this premise in concluding that no environmental harm would result from the variance. IEPA Recommendation at ¶¶ 63, 66.

reductions that AER attributes to its December 2011 shutdowns of Meredosia and Hutsonville[106] and ii) the difference between AER's actual, historical emissions during calendar years 2010 and 2011 and the maximum emissions that would have been allowed under the MPS during those years.[107] As discussed in section III.C, *infra*, neither element should be considered when describing the "injury to the public or the environment *from a grant of the variance*." *Marathon Oil Co.*, 242 Ill. App. 3d at 206 (emphasis added). *See also* 35 Ill. Adm. Code 104.204(g)(1) (requiring the comparison of emissions "if the variance is granted . . . to those that would result if immediate compliance were required").

Assessing the actual, real-world effects of the proposed variance, it would allow AER to emit over 32,000 more tons of SO_2 for the period of 2012 to 2020—nearly an additional year's worth of emissions from its fleet:

[106] July 5, 2012 Hearing Officer Order (Question 3(b): "Please state the amount of SO2 emissions if the requested variance is granted, compared to that which would result if immediate compliance is required. In particular, please readdress Table 1 on page 26 of the petition to provide a specific estimate of the net difference between the projected SO2 emissions under the current rule and under the proposed variance if Meredosia and Hutsonville are not considered in the system-wide analysis."); First AER Response at 6-10 and Tables 2 and 3 (purporting to respond to this question).

[107] See July 25, 2012 Hearing Officer Order (Question 2(k): "Please readdress Table 1 on page 26 and Attachment 1 of Exh. 7 of the petition to also show 'Cumulative SO2 Variance Reduced Tons' if 2010 and 2011 are not considered."); Second AER Response at 5-6 and Table 4 (purporting to respond to the question).

Table 1: Corrected Comparison of Emissions Under MPS Baseline and Proposed Variance

Year	Heat Input (mmBtu)[108]	MPS Baseline SO_2 Emission Limit (lb/mmBtu)	MPS Baseline SO_2 Allowed Emissions (tons)	Proposed Variance SO_2 Emission Limit (lb/mmBtu)	Proposed Variance SO_2 Allowed Emissions (tons)	Annual Increase in Allowed SO_2 Emissions Because of Variance (tons)	Cumulative Increase in Allowed SO_2 Emissions Because of Variance (tons)
2012	312,003,694	0.50	78,001	0.38	59,281	-18,720	-18,720
2013	312,003,694	0.50	78,001	0.35	54,601	-23,400	-42,120
2014	312,003,694	0.43	67,081	0.35	54,601	-12,480	-54,601
2015	312,003,694	0.25	39,000	0.35	54,601	15,600	-39,000
2016	312,003,694	0.25	39,000	0.35	54,601	15,600	-23,400
2017	312,003,694	0.23	35,880	0.35	54,601	18,720	-4,680
2018	312,003,694	0.23	35,880	0.35	54,601	18,720	14,040
2019	312,003,694	0.23	35,880	0.35	54,601	18,720	32,760
2020	312,003,694	0.23	35,880	0.23	35,880	0	32,760

By contrast, the tables provided by AER in its responses to the Board's questions are, to put it mildly, confusing. For both Tables 2 and 3 from the First AER Response, it is unclear how the calculations from the last column, for "Cumulative SO_2 Variance Reduced Tons," were derived. They certainly do not reflect the annual differences between the "MPS Baseline SO_2 Tons" column and the "Variance SO_2 Tons" columns, as one would expect. Neither do the tables describe the scenarios AER claims they do. In its narrative responses, AER stated that Table 2 represents an analysis removing the impact of the closure of Meredosia and Hutsonville, in response to Question 3(b) in the Hearing Officer's July 5, 2012 Order, (Resp. at 9), and that Table 3 represents an analysis removing the impact of calendar years 2010 and 2011[109] (*id.* at 10).

[108] This heat input is taken from Table 4 of the Second AER Response, and reflects the heat input of AER's remaining fleet, without Meredosia and Hutsonville.
[109] AER First Response at 9, 10.

However, the tables appear to be reversed.[110] Moreover, Table 3 actually shows, in line with the Citizen Groups' Table 1 above, that the variance will allow significantly more SO_2 emissions through the term of the variance, when the Meredosia and Hutsonville shutdowns and calendar years 2010 and 2011 are removed from the comparison. Table 3 equalizes the heat inputs and emission rates for calendar years 2010 and 2011 and, most importantly, equalizes the heat inputs for calendar years 2012 through 2020. With those adjustments—and disregarding the "Cumulative SO_2 Variance Reduced Tons" column, which seems to have been taken from an entirely different table—Table 3 actually shows that AER's proposed variance would allow 691,106 tons of SO_2 emissions between 2010 and 2020, and the MPS baseline 655,359 tons: a difference of 35,747 tons *more* for the variance. Thus, AER inadvertently proves the Citizens Groups' point: when irrelevant considerations are removed from the analysis, the variance will allow significantly more SO_2 emissions than the current MPS would.

C. Any Emission Reductions From the Shutdowns of Meredosia and Hutsonville, Or Emissions From Past Years, Cannot Be Credited to the Variance.

The Board should reject AER's attempts to claim "offsets" from the shutdowns of Meredosia and Hutsonville. Those shutdowns are irrelevant to a consideration of the "injury to the public or the environment *from a grant of the variance*," *Marathon Oil Co.*, 242 Ill. App. 3d at 206, because these plants will remain shuttered whether the variance is granted or not. At the hearing, Mr. Menne testified that "AER's commitment to keep these plants shut down during the pendency of the variance is a real and meaningful commitment with consequences."[111] To the

[110] Table 2 does not remove the impact of the Meredosia and Hutsonville shutdowns, but rather removes the impact of calendar years 2010 and 2011 by equalizing the heat inputs and emission rates for those years. It shows that, without the effect of calendar years 2010 and 2011, but still giving the variance credit for the closure of Meredosia and Hutsonville, the variance would allow 7,700 tons less SO2 emissions than the current MPS form 2012 through 2020.

[111] Menne Test. Tr. at 27:6-9.

contrary, AER's commitment is inconsequential. Whatever happens in this proceeding, the plants will remain shuttered because i) the shutdowns are necessary for AER's compliance with the MPS and CSAPR and ii) the plants clearly are uneconomical for AER to operate.

AER has publicly acknowledged that shutting down Meredosia and Hutsonville is part of its compliance strategy with both the MPS and CSAPR. This is made clear in Ameren Corporation's Form 10-Q for the third quarter of 2011, filed well before AER's variance request, in which Ameren discussed the shutdowns.[112] Ameren stated:

> Under the MPS, as amended, Illinois generators are required to reduce mercury, SO_2, and NO_x emissions by 2015. . . . *Genco's compliance plan includes the closure of the Meredosia and Hutsonville energy centers at the end of December 2011.*[113]

Elsewhere in the filing, Ameren stated:

> Closure of the Meredosia and Hutsonville energy centers will reduce the Merchant Generation segment's fleet emission levels. *As a result, the Merchant Generation environmental compliance plan no longer includes the use of dry sorbent injection at its E.D. Edwards energy center to comply with the CSAPR or MPS.* The closure of these two energy centers has allowed the Merchant Generation segment additional flexibility in the methods to achieve compliance with environmental standards. As a result, the Merchant Generation segment has further reduced its expected 2011 through 2015 capital expenditures by approximately $70 million compared to those estimates disclosed in the Form 10-Q for the quarter ended June 30, 2011.[114]

Put simply, AER is trying to double-count emission reductions. AER already is relying on the shutdown of Meredosia and Hutsonville to bring down its fleet-wide SO_2 emission rate so that it will not have to install earlier planned pollution controls—such as dry sorbent injection at E.D. Edwards—in order to comply with the MPS. Thus, crediting AER with emission reductions for shutting down Meredosia and Hutsonville would be no different from crediting

[112] Ameren Corp., Quarterly Report (Form 10-Q) (Nov. 8, 2011), *available at* http://www.sec.gov/Archives/edgar/data/18654/000119312511302027/d238905d10q.htm.
[113] *Id.* at 50 (emphasis added).
[114] *Id.* at 7-8 (emphasis added).

AER for emission reductions it achieved by installing a scrubber at its Duck Creek facility. In both cases, AER simply has partially complied with the MPS by lowering its fleet-wide rate.

The error in AER's logic is made clear by its claim that the proposed variance would keep Meredosia and Hutsonville closed because its interim emissions rates are "set at a level at which uncontrolled units at [the plants] will not be able to resume operations without additional control technology being installed within the generating system."[115] This may be true, but what AER neglects to mention is that the MPS as it currently stands will mandate *the exact same result*. AER has stated that the annual SO_2 emission rate from its MPS Group in 2011, before it closed Meredosia and Hutsonville, was 0.46 lb/mmBtu.[116] As depicted in Table 1, *supra*, the MPS currently requires AER to comply with an SO_2 emission rate of 0.43 lb/mmBtu in 2014, and with declining rates thereafter. Without keeping Meredosia and Hutsonville shut down or installing pollution controls, it would be unlikely that AER could meet even the 2014 rate, a rate for which it is not seeking a variance. So the plants will remain closed whether or not a variance is granted—and AER will have saved $70 million in capital expenditures by abandoning a DSI project at E.D. Edwards that would have created further SO_2 reductions.[117] Essentially, AER is now asking the Board to pretend that Meredosia and Hutsonville are not part of its fleet for purposes of the MPS, and therefore that their shutdown could be used to offset non-compliance by AER's remaining fleet.

AER's attempt to credit the variance with the shutdowns of Meredosia and Hutsonville also disregards the fact that the shutdowns will be necessary to comply with a reinstated

[115] Petition, Ex. 7, Whitworth Aff. at ¶ 3.
[116] First AER Response at 7.
[117] In its Recommendation, IEPA contends that "providing credit for actions (*e.g.*, unit shutdowns) that result in emission reductions is an acceptable part of the established regulatory process." (IEPA Recommendation at ¶ 24). What IEPA fails to take into account is that AER already will receive "credit" for the shutdowns under the MPS: the shutdowns have lowered AER's overall emissions rate and are necessary for AER to meet the goal of even partial compliance that it has set out in its proposed variance.

CSAPR.[118] As Mr. Menne testified at the hearing, a reinstated CSAPR would be a more stringent regime than AER's proposed 0.35 lb/mmBtu emission rate for 2015 to 2019, requiring AER to take "additional measures" to reduce its fleet's SO_2 emissions—including the use of lower sulfur coal or sorbent injection.[119] Thus, AER also will need to keep Meredosia and Hutsonville shut down in order to comply with a reinstated CSAPR. Again, AER's commitment to keep the plants shuttered is pointless. Whatever happens in this proceeding, Meredosia and Hutsonville will remain shut down as a necessary part of AER's CSAPR compliance strategy.

In addition, AER's statements outside of this proceeding, as well as the historical utilization rates for the plants, indicate that Meredosia and Hutsonville also will remain closed because they are uneconomical for AER to operate. In May 2009, AER's subsidiary, Ameren Energy Generating Company ("AEG"), proposed site-specific rules related to one of Hutsonville's coal ash ponds.[120] In its Motion for Expedited Review of that petition, AEG stated: "Ameren has placed the Hutsonville Power Plant on the market for sale *to reduce the cost to Ameren of operating the plant.*"[121] In short, AER has viewed Hutsonville as an albatross since 2009.

AER made clear in an August 12, 2009 press release that it was trying to sell not only Hutsonville, but also Meredosia, too. AER could find no buyers for its aging, inefficient plants, though.[122] Therefore, AER reported that it was laying off employees at both plants and

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[118] *See* Tr. at 40-41 ("But if you believe that CSAPR is going to come back, *which most people do*, that it will come back into effect in '14 or '15 . . . . we've also been looking at what else we could possibly do *when CSAPR gets reinstated.*") (emphasis added); *see also* Petition at 15 ("AER believes that either [CSAPR] or a regulatory replacement will be in place before the expiration of the requested variance term.").
[119] Menne Test. Tr. at 42:7-13.
[120] *In the Matter of: Proposed Rules Establishing 35 Ill. Adm. Code Subchapter J, Part 840, and Subpart A, Site-Specific Rules Providing for the Closure of Ash Pond D at the Hutsonville Power Station*, PCB 09-21 (Rulemaking—Land) (May 9, 2009).
[121] *Id.*, *available at* http://www.ipcb.state.il.us/documents/dsweb/Get/Document-65178, at 75.
[122] *See* Press Release, Ameren Energy Resources Co., Ameren Energy Resources Announces Staff Reductions at Three Illinois Power Plants in Response to Changes in Power Markets, Tough Economy (Aug. 12, 2009), *available*

"retiring" two of four units at Meredosia.[123] AER's then-President and Chief Executive Officer stated:

> While we regret having to take this action, the challenges we face demand a new model for our merchant generation business—we must build a leaner, more streamlined organization that can more effectively compete in today's difficult economy where we see much lower prices for our power.[124]

Less than a year later, AER announced additional layoffs and stated that it would "also be evaluating temporarily ceasing operations at its least efficient plants . . . ."[125] Finally, in October 2011, AER announced that it would be closing the plants entirely.[126]

AER's economic circumstances surrounding Meredosia and Hutsonville are also reflected in the declining utilization rates of those plants from 2008 on. From 2008 to 2009, AER slashed its usage of Meredosia and Hutsonville.[127] At Hutsonville, AER decreased its utilization rate from 68.3% (at 11,459, 911.9 mmBtu) to 39.3% (at 6,586,354 mmBtu). At Meredosia, AER virtually ceased operations, cutting the utilization rate from 38.3% (at 17,070,473.5 mmBtu) to 13.7% (at 6,103,183.4 mmBtu). These depressed utilization rates remained consistent through the end of 2011.[128] In summary, there is no basis to conclude that AER will in any realistic scenario seek to re-open Meredosia and Hutsonville, given that i) AER will rely on their closures to comply with the MPS and CSAPR and ii) they are uneconomical for AER to operate.

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at http://www.prnewswire.com/news-releases/ameren-energy-resources-announces-staff-reductions-at-three-illinois-power-plants-in-response-to-changes-in-power-markets-tough-economy-62215822.html.

[123] *Id.*

[124] *Id.*

[125] Press Release, AER Energy Resources Co., AER Subsidiary Announces Reductions in Response to Continuing Declines in Power Markets (May 3, 2010), *available at* http://www.prnewswire.com/news-releases/ameren-subsidiary-announces-reductions-in-response-to-continuing-declines-in-power-markets-92697009.html.

[126] http://www.prnewswire.com/news-releases/two-ameren-merchant-generating-company-energy-centers-to-cease-operations-131044393.html.

[127] *See* Presentation of IEPA at ICC Meeting (Nov. 11, 2011), at slides 8-9, PDF *available at* http://www.icc.illinois.gov/electricity/policycommitteemtg.aspx\

[128] *Id.*; *see also* Petition, Ex. 1. Using the 2011 SO2 emission rates and mass emissions provided by AER, the 2011 heat inputs for Hutsonville and Meredosia were 8,755,752 mmBtu and 9,989,090 mmBtu, respectively.

Aside from claiming reductions from the otherwise-required shutdowns of its Meredosia and Hutsonville plants, AER also asserts that its variance should be credited with the difference between its fleet's actual emissions during calendar years 2010 and 2011 and the maximum emissions that would have been allowed under the MPS for those years.[129] Quite simply, AER has provided no support for its assertion that wholly past emissions should be considered in evaluating a proposed variance. Instead, this argument is contrary to the basic proposition that a proposed variance should be evaluated on what its prospective effect on a petitioner's emissions would be, compared to what emissions would be allowed if compliance were required. Therefore, the Board should ignore AER's references to its fleet's 2010 and 2011 emissions. AER's failure to accurately describe these emissions mandates that its Petition be denied.

D. AER Fails to Address the Environmental Impacts of Increased SO_2 Emissions.

By grossly understating the excess SO_2 emissions that would result from a grant of the variance, AER and IEPA both avoid any discussion of the significant negative public health impacts that subverting the MPS would have. When asked about the health effects of SO_2 emissions by Board Member Burke at the hearing, Mr. Menne responded: "Well, although I've studied it for many years, I'm not a health expert, and I'm not going to go into health consequences."[130]

AER and IEPA's current silence on the public health benefits of the MPS stands in stark contrast to their representations at the time they proposed the standard. In their Joint Statement in the original MPS rulemaking, AER and IEPA made clear that the SO_2 emission reductions required by the MPS would have a significant positive environmental impact:

[129] See Petit. at 26, Table 1; AER First Response at 10.
[130] Menne Test. Tr. at 39:1-3.

> Ameren and the Illinois EPA anticipate that the installation and operation of pollution control equipment as contemplated by Section 225.233 will achieve significant additional reductions of SO_2 and NO_x, beyond that required from existing regulations and thereby further improve air quality . . . . Emission limits of NO_x and SO_2 that are beyond standards set forth in the Clean Air Interstate Rule ("CAIR") will further reduce ambient levels of ozone and PM2.5, *and provide substantial environmental benefits to the residents of Illinois* . . . .[131]

Further, in testimony delivered to Congress in 2009, IEPA's then-Director, Douglas Scott, called the MPS "one of the most important environmental and public health advances in Illinois in recent decades."[132] He continued:

> The benefits of removing SO_2 and NO_x are well established and most notably will result in reductions in both particulate matter and ozone. SO_2 is a precursor to particulate matter and NO_x is a precursor to both particulate matter and ozone. Particulate matter related annual benefits include fewer premature fatalities, fewer cases of chronic bronchitis, fewer non-fatal heart attacks, fewer hospitalization admissions (for respiratory and cardiovascular disease combined) and should result in fewer days of restricted activity due to respiratory illness and fewer work loss days. Moreover, there should be health improvements for children from reduced upper and lower respiratory illness, acute bronchitis, and asthma attacks.[133]

In further contrast to AER and IEPA's current silence on the public health impacts of thousands of tons of additional emissions of SO_2 annually between 2015 and 2019, dozens of Illinois health professionals, representing universities across the State, are now speaking out in defense of the MPS. Today, Dr. Peter Orris submitted to the Board a letter signed by over eighty health professionals from across the State, attached hereto as Exhibit 5, expressing concern at the present effort to weaken the MPS, and urging the Board to vote against any action eroding MPS standards. The health professionals cite to the harmful effects of SO_2 emissions in and of

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[131] *In the Matter of: Proposed New 35 Ill. Adm. Code 225 Control of Emissions From Large Combustion Sources*, PCB 06-25 (July 28, 2006) (Joint Statement at 2).
[132] Ex. 1, Scott Test., at 2.
[133] *Id.* at 9.

themselves, and also as precursors to fine particle pollution, noting that the linkages between short- and long-term exposure to PM2.5 with premature mortality and cardiovascular effects.

Such negative public health impacts were quantified in a 2010 National Research Council study referenced by the health professionals.[134] This study measured the externalities associated with local and global air pollution for individual coal-fired and gas-fired power plants in the United States.[135] Overall, the study quantified the damage caused by emissions of SO_2, NO_x, PM2.5, and PM10 from U.S. coal-fired power plants during 2005 as approximately $62 billion—with 85% of those damages (or approximately $53 billion)[136] being caused by SO_2 emissions.[137] Almost all of the damages (94%) were due to premature mortality.[138]

As part of their analysis, the authors of NRC study calculated damages per ton of each criteria pollutant emitted by each coal-fired power plant in the United States—including AER's fleet. The spreadsheet detailing these results is attached hereto as Exhibit 6. For AER's remaining fleet of coal plants, the damages per ton of SO_2 emitted in 2005 ranged from $4,850 (at Newton) to $6,580 (at E.D. Edwards). As set forth in Table 1, above, AER's proposed variance would result in 32,760 tons of excess SO_2 emissions from 2012 through the end of the variance in 2020. Using the costs per ton in the study as a benchmark, the cost to the public health and the environment from AER's five-year delay in compliance with the MPS' SO_2 limits can be estimated to range from $159 million to $216 million.

The expected health impacts of the variance also were addressed in comments of Dr. Samuel Dorevitch (filed as PC#1919). Dr. Dorevitch concluded:

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[134] National Research Council, *Hidden Costs of Energy: Unpriced Consquences of Energy Production and Use* (2010), available at http://www.nap.edu/catalog.php?record_id=12794 (also submitted in PC #1918).
[135] *Id.* at 67.
[136] All dollar amounts from the study are expressed in 2007 USD.
[137] *Id.* at 87-88, 92.
[138] *Id.* at 94.

> In light of the health impacts of even moderate levels of SO_2 pollution, and the long-term health risks of PM2.5 pollution, failure to lower [AER's sulfur dioxide emissions] on the agreed upon schedule would be expected to keep rates of asthma attacks and other health problems higher than they would be at the agreed upon, lower levels.

Id. at 1.

AER has failed to meet its duty to show an arbitrary or unreasonable hardship, because it has failed to present any credible evidence of the actual environmental impact of its proposed variance. *See City of Mendota v. IPCB*, 161 Ill. App. 3d 203, 209 (3d Dist. 1987). In *City of Mendota*, the court upheld the Board's denial of a variance when the petitioner did not present any evidence regarding the effects of its sewage effluent discharges on the environment, other than the plant operator's conclusion that they were "acceptable." *Id.* at 208. *See also Plexus Scientific Corp. v. IEPA*, PCB 01-120 (Apr. 5, 2001), at 3 (finding variance petition deficient because it "summarily state[d]" that proposed activity was "not expected to have a measurable environmental impact"). Similarly, AER here relies entirely on the conclusory—and incorrect—contention that its variance will not increase emissions. By failing to properly address its proposed variance's environmental impact, AER has failed to carry its burden to demonstrate an arbitrary or unreasonable hardship.

E. AER's Proposed Variance Would Harm Environmental Regulation in Illinois.

AER's proposed variance threatens harm to Illinois' environmental standards beyond the excess SO_2 emissions allowed to AER. As discussed in the Citizen Groups' earlier objection (PC #6 at 3), allowing the variance would undercut a negotiated, statewide standard, with potential for further public health injury and a chilling effect on future negotiations. Not only would granting AER's proposed variance embolden other EGU owners in the State to seek their own variances from the MPS and the related Combined Pollutant Standard ("CPS"), thereby

allowing additional pollution, it also would discourage future negotiated standards between regulated entities, the State, and environmental groups. IEPA's then-Director rightly hailed the MPS as "a tremendous win-win-win for the environment, public health and the regulated community."[139] Quite simply, if IEPA will not defend the standards it negotiates, or the Board the regulations it promulgates, there will be no such future victories.

The Citizens Groups are not alone in believing that an AER variance would destabilize the carefully constructed balance of the MPS and CPS. In a news story on the proposed variance, a spokesperson for Dynegy Inc. described AER's request for a variance from the agreed standard as "challenging":[140]

> Dynegy Inc., which owns four coal-fired power plants in Illinois, has already invested $1 billion "funded by shareholders" allowing it to meet the state emissions limits, said spokesperson Katy Sullivan. She said it is "challenging" for a company like Dynegy when one of its competitors seeks an exemption from rules that other players have agreed to comply with. Both Dynegy and Ameren sell power in the MISO wholesale market.
>
> "One reason that market prices are low in MISO and Illinois is that there is an oversupply of power generation capacity in MISO," Sullivan said. "Prolonged low prices are typically a signal for uneconomic plants to exit the market. *Granting AER its variance defies the market signals and potentially will keep uneconomic plants in the market longer than they would otherwise operate.* We believe the marketplace should determine which facilities are competitive and allowed to continue operation. Regulatory intervention, essentially picking winners and losers, serves to alter the playing field, creating unfair competitive advantages for some and not for others."

In this case, the Citizens Groups can agree wholeheartedly with Dynegy: AER is asking this Board to pick winners and losers in the Midwest energy market, with Illinois citizens bearing the brunt of excess SO_2 emissions. Because AER has failed to justify the harms that its variance would cause, this Board should deny AER's Petition.

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[139] Ex. 1, Scott Testimony at 14.

[140] *See* Kari Lydersen, *Ameren wants more time to clean up Illinois emissions*, MIDWEST ENERGY NEWS (Aug. 6, 2012), http://www.midwestenergynews.com/2012/08/06/ameren-wants-more-time-to-clean-up-illinois-emissions/ (emphasis added).

IV. If the Board Does Not Deny AER's Petition, Then It Should Strictly Condition Any Variance

As set forth in these Comments, AER has failed to meet its burden to justify a variance from the MPS. Were the Board to determine to grant AER a variance, though, any variance must be strictly conditioned. As set forth in Sections I and II, above, AER has failed to present a definite compliance plan and failed to demonstrate that it has investigated all feasible compliance alternatives. Both issues would need to be addressed before the Board could grant AER any variance.

First, AER's current compliance plan involves little more than AER providing "updates" on vaguely described "engineering" work until the potential completion of the Newton FGD project in 2020. Menne Test., Tr. at 32:9-33:6. Should the Board grant AER any variance, AER must provide a detailed description of the work it will perform, and a binding schedule for its completion. This schedule must not be dependent on energy prices, but rather guaranteed to result in AER's compliance with the MPS by the end of the variance.

Second, AER must better demonstrate that it has explored all options for lowering its fleet's SO_2 emissions rate. Specifically, as discussed in Section II, above, AER must address the possibility of a "suite" of pollution control strategies that individually might not allow for MPS compliance, but together would result in significant emission reductions below AER's currently proposed emission limits. In particular, AER should describe in detail the measures it would implement in the event of a reinstatement of CSAPR. Mr. Menne's testimony made clear that AER has considered control options that, even if they would not yield full compliance with the MPS's requirements, would at least lower AER's emission rate below 0.35 lb/mmBtu. Menne Test. Tr. at 41:19-42:23. There is no reason such measures should not be implemented in partial compliance with the 2015 MPS emission limits. AER's duty to explore compliance alternatives

must be ongoing, and its SO_2 emission limit conditioned on the results of its demonstration of available alternatives.

Finally, AER's proposed variance term of five years is, in any case, far too long. Given AER's refrain of the "uncertainty" of markets, any variance granted AER should be no longer than two years, so that all parties may continue to assess the prospects of AER's future implementation of pollution control measures, and, indeed, the ongoing viability of AER as a merchant generator. In granting any variance, the Board should also make clear to AER that it is the last such variance the company will receive from compliance with the MPS.

V. Conclusion

For the reasons set forth in these Comments, the Board should deny AER's Petition for Variance.

Respectfully Submitted,

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DATED: August 10, 2012

CERTIFICATE OF SERVICE

I, Andrew Armstrong, hereby certify that I have served the attached **Comments of Environment Illinois, the Environmental Law & Policy Center, Natural Resources Defense Council, Respiratory Health Association, and Sierra Club** upon the attached service list by electronic mail and by depositing said documents in the United States Mail, postage prepaid, in Chicago, Illinois on August 10, 2012.

Respectfully submitted,

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BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

AMEREN ENERGY RESOURCES,	)	
	)	
Petitioner,	)	PCB 12-126
	)	(Variance - Air)
v.	)	
	)	
ILLINOIS ENVIRONMENTAL PROTECTION AGENCY,	)	
	)	
	)	
Respondent.	)	

CITIZENS GROUPS' EXHIBITS

1. Written Testimony of Douglas P. Scott, Director, Illinois Environmental Protection Agency, Before the U.S. Senate Committee on Environment and Public Works/Subcommittee on Clean Air and Nuclear Safety On the Issue of: "Oversight: Environmental Protection Agency's Clean Air Regulations – One Year after the CAIR and CAMR Federal Court Decisions" (July 9, 2009)

2. The Shaw Group, *EEI Joppa Generating Station Dry Sorbent Injection Test Program Final Report* (September 24, 2010)

3. Comments of Kimberly Gray (August 1, 2012)

4. Citizens Utility Board, *Ameren Corporation's Performance Under the Illinois Electric Service Customer Choice and Rate Relief Law of 1997* (February 2006)

5. Comments of Illinois Health Professionals (August 10, 2012)

6. National Research Council, *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use* (2010), Public Access File 34, Estimates of damages associated with specific coal-fired electricity-generating facilities and natural-gas-fired electricity generating facilities

EXHIBIT 1

Written Testimony of Douglas P. Scott, Director, Illinois Environmental Protection Agency, Before the U.S. Senate Committee on Environment and Public Works/Subcommittee on Clean Air and Nuclear Safety On the Issue of: "Oversight: Environmental Protection Agency's Clean Air Regulations – One Year after the CAIR and CAMR Federal Court Decisions" (July 9, 2009)

Written Testimony of Douglas P. Scott
Director, Illinois Environmental Protection Agency
Before the:
U.S. Senate Committee on Environment and Public Works/
Subcommittee on Clean Air and Nuclear Safety
On the Issue of:
"Oversight: Environmental Protection Agency's Clean Air Regulations – One Year after the CAIR and CAMR Federal Court Decisions"
July 9, 2009

Mr. Chairman and Members of the Committee: My name is Doug Scott and I am the Director of the Illinois Environmental Protection Agency. I want to thank Senator Carper and the other members of the Senate Subcommittee on Clean Air and Nuclear Safety for this opportunity to testify on Illinois' regulations to control sulfur dioxide, nitrogen oxides and mercury emissions from the State's coal-fired power plants.

I received a Bachelor's Degree with honors from the University of Tulsa in 1982, and received a graduate Juris Doctor law degree with honors from Marquette University in 1985. I served as Assistant City Attorney and City Attorney for the City of Rockford, Illinois from 1985 to 1995. I also represented the City on a number of environmental issues. From1995-2001 I served as an Illinois State Representative for the 67th District and served on the House Energy and Environment Committee, and was a member of the committee that rewrote the States' electric utility laws. I was elected to the Office of the Mayor of Rockford in April 2001 and served a four-year term and served as President of the Illinois Chapter of the National Brownfields Association. I was appointed as the Director of the Illinois EPA by Governor Rod Blagojevich in July 2005, and have served as Chair of the Air Committee of the Environmental Council of the States (ECOS), the national organization of state environmental agency leaders.

I am pleased to be here to provide testimony on the "three pollutant" approach and Illinois' experience in reaching agreements with our state's three largest coal-fired power plant system owners. My testimony will provide background information and a broad overview of the

development of Illinois' multi-pollutant reduction agreements. I will address some of the measures the Illinois EPA took during rule development to ensure that we relied on accurate and current information as we crafted the rule.

Illinois Multi-Pollutant Regulatory Approaches

Illinois is a large industrial state with a population of about 13 million people and a gross state product of $522 billion. Each of these are approximately four percent of the U. S. total and ranks Illinois as fifth among the nation in these categories. Illinois obtains more than 40 percent of its electricity from coal-fired power plants and sits on top of 38 billion tons of coal, giving it the third largest coal reserves in the nation. Coal-fired power plants in Illinois constitute the largest source of man-made emissions of mercury (Hg) and sulfur dioxide (SO_2), and one of the largest sources of nitrogen oxides (NO_x). Illinois is home to 21 large coal-fired plants that operate electric generating units.

Over the last several years in Illinois, exceptional progress has been made in reducing the emissions that contribute to ozone and particulate matter (PM) air pollution, as well as reducing toxic Hg emissions that deposit into and contaminate Illinois' waters and fish. In particular, the Illinois Environmental Protection Agency (Illinois EPA) reached landmark multi-pollutant standard agreements with the three largest coal-fired power plant systems operating in Illinois: Midwest Generation, Ameren and Dynegy. These three companies represent 88% of Illinois' 17,007 megawatts of coal-fired electric generating capacity and account for hundreds of thousands of tons of air emissions each year.

These multi-pollutant standards (MPS) are expected to result in measurable air quality improvements in Illinois and also in regional air quality by dramatically reducing Hg, SO_2, and NO_x emissions from Illinois' coal-fired power plants. The agreed-to multi-pollutant standards are one of the most important environmental and public health advances in Illinois in recent decades. They represent the largest reductions in air emissions ever agreed to by individual companies in Illinois under any context, whether through an enforcement action or regulation.

As a result of the knowledge and experience gained through Illinois' efforts, the Illinois EPA supports a comprehensive national strategy for reducing emissions of multiple pollutants from electric generating units. A comprehensive, integrated approach benefits both regulators and the regulated community. Multi-pollutant approaches should supplement, not replace, the existing Clean Air Act programs such as New Source Review (NSR), Maximum Achievable Control Technology (MACT) standards and regional haze, as well as other important statutory requirements for achieving and sustaining clean air.

In meeting emission goals, the regulated community should be afforded flexibility, where appropriate, which may include an emissions trading mechanism for NOx, and SO_2, but not pollutants where local impacts are of great concern or where concentrated emissions at a local scale may occur – as in the case of Hg. Any multi-pollutant strategy must also ensure that regions, states and localities retain their authority to adopt and implement measures which are more stringent than those of the federal government.

A 3-pollutant approach for controlling the emissions of Hg, SO_2, and NO_x from coal-fired power plants can have numerous advantages over the traditional, single pollutant schemes. For example, a well crafted multi-pollutant standard can increase the protection of public health and the environment, reduce pollution more cost-effectively, and offer greater certainty to both industry and regulators. Since Hg emission reductions can be obtained as a "co-benefit" from the control devices used to reduce SO_2 and NO_x, it makes sense to allow companies the option to synchronize the control of these pollutants, provided that public health and the environment are likewise positively impacted. Whereas the federal Clean Air Mercury Rule (CAMR) single-mindedly tackled mercury emissions, and the federal Clean Air Interstate Rule (CAIR) addressed SO_2 and NOx, Illinois was able to use a multi-pollutant strategy that accomplishes the aforementioned benefits in a unified regulatory framework accounting for planning, engineering, availability of financing and other issues that accompany a multi-pollutant control strategy.

Illinois believes the most feasible method of obtaining reliable emission reductions in a cost-effective manner is through a combination of emission rate based limits along with emissions trading. Although sources under the MPS are not allowed to utilize allowances to meet the

numeric emissions standards, sources are free to sell or trade allowances that are generated as a result of emissions being below the allowable emission rates. This provides an incentive for companies to go beyond the reductions required under the MPS in order to recover some of the costs associated with the control measures taken. Moreover, emissions' trading is recognized to provide market incentives for sources to control emissions as far and as fast as reasonably possible. Of note is that emissions trading under a cap and trade program has historically resulted in the highest emitting plants making the deepest reductions in emissions – a key finding that strongly supports the inclusion of emissions trading into any control strategy.

Illinois Multi-Pollutant Agreements

The catalyst for Illinois' agreements was the position taken in early 2006 that Illinois would propose an aggressive mercury regulation focused on cutting mercury emissions by 90% from coal-burning power plants by mid-2009. After the Illinois EPA presented its findings in support of the mercury rule during two weeks of well-attended and hotly contested public hearings, the Agency was approached by Ameren who expressed a desire to work with the Agency toward common goals. Subsequent to long hours of negotiation, an alternative standard was proposed that involved allowing some flexibility in complying with the mercury standards in exchange for commitments to also significantly reduce SO_2 and NOx emissions from Ameren's coal-fired power plants. This initial agreement led to similar discussions and agreements with Illinois' other two large coal burning systems, Dynegy and Midwest Generation.

The agreements reached and memorialized in the Multi-Pollutant Standard (MPS) and Combined Pollutant Standard (CPS) are significant not only for the magnitude of emissions reductions that occur, but also for the rule support that accompanied the agreements. The Illinois mercury rule was vehemently opposed by a unified coal-fired power industry. The initial agreement established that mutual goals were achievable, set the guiding principles, and opened the door for other companies to follow –which they did. Ultimately, the mercury rule was unanimously approved in 2006 by both the Illinois Pollution Control Board and the Joint Committee on Administrative Rules, the two governing oversight bodies for regulations in Illinois.

Both the MPS and CPS provisions provide some flexibility on the timing of mercury reductions in exchange for commitments to make significant reductions in both SO_2 and NOx. All of the provisions include some level of trading restrictions on SO_2 and NOx allowances provided under CAIR. Ameren, Dynegy and Midwest Generation will install a multitude of pollution control equipment on their boilers costing several billion dollars, including wet and dry scrubbers, selective catalytic reduction (SCR) and selective non-catalytic reduction (SNCR) devices, and fabric filters. Recent discussions with representatives of Illinois' coal-fired power plants indicate that they are all preparing to meet the requirements of the MPS and CPS, which initiate in 2010. In doing so, a wide array of emissions control equipment costing billions of dollars will come on-line in Illinois over the next several years. Illinois coal-fired power plants have already installed and begun operating numerous halogenated activated carbon injection (ACI) systems for mercury control. The first of many new scrubbers for SO_2 control will begin operation shortly. Fabric filter controls will accompany the installation of many of the scrubbers and result in the co-benefit of particulate matter reductions. Selective catalytic reduction devices and other new NOx controls are being scheduled for installation across Illinois. The shutdown of a few of the older, most polluting electric generating units began in December 2007 with two more units scheduled for shutdown by December 2010.

Illinois Mercury Rule

The Illinois mercury rule is designed to achieve a high level of mercury control, based on Illinois EPA's finding that there exists mercury control technology that is both technically feasible and economically reasonable. Mercury emissions may be reduced through the application of control technology specifically designed to control mercury (e.g., activated carbon injection), or through co-benefit from other control technologies designed to control SO_2, NOx, and PM. Depending on several variables, including coal and boiler type, there are a number of control technologies that will achieve 90+% removal of mercury. Mercury emissions control technology is a rapidly advancing field, with halogenated sorbents being an affordable and effective option for most applications. Although there may be some challenges to achieving 90% removal of mercury for

all applications, in almost every case each of these challenges can be overcome or addressed through technology that is economically reasonable and available today.

The Illinois mercury rule provides substantial flexibility in order to reduce the costs of compliance and risk of noncompliance for power plants. This flexibility includes the ability to meet either a 90% reduction or an output based standard of 0.0080 pounds mercury/GWh, phasing in standards over a period of 3 ½ years with a less restrictive standard in phase one, compliance by averaging of emissions, and the avoidance of installing controls on units that will be shutdown in the near future provided companies make an enforceable commitment to shutdown those units by a date certain.

Additional flexibility is provided via a "Temporary Technology Based Standard" (TTBS) that provides relief for units that install appropriate mercury controls but do not achieve full compliance. Eligible units only need to operate the mercury controls in an optimal manner to comply. This provision is available through June 2015 and can be used by up to 25% of a company's generating capacity.

Companies may choose to voluntarily comply with the MPS or CPS as an alternative to the otherwise applicable requirements of the mercury rule. These provisions provide additional flexibility in regards to mercury control in return for companies achieving significant reductions in the emissions of SO_2 and NOx.

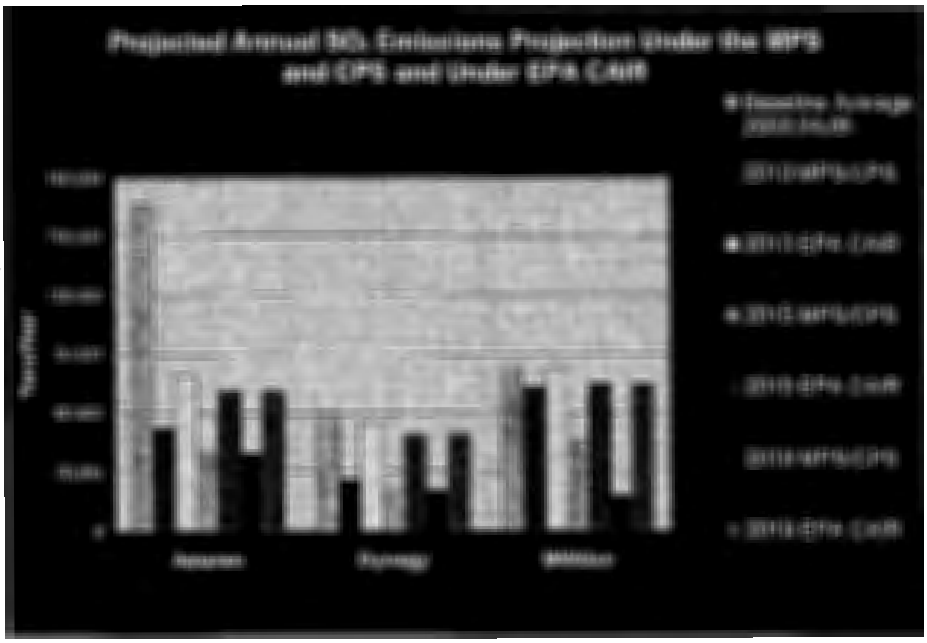
Under the MPS and CPS, companies can commit to voluntarily meet numerical emission standards for both NOx and SO_2 and in return are provided additional flexibility in complying with the mercury emission standards. The MPS and CPS provisions also contain restrictions on the trading of NOx and SO_2 allowances provided under CAIR. By regulating the emissions of NOx and SO_2 and restricting the trading of allowances, the MPS and CPS have obvious implications for the proposed CAIR NOx and SO_2 cap and trade program. As modeling has demonstrated, the benefits of these reductions will mostly impact Illinois and a few of the closest neighboring states (i.e., Indiana, Wisconsin and Missouri) with lesser benefits further downwind. While the positive impacts of the reductions are most significant within Illinois and its closest

neighbors, Illinois does support emissions trading as the most cost effective controls will be installed and the timing of controls is likely to occur more quickly than under a command and control option.

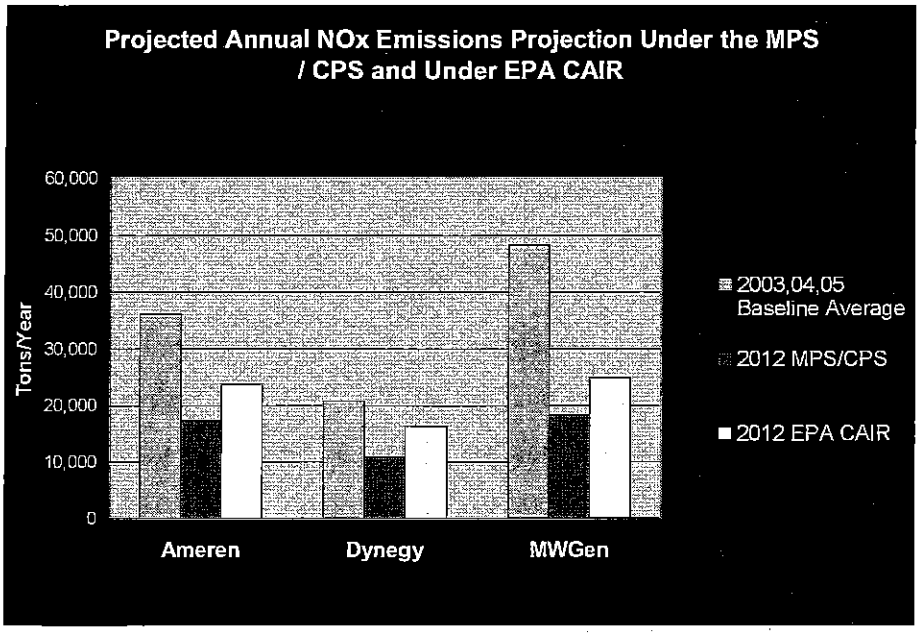
Emission Reductions

The combination of the Illinois mercury rule, CAIR, and the MPS and CPS will have enormous positive impacts, reducing mercury, SO_2 and NOx emissions far beyond the levels required under the federal CAMR and CAIR alone.

Under CAIR, U.S. EPA estimates that coal-fired power producers in Illinois would only have been required to reduce their SO_2 emissions by 34%, not the estimated 76% for Ameren, 65% for Dynegy, and 80% for Midwest Generation required under the MPS and CPS. The emissions of NOx are likewise expected to be reduced beyond the levels obtained by the model CAIR. In addition, both the MPS and CPS contain trading restrictions designed to ensure that the SO_2 and NOx reductions occur in Illinois.



The reductions agreed to under the MPS and CPS for SO_2 and NOx are expected to go a long way toward helping Illinois achieve attainment of the ozone and PM standards. The modeling demonstrates that the emission reductions are very substantial.



The Illinois EPA estimates the total emission reductions from all three power companies at:

- SO_2 = 233,600 tons per year eliminated
- NOx = 61,434 tons per year eliminated
- Mercury = 7,040 pounds per year eliminated

Under CAMR, coal-fired power producers in Illinois would have only been required to reduce their mercury emissions by 47% in 2010 and 78% by 2018, not the 90% reduction by 2009 specified in the Illinois rule. The timing of mercury reductions for

those sources that opt-in to the MPS or CPS is essentially the same, and the amount of reduction is expected to be close to 90%, although the companies will not be required to comply with the 90% reduction requirement on a 12 month rolling basis until 2015. Sources under the MPS and CPS are expected to have mercury emission reductions that exceed the required 90% after 2015 due to the co-benefit reductions achieved from the installation of controls needed to comply with the corresponding SO_2 and NOx standards.

Impacts of Emissions Reductions

Under the agreements between the Illinois EPA and Midwest Generation, Ameren and Dynegy, the decreases in Hg, SO_2, and NOx emissions are estimated to far exceed the reductions required under the federal CAMR and CAIR.

In regards to mercury, over time Illinois expects to see reductions in deposition of Hg to Illinois' lakes and streams and corresponding mercury decreases in Illinois' fish, making those fish caught in Illinois waters safer to eat. There will be several recognized benefits to the State from tighter mercury controls beyond the expected public health benefits that come with a reduction in deposition to Illinois' waters and fish. Such benefits include support for existing jobs and the potential for additional jobs resulting from the installation and operation of additional pollution control devices.

The benefits of removing SO_2 and NO_x are well established and most notably will result in reductions in both particulate matter and ozone. SO_2 is a precursor to particulate matter and NO_x is a precursor to both particulate matter and ozone. Particulate matter related annual benefits include fewer premature fatalities, fewer cases of chronic bronchitis, fewer non-fatal heart attacks, fewer hospitalization admissions (for respiratory and cardiovascular disease combined) and should result in fewer days of restricted activity due to respiratory illness and fewer work loss days. Moreover, there should be health improvements for children from reduced upper and lower respiratory illness, acute bronchitis, and asthma attacks.

Ozone health-related benefits are expected to occur during the summer ozone season and include fewer hospital admissions for respiratory illnesses, fewer emergency room admissions for asthma, fewer days with restricted activity levels, and fewer days where children are absent from school due to illnesses. In addition, there should be ecological and welfare benefits. Such benefits include visibility improvements; reductions in acidification in lakes, streams, and forests; reduced nutrient replenishing in water bodies; and benefits from reduced ozone levels for forests and agricultural production.

CAMR and CAIR Vacatur Impact on Illinois Regulations:

On February 8, 2008, the United States Court of Appeals for the District of Columbia Circuit vacated the federal CAMR. The Illinois mercury rule is separate from the federal CAMR and therefore the vacatur of CAMR had minimal impact on the Illinois rule. However, this court action raised concerns regarding the status of certain federal provisions dealing with the monitoring of mercury emissions. Given the uncertainty surrounding federal mercury monitoring provisions, the Illinois EPA determined that a revision to the Illinois mercury rule was appropriate. The revisions focused on the methods used to measure or monitor mercury emissions, and did not include any revisions to the control standards themselves. The rule was amended to allow a source to demonstrate compliance for a three year period using stack testing. The Illinois mercury rule remains in full effect and all Illinois companies began complying with the rule on July 1st of this year.

In July of 2008, the U.S. Court of Appeals for the District of Columbia Circuit (DC Court of Appeals) vacated the CAIR rule in its entirety. After entertaining motions for reconsideration from the parties, on December 23, 2008, the same court issued an opinion stating that the federal CAIR was remanded to U.S. EPA without vacatur. U.S. EPA subsequently confirmed that it has begun implementation of CAIR starting January 1, 2009. Illinois CAIR is in full effect. For a number of reasons, the vacatur and reinstatement of Phase I of CAIR have had minimal impact on Illinois sources and the MPS and CPS remain in effect. However, for the reasons discussed below, Illinois strongly favors federal multi-pollutant legislation to "remedy" the flaws in CAMR and CAIR.

The decision of the DC Court of Appeals vacating CAIR in part, i.e., vacating Phase II of CAIR but reinstating Phase I of CAIR, has thus far had minimal impact on Illinois. CAIR Phase I required reductions up until the beginning of CAIR Phase II in January 1, 2015. Although Illinois relied upon CAIR Phase I as part of our 8-hour ozone (85 ppb) and annual PM2.5 attainment plans, air quality in Illinois' two 8-hour ozone (85 ppb) and annual fine particulate matter nonattainment areas has improved to a very significant degree without these expected reductions. As a result, all but one monitor is in attainment for these standards, and it is expected to be in attainment in 2012. Because the MPS and CPS result in significant reductions before 2015, Illinois is not dependent on CAIR Phase II reductions for the newest 8-hour standard (75 ppb) or the newest daily fine particulate matter standards, and for which attainment plans are not yet due. Despite the improvement in air quality, Illinois would have much more significant problems in demonstrating attainment in it state implementation plan if CAIR Phase I was not reinstated.

There is some concern that Illinois coal-fired power plants may delay or cancel some controls that were being installed to comply with CAIR Phase I due to the loss of value in SO_2 and NOx allowances. The market value of these allowances is uncertain, because there is controversy over whether the DC Court of Appeal's opinion has disallowed an emissions trading program. As a result, companies have no incentive to go beyond the reductions required by CAIR Phase I because the incentive to install controls early due to the cost recovery benefit of the allowances obtained is removed. Also, many companies have a significant number of banked allowances available for their use or for sale, and these banked allowances will be depleted rather than companies meeting the "emissions cap" through installation and operation of pollution control equipment, perhaps even to the extent of not operating existing or recently installed controls. However, we believe the MPS and CPS should keep Illinois sources on track for installation and operation of the planned control devices and reductions.

After the vacatur of CAIR, the Northeast and Midwest states began a process, called the "State Collaborative Process", the stated intent of which was to develop a multi-pollutant strategy to achieve levels of NOx and SO_2 reductions from the electric utility sector in the 28-state CAIR

region as expeditiously as possible that would remedy CAIR's flaws in accordance with the Court's July 11, 2008 opinion and satisfy the requirements of the Clean Air Act to attain the 1997 national ambient air quality standards (NAAQS) for ozone and PM. While significant progress was made in developing a framework for a CAIR replacement rule, no final recommendation to USEPA has yet been developed. The participating states disagree over the level of reductions that should be required, whether best available controls should be required on every power plant or just the larger/largest units, the timing of controls, whether emissions trading (or even intra-state emissions averaging) is allowable under the Court's decision, and whether a replacement rule can forestall Section 126 petitions under the Clean Air Act.

It is Illinois' experience that emissions trading will result in the greatest amount of reductions at the lowest cost. More importantly, emission trading will encourage companies to install controls earlier, and go beyond required reduction levels, as compared to a command and control strategy. Under a command and control strategy, the regulatory compliance deadline must be set such that there is 100% assurance that every affected source will be able to comply in consideration of the time necessary for planning, engineering and construction deadlines. In other words, there must be sufficient availability of engineering firms, control equipment and construction companies to plan, engineer, build and install all of the pollution control equipment required for compliance. Such a regulatory compliance date would certainly be difficult to establish and likely result in far fewer reductions in the near term when compared to an approach that includes emissions trading. Also, the construction season in many of the affected CAIR states is limited to a 7 to 8 month window, when electric demand is at its highest, further complicating this approach.

In addition to regulatory compliance deadlines, sources (and the states) must be concerned with power outages. In Illinois' opinion and experience in negotiating the MPS and CPS, within the CAIR region, it is not practical (and may not be possible) to retrofit all coal-fired power plants of any significant size (e.g., 25 MWe or more) in the same 3-year window (or even 5-year window). A command and control strategy necessarily sets a date certain for compliance for each affected and similarly situated source. Emissions trading will allow those time frames to be compressed, as source by source compliance is not required.

As Illinois discovered during its MPS and CPS negotiations, there are very significant costs associated with installing pollution controls of the magnitude negotiated under Illinois' rules – estimated in excess of 3 billon dollars. While this cost may be seem small on a kilowatt hour basis, these companies must obtain a rate increase if they are in a regulated state or financing if they are in a deregulated state like Illinois. The ability to obtain a rate increase or financing for these projects is uncertain and takes time, which must be accounted for in a compliance date for any command and control strategy. Emissions trading will allow those time frames to be compressed as well, as source by source compliance is not required.

The vacatur of both CAMR and CAIR emphasizes the high risk associated with moving forward with federal regulations subject to widespread opposition and controversy. Federal regulations will almost certainly be challenged, potentially resulting in further delay of a vital strategy for the states to achieve attainment of the federal air quality standards. Section 126 petitions will surely also be filed by any state that believes its neighbor and upwind states could do more to address nonattainment, even if the complaining state's air quality issues are largely a result of emissions from its own sources (area, mobile and point) and even if the targeted other state(s) has done more to address emissions from its coal-fired power plants than the complaining state. Section 126 petitions will use precious resources that are needed to address the newest recent daily PM2.5 standard, the revised 8-hour standard (75 ppb), the newest lead standard, and the recently-announced, revised NO2 standard. Federal multi-pollutant legislation represents the best option for addressing the points of disagreement among the states, without being bound by interpretations of the scope and flexibility provided under the 1990 Clean Air Act amendments, and in a way that best serves the goal of obtaining the greatest reductions in SO_2, NOx and Hg, in the shortest possible time frame, while taking into account electric costs and reliability.

In conclusion, the multi-pollutant approach taken in Illinois for controlling the emissions of Hg, SO_2, and NO_x from coal-fired power plants has numerous advantages. Whereas the federal CAMR focuses solely on mercury emissions, and CAIR concentrates on SO_2 and NO_x, Illinois' has taken a combined approach that exceeds the goals in the context of a single regulatory framework, accommodating engineering and construction issues and outage schedules, as well as

financing issues. The result has been a tremendous win-win-win for the environment, public health and the regulated community.

Multi-Pollutant Standard & Combined Pollutant Standard – Required Emissions Rates and % Reductions

	CAIR/CAMR[1]		Midwest Generation		Ameren		Dynegy	
	Emission Rate (lbs/mmbtu)	% Reduction	Emission Rate (lbs/mmbtu)	% Reduction	Emission Rate (lbs/mmbtu)	% Reduction	Emission Rate (lbs/mmbtu)	% Reduction
[redacted]								
2010					0.50	52%		
2013	0.50	31%	0.44	13.7%			0.24	56%
2014			0.41	19.6%	0.43	56%		
2015	0.45	34%	0.28	45.1%	0.25	76%	0.19	65%
2016			0.195	61.8%				
2017			0.15	70.6%	0.23	78%		
2018			0.13	74.5%				
2019	0.45	34%	0.11	78.4%[2]	0.23	78%	0.19	65%
NOx								
Annual – 2012	0.15	44%	0.11	62%[3]	0.11	52%	0.10	48%
Annual - 2015	0.12	55%	0.11	62%[3]	0.11	52%	0.10	48%
Seasonal - 2012	-	-	0.11	51%	0.11	22%	0.10	25%

[1]CAIR emission rate numbers from page 5 of the June 28, 2005 USEPA presentation to LADCO (http://www.ladco.org/reports/rpo/Regional%20Air%20Quality/June28_2005/June-Workshop/CAIR%20LADCO%20.pdf). Percent reductions from the USEPA website that provides CAIR reductions expected in Illinois (http://www.epa.gov/cair/il.html). Emissions used for calculations are from Clean Air Markets Divisions of USEPA.

[2]80% including planned shutdowns.

[3]68% including planned shutdowns.

Note: Ameren SO2 rates reflect changes to allowable rates as contained in proposed revision to Illinois mercury rule.

Percent Mercury Reductions from CAMR, Illinois Combined Pollutant Standard (CPS) and Multi-Pollutant Standard (MPS)

Beginning Period	CAMR	[redacted] - CPS	Dynegy - MPS	Ameren - MPS
Mid 2008		21%		
Mid 2009		84% (ACI installed on most units)	(ACI installed on most units)	(ACI installed on most units)
2010	47%		86%	86%
2011		90% (ACI on all units)		
2013[1]		90%	90%	90%
2015[2]		>90%	94.4%	93.5%
2018	78%	95%		

[1]All units have controls installed that are designed to achieve 90% reduction in mercury emissions.

[2]Several units at plant have combination of Scrubber, Baghouse, SCR and/or ACI and many units will achieve greater than 90% reduction in mercury emissions.

All numbers are Illinois EPA estimates.

EXHIBIT 2

The Shaw Group, *EEI Joppa Generating Station Dry Sorbent Injection Test Program Final Report* (September 24, 2010)

* * * * * PC# 2409 * * * E.T.R. 127855AAC STI

6/16/10

Electric Energy, Inc.

FILE IN ORANGE

NFR (A) no seal

October 20, 2010

Mr. Ray Pilapil
Compliance and Systems Management Section
Division of Air Pollution Control
Illinois Environmental Protection Agency
P.O. Box 19276
Springfield, IL 62794-9276

Dear Mr. Pilapil:

On April 28, 2010 Electric Energy, Inc. (EEI) received the Construction Permit (I.D. 127855AAC, Application No. 10030045) for "Pilot Evaluation of Injection System for SO2 Control".

Between June 4, 2010 and June 16, 2010, EEI performed a Dry Sorbent Injection Test by injecting both trona and sodium bicarbonate into the flue gas of units 5 and 6.

As required by Special Condition 6 of the above construction permit, I am submitting a summary of EEI's Dry Sorbent Injection Test.

If you any questions on the enclosed report, please contact Bruce Parker, Senior Engineer, at (618) 543-3458.

Sincerely,

W H Sheppard

William H. Sheppard
President

BP
Certified Mail
Xc: John Justice, IEPA Collinsville Office

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Electric Energy, Inc.

Shaw®
The Shaw Group Inc.®

Joppa Generating Station

EEI

Joppa Generating Station

Dry Sorbent Injection Test Program

Final Report

September 24, 2010

1 Introduction

Electric Energy, Inc (EEI) commissioned The Shaw Group (Shaw Power and Shaw Environmental & Infrastructure, collectively Shaw) to determine whether Dry Sorbent Injection (DSI) in front of the existing electrostatic precipitators (ESP)s would be successful in removing 50% or more of the SO_2 in the gas stream without detrimentally impacting the operation of the ESPs and fly ash handling system.

The scope of work developed jointly by EEI and Shaw was a high level test program. It presented a 10 day test program to determine the optimum location of DSI (before or after the air heaters), the condition the DSI (Trona or sodium bicarbonate) should be injected as (milled or un-milled), and the DSI rate (lbs/hr needed to achieve 50% SO_2 removal).

At the completion of parametric testing on Unit 6, Units 5 and 6 were tested with flue gas testing being performed in the combined stack. This performance testing was to last up to 5 days on a continuous 24 hour basis to determine:

- whether continuous 50% or better SO_2 reduction and continuous 90% mercury removal can be achieved during normal plant operations including turn down of the units due to market demands;
- whether there is an impact to the air heaters (if upstream of the air heaters was the selected DSI point);
- whether there is an impact to the ESP from either DSI reagent
- whether there is an impact to the operation of the fly ash handling system, and;
- whether there are any issues in the handling of DSI that would cause undue hardship on the plant operation.

1.1 Joppa Station

The Joppa Generating Station is a six unit coal fired power plant located at 2100 Portland Road, in Joppa Illinois. The station is located on the Ohio River. Each unit is rated for 181 MW. The plant was commissioned between 1953 and 1955. The plant is currently burning various Powder River Basin Coals.

The Joppa station is operated by Electric Energy Inc., an independent power producer, and is owned by Ameren (80%) and Kentucky Utilities (20%).

The plant's capacity factor is historically greater than 92% inclusive of all planned and forced outages. Normally, all six units are continuously operating at or near their capacity. Therefore, it is imperative that any backend environmental controls implemented at the site are robust and the designs are redundant so as to be highly reliable and not cause forced outages of the plant technology.

The plant is currently equipped with a SO_3 injection systems for flue gas conditioning (fly ash resistivity treatment) and activated carbon injection systems for mercury removal. (The SO_3 injection system was not active during this test program.)

1.2 Division of Responsibility

The study was a collaborative effort among several entities. Overall direction was provided by EEI with support from Shaw, Solvay, and NolTec. The general Division of Responsibilities was as follows:

EEI

- Overall program management
- Plant operations
- Obtain permits / approvals from IEPA
- Obtain reagents and arrange delivery
- Obtain experimental injection equipment and operating services
- Provide plant tie-ins including injection sites, electrical power and trailer space
- Provide office space, conference room and sanitary facilities
- Obtain coal and byproduct samples
- Provide PI data output

Shaw (Shaw Power and Shaw E&I)

- Assist EEI with test program development
- Perform flue gas testing
- Obtain laboratory analysis of solid media
- Perform a characterization study of byproduct materials
- Provide assistance with overall coordination
- Data analysis
- Draft and final reports

NolTec Systems

- Provide, install and demobilize DSI storage, milling and injection equipment
- Provide operators for their equipment
- Record feed rates
- Analyze reagents

Solvay Chemicals

- Arrange for the procurement and delivery of reagents
- Provide consultation on use of reagents

2 Conduct of the Study

2.1 Experimental Design

The study objectives were:

- demonstrate 50% SO_2 removal using DSI
- determine effect of DSI on mercury removal
- determine effect on ESP performance and outlet particulate emissions and opacity
- quantify any changes in certain pollutants including acid gases and some metals
- determine byproduct characteristics to assist with landfill operations; and
- assess the impact of overall operation on plant equipment and infrastructure.

The conduct of the study as it was performed over portions of three weeks is shown in Table 2-1. Some changes were made from the original design as the program progressed in the field. Changes were judged necessary given data as it was reviewed or in some cases, changes were made because it was judged that results would not be meaningful.

Sample point locations included the following locations:

- Economizer Outlet - consisted of two parallel ducts (Duct A & B) each with a cross sectional area of 230 square feet at the sampling location.
- ESP Inlet - consisted of two parallel ducts (Duct A & B) each with a cross sectional area of 230 square feet at the sampling location.
- ESP Outlet - consisted of two parallel ducts (Duct A & B) each with a cross sectional area of 250 square feet at the sampling location.
- Common #3 Tall Stack - single annular stack with an 18 foot diameter at the sampling location.

For gas samples (Hg and CEMs) selection of the sampling point at each location was based on first traversing each location taking flow and temperature readings and selecting the point most representative for that location. For particulates the locations were traversed during sampling (2 ports for the ESP sample locations). This sampling methodology, though not totally consistent with EPA sampling protocols, was chosen based on cost considerations and the comparative analyses needed for this engineering study.

All CEMS (e.g. O_2, CO_2, NO_x) measurements were conducted at a single point centrally located inside Duct A of each designated sampling location, simultaneously with each wet chemistry method (e.g. PM, Hg). Wet chemistry sampling trains were located at the common #3 Tall Stack and a single centralized location inside Duct B of each sampling location .

Table 2-1 - DSI Test Program
(as performed)
Units 5 and 6 - Joppa Station

Date	Test Day	Purpose	Injection location	Reagent Injected	Sampling	Additional Information
June 1,2,3 Tuesday		Travel and mobilization, Setup injection and test equipment	NA	NA	NA	NA
June 4 Friday	1	Baseline testing.	NA	None	Two runs. Unit 6. CEMs in/out; OHM in/out; PM in/out; stack-OHM, TM29, TM26A, TM8A; TM30B. Coal, ash, byproduct.	Test coal at ~1 lb SO_2/MMBtu . 5 lb AC/Macf. No DSI. No SO_3 injection.
June 5 Saturday	2	Baseline testing.	NA	None	Two runs. Unit 6. CEMs in/out; OHM in/out; PM in/out; stack-OHM, TM29, TM26A, TM8A; TM30B. Coal, ash, byproduct.	Test coal at ~1 lb SO_2/MMBtu . 5 lb AC/Macf. No DSI. No SO_3 injection.
June 7 Monday	3	Un-milled Trona injection	Upstream of air heater	Trona	Three runs. CEMs in/out; OHM in/out; PM in/out.	Determine un-milled Trona injection rate for 50% reduction.
June 8 Tuesday	4	Milled Trona injection	Upstream of air heater	Trona	Three runs. CEMs in/out; OHM in/out; PM in/out.	Determine milled Trona injection rate for 50% reduction. Onsite milling.
June 9, Wednesday	5	Milled Trona Injection	Down-stream of air heater	Trona	Morning runs. CEMs (only) in/out	Determine milled Trona injection rate for 50% reduction. Onsite milling.

Table 2-1 - DSI Test Program
(as performed)
Units 5 and 6 - Joppa Station

Date	Test Day	Purpose	Injection location	Reagent Injected	Sampling	Additional Information
June 9, Wednesday	5	Pre-milled SBC injection	Down-stream of air heater	SBC	Afternoon runs. CEMs (only) in/out	Determine SBC injection rate for 50% reduction
June 10 Thursday	6	Pre-milled SBC injection	Upstream of air heater	SBC	Three runs. CEMs in/out; OHM in/out; PM in/out.	Determine SBC injection rate for 50% reduction.
June 11, Friday	7	Pre-milled SBC injection	After air heater	SBC	Units 5 & 6. Three runs. CEMs (only) in/out	Parametric study to determine SO_2 reduction at varying feed rates.
June 14, Monday	8	Pre-milled SBC injection	After air heater	SBC	Units 5 & 6. Three runs. CEMs (only) in/out (stack CEMs)	Determine SBC injection rate for 50% reduction, two unit injections.
June 15 Tuesday	9	Pre-milled SBC injection	After air heater	SBC	Three runs. Unit 5&6. CEMs in/out; OHM in/out; PM in/out; stack-OHM, TM29, TM26A, TM8A; TM30B. TM5 and 202; Coal, ash, byproduct (5 x 5 gallons).	
June 16, Wednesday		Testing terminated due to Unit 5 tube leak outage.				

2.2 Reagent Characteristics

2.2.1 Trona

Trona is derived from sodium sesquicarbonate rock. Its formula is $Na_2CO_3.NaHCO_3.2H_2O$. The rock is typically milled and delivered at a fineness of 30 – 35 microns. Typical moisture of delivered product is 0.03%. (SOLVAY, 2010). Delivery sheets are found in Attachment 5.

Trona materials were secured from Solvay Chemicals, Inc, Houston, Texas. The product is identified as: SOLVAir Select 200 BULK (Material Code 60178). Customer Specification Number is SS200-0108. Characteristics of Trona as delivered comes from truck invoices, as follows:

Table 2-2 – Trona Characteristics as Delivered

Rail Car ACFX045644 – Two loads reported				
	Result	Unit	Minimum	Maximum
Wet Trona	97.3	%	95.0	
Free Moisture	0.02	%		0.07
D(50)	31	Micron		46
+70 Micron	27	%		
Rail Car ACFX051251 – Two loads reported				
	Result	Unit	Minimum	Maximum
Wet Trona	97.6	%	95.0	
Free Moisture	0.03	%		0.07
D(50)	39	Micron		46
+70 Micron	32	%		
Rail Car SHPX450385 – One load reported				
	Result	Unit	Minimum	Maximum
Wet Trona	96.9	%	95.0	
Free Moisture	0.02	%		0.07
D(50)	41	Micron		46
+70 Micron	33	%		
Rail Car ACFX045451 – One load reported				
	Result	Unit	Minimum	Maximum
Wet Trona	97.8	%	95.0	
Free Moisture	0.02	%		0.07
D(50)	46	Micron		46
+70 Micron	36	%		

On certain days, onsite milled Trona was used for injection. Particle size analysis was conducted by Sturtevant from samples provided by NolTec. Laboratory data are provided in Attachment 5. The "as delivered" Trona had a D50 of 39 microns. The milled Trona had a measured D50 of 26 microns.

2.2.2 Sodium Bicarbonate (SBC)

Sodium bicarbonate is a downstream product made from Trona. Its formula is $NaHCO_3$. Pre-milled materials are delivered at D_{90} of < 40 microns. In literature, Solvay recommends onsite milling to <20 microns prior to injection (Solvay, 2010. Dry Sorbent Injection of Sodium Sorbents. Emissions Control and Measurement Workshop. March 24-25, 2010).

The pre-milled SBC materials were secured from Solvay Chemicals, Inc, Houston, Texas. The product is identified as: BIR SOLVAIR SELECT 350 HNM BULK (Solvay Material Code 65591) also known as SOLVAIR 350 BULK. The trucks delivering the product were loaded from bulk bags which had been storing the pre-milled SBC.

Material Certifications provided with each delivery had descriptions –

Customer Material Specification:

Sodium, as Na >= 27.00 %
Sodium Bicarbonate, as $NaHCO_3$ = 99.0 – 100.50%
Screen Analysis % Retained…
US 200 (75 micron) 20 – 100%
US 325 % (45 micron) 60 - 100%

It should be noted that much of the delivered SBC had clumps of material within the delivered bulk causing unloading problems. These clumping and unloading problems were not seen with the delivered un-milled Trona. Certifications are provided in Attachment 5.

2.3 NolTec DSI Feed Equipment

The DSI system was "Sorb-N-Ject" provided by NolTec Systems, Lino Lakes, MN. (Drawings and additional information on the NolTec provided system can be found in Attachment 3.) The system had one portable free standing storage silo. The silo capacity was 1450 cu ft. The silo had load cells for monitoring weight loss of materials. Weight loss as a function of time was used in the field to quantify the feed rate. When filling, a bin vent filter controlled dust from displaced air and material transport air. Feed was controlled by dual-speed adjustable rotary feeders. The silo was filled, as needed, by bulk carrier trucks. Trucks generally contained 45,000 – 50,000 pounds of material. Silo fill time was about one hour when there was no reagent clumping.

A portable blower trailer was also provided. The design capacity of the sorbent feed system was 20,000 lb/hr. The blowers were positive displacement rotary blowers driven by a 40 HP motor. Each blower was capable of providing 500 scfm at 11.5 psig. The system included a heat exchanger, conveying piping and injection lances. The trailer also housed control and electric supply equipment and operator space.

The in-line milling system was designed for use with Trona. The Sturtevant Simpactor was a centrifugal, pin-type impact mill. The system had dual plate rotor with one row of pins.

NolTec provided lances were inserted above the air heater (one unit) and below the air heater (two units). They were straight pipes with flat, cutoff ends. Lances were inserted at staggered lengths before the air heater. Lances after the air heater were all the same length.

2.4 Coal

During the performance of the test program, the plant burned two Powder River Basin (PRB) coals; East Thunder (Jacobs Ranch) and Belle Ayr. The significant difference between these two coals was sulfur content with the Jacobs Ranch coal having almost twice the sulfur content with 1.07 lbs/MMBtu SO_2 versus 0.58 lb/MMBtu SO_2 for the Belle Ayr coal. The mercury concentration in the Jacobs Ranch coal was also higher. Table 2-3 presents the analyses of the daily samples of the coals. It should be noted that for coal utilization, the daily sample was taken from the .

Table 2-3 - Coal Analyses Results

Coal Source	Sample day	Btu/lb	Ash %	Ash lb/ MMBtu	S %	SO_2 lb/ MMBtu	Cl %	As ppm	Ba ppm	Cd ppm	Cr ppm	Pb ppm	Se ppm	Ag ppm	Hg ppm	Hg lb/ TBtu
Jacobs Ranch	6/2/10	8420	5.96	7.08	0.48	1.14	0.02	3.01	302	<1	6.65	3.16	<2	1.5	0.129	15.32
Jacobs Ranch	6/3/10	9150	6.79	7.42	0.49	1.07	0.02	2.48	307	<1	6.5	2.43	<2	1.5	0.097	10.60
Jacobs Ranch	6/4/10	8420	5.85	6.95	0.5	1.19	0.01	<2	308	<1	6.21	2.14	<2	1.49	0.098	11.64
Jacobs Ranch	6/5/10	8370	5.5	6.57	0.48	1.15	0.02	<2	315	<1	6.0	3.2	<2	1.47	0.099	11.83
Jacobs Ranch	6/6/10	8710	5.64	6.48	0.44	1.01	0.02	<2	300	<1	5.91	1.65	<2	1.8	0.111	12.74
Jacobs Ranch	6/7/10	8630	5.7	6.60	0.49	1.14	0.01	2.21	344	<1	5.92	2.29	<2	1.68	0.081	9.39
Jacobs Ranch	6/8/10	7840	5.17	6.59	0.35	0.89	0.01	<2	377	<1	6.54	2.61	<2	1.59	0.131	16.71
Jacobs Ranch	6/9/10	8390	6	7.15	0.43	1.03	0.02	<2	321	<1	6.38	2.27	<2	1.46	0.103	12.28
Jacobs Ranch	6/10/10	8470	5.63	6.65	0.45	1.06	0.02	<2	311	<1	6.24	2.72	<2	1.27	0.113	13.34
Jacobs Ranch	6/11/10	8430	5.79	6.87	0.45	1.07	0.02	<2	330	<1	5.9	2.49	<2	1.7	0.164	19.45
Comb-ination?	6/12/10	8390	5.02	5.98	0.36	0.86	<0.01	<2	307	<1	5.52	2.05	<2	1.42	0.151	18.00
Belle Ayr	6/13/10	8380	5.04	6.01	0.24	0.57	<0.01	<2	355	<1	4.94	1.66	<2	1.4	0.085	10.14

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Table 2-3 - Coal Analyses Results

Coal Source	Sample day	Btu/lb	Ash %	Ash lb/ MMBtu	S %	SO_2 lb/ MMBtu	Cl %	As ppm	Ba ppm	Cd ppm	Cr ppm	Pb ppm	Se ppm	Ag ppm	Hg ppm	Hg lb/ TBtu
Belle Ayr	6/14/10	8350	5.11	6.12	0.23	0.55	0.02	<2	319	<1	4.63	1.72	<2	1.62	0.083	9.94
Belle Ayr	6/15/10	8510	4.59	5.39	0.26	0.61	0.01	<2	295	<1	4.31	2.19	<2	1.42	0.071	8.34
Averages																
Jacobs Ranch		8483	5.80	6.84	0.46	1.07	0.017	<2.17	322	<1	6.23	2.50	<2	1.55	0.113	13.27
Belle Ayr		8413	4.91	5.84	0.24	0.58	<0.013	<2	323	<1	4.63	1.86	<2	1.48	0.080	9.47
Percent Belle Ayr of Jacobs Ranch		99.18	84.7	85.5	53.4	53.84	76.47	92.2	100.5	100	74.3	74.4	100	95.7	70.75	71.34

3 Test Program Results

The experimental design for the program is described in Section 2.1. The program considered two reagents, Trona and Sodium Bicarbonate (SBC). Trona was injected into duct work at as delivered particle size and after onsite milling. SBC was injected as received. SBC was milled prior to shipping to the site. However, there was some clumping of the SBC in the bulk delivery vehicles. Trona was injected both upstream (un-milled and milled) and downstream (milled) of the air heater (AH). SBC was also injected both upstream and downstream of the air heater. The feed rates of the DSI were varied throughout the test program with the general intent to achieve 50% SO_2 removal and to determine DSI utilization trends versus SO_2 removal. Table 3-1 provides the average DSI feed rates used throughout the tests. These average feed rates are based on the NolTec DSI storage silo load cell readings which are provided in Attachment 6. It should be noted that during some of the test runs DSI was added to the storage silo resulting in unusable load cell readings. During these occasions rotary feeder speeds were used to estimate average DSI rates based on available data near the time of the silo feeding event.

Table 3-1 - Average Dry Sorbent Injection Rates Per Test Event

Date	Run	Start time	End Time	DSI	Injection Location	Average Injection Rate (LB/Hr)	Comments
4-Jun				None	NA	NA	Baseline Testing
5-Jun				None	NA	NA	Baseline Testing
7-Jun	1	12:00	13:00	Un milled Trona	Before air heater – Unit 6	5,971	
7-Jun	2	15:15	17:00	Un milled Trona	Before air heater – Unit 6	11,659	
7-Jun	3	18:00	18:34	Un milled Trona	Before air heater – Unit 6	10,219	
8-Jun	1	9:45	10:47	Milled Trona	Before air heater – Unit 6	8,838	
8-Jun	2	12:29	13:35	Milled Trona	Before air heater – Unit 6	8,561	
8-Jun	3	15:21	16:21	Milled Trona	Before air heater – Unit 6	8,688	
9-Jun	1	10:52	12:31	Milled Trona	After air heater – Unit 6	14,237	
9-Jun	2	15:27	16:00	Pre-milled SBC	After air heater – Unit 6	11,643	
10-Jun	1	10:00	11:03	Pre-milled SBC	Before air heater – Unit 6	7,733	
10-Jun	2	12:45	13:50	Pre-milled SBC	Before air heater – Unit 6	7,275	

Table 3-1 - Average Dry Sorbent Injection Rates Per Test Event

Date	Run	Start time	End Time	DSI	Injection Location	Average Injection Rate (LB/Hr)	Comments
10-Jun	3	15:20	16:27	Pre-milled SBC	Before air heater – Unit 6	6,921	
11-Jun	1	11:23	11:52	Pre-milled SBC	After air heater - Units 5 and 6	5,882	
11-Jun	2	12:14	13:31	Pre-milled SBC	After air heater - Units 5 and 6	11,077	
11-Jun	3	16:14	17:31	Pre-milled SBC	After air heater - Units 5 and 6	14,665	SBC added to silo during test, usage estimates were based on feed valve speed
14-Jun	1	9:53	12:38	Pre-milled SBC	After air heater - Units 5 and 6	9,284	SBC added to silo during test, usage estimates were based on feed valve speed
14-Jun	2	13:05	17:07	Pre-milled SBC	After air heater - Units 5 and 6	9,683	SBC added to silo during test, usage estimates were based on feed valve speed
15-Jun	1	8:50	9:50	Pre-milled SBC	After air heater - Units 5 and 6	10,200	SBC added to silo during test, usage estimates were based on feed valve speed
15-Jun	2	12:15	13:33	Pre-milled SBC	After air heater - Units 5 and 6	9,956	
15-Jun	3	14:59	16:08	Pre-milled SBC	After air heater - Units 5 and 6	10,438	

3.1 Air Emissions Test Results

This section presents summary results of air emissions test data. Details of the tests performed are found in Attachment 1. The plant's SO_3 injection flue gas conditioning system was taken out of service for all tests. Trona, like SO_3, is also used to increase the conductivity of fly ash for removal in ESPs. Trona would also remove the SO_3 before it would be effective. The plant's PAC injection mercury control system remained in operation. PAC was injected at a minimum of 5 lb of PAC/mmacf. At the time of the DSI Test Program, PAC was injected upstream of the air heaters on Units 5 and 6. Plant PI data records were secured during all tests to document plant loads and performance during the test date.

3.1.1 Baseline program

The purpose of the base line program was to document emissions and plant operating characteristics prior to reagent injections. The results from the test injections are compared to the baseline as appropriate.

Baseline testing occurred June 4 and 5. Two test runs were performed on each of the two days. The plant was burning Powder River Basin (PRB) coal with approximate 0.9 to 1.2 lb SO_2/MMBtu content (East Thunder – Jacobs Ranch coal). This is a somewhat higher sulfur content than what the plant normally fires.

At Unit 5, particulate and mercury were measured before the ESP. At Unit 6, SO_2, mercury and particulate were measured before the ESP and particulate, mercury, SO_2 after the ESP. At the combined stack, particulate, mercury, metals, acid gases and SO_3 were measured. Coal was sampled during baseline testing and a five gallon ash sample was secured for comparison to mixed ash/spent reagent.

Plant PI data records were secured during all tests to document plant loads and performance during testing.

Summary SO2 data are shown in Table 3-2. The values presented are the averages of four runs taken over two days.

Table 3-2 - Baseline Summary SO_2 Data
June 4-5, 2010

Measurement	Unit	Value
SO_2 (Unit 6), Economizer Outlet	Lb/hr	1701.95
SO_2 (Unit 6), Economizer Outlet	Lb/MMBtu	0.980
SO_2 (Unit 6), ESP Outlet	Lb/hr	1652.87
SO_2 (Unit 6), ESP Outlet	Lb /MMBtu	0.958

These results were compared to the #3 Tall Stack (units 5 and 6) CEMs data for confirmation. The average SO2 emission from #3 Tall Stack during these test runs was 3,756 lb/hr or based on the assumption that emissions from Unit 5 equal Unit 6 the emission from Unit 6 would be 1,878 lb/hr or about 12% higher than what was read at the ESP outlet. The difference in the results is likely the result of non-uniformed sampling in the duct due to stratification of the flue gas path. Because of this apparent bias between CEMs readings a decision was made to compare sulfur dioxide removal against the stack CEMs readings.

Particulate matter emissions data are shown in Table 3-3. The values presented are the averages of four runs taken over two days. Data indicate overall ESP efficiency of 98.88 percent. The removal efficiency is used in comparing baseline operation with operation during DSI.

Table 3-3 - Baseline Summary Particulate Matter Data
June 4-5, 2010

Measurement	Unit	Value
ESP Inlet (Unit 5 & 6)	Lb/hr	13,685
Combined Outlet	Lb/hr	152.87
Removal Efficiency	Percent	98.88

Total mercury emissions data are shown in Table 3-4. The values presented are the averages of four runs taken over two days for #3 Tall Stack (units 5 and 6). Data indicate overall removal efficiency of 93 percent (based on coal mercury concentration) using the plant's installed PAC injection system. The removal efficiency is used in comparing baseline operation with operation during DSI.

Table 3-4 - Baseline Summary Mercury (Total) Data
June 4-5, 2010

Measurement	Unit	Value
Coal	Lb/hr	0.0468
Coal	Lb/TBtu	11.22
Stack	Lb/hr	0.0033
Stack	Lb/TBtu	0.97
Removal Efficiency	Percent	93

3.1.2 Trona, Un-milled Upstream of the Air Heater

The purpose of this program segment was to document emissions and plant operating characteristics injecting un-milled (D50 of 39 microns) (not milled on site) Trona upstream of the AH. The Trona size analysis is shown in Section 2.2.

The test occurred on 7 June. Three test runs were performed on the test date. The plant was burning coal from the East Thunder (Jacobs Ranch) mine with an approximate 0.9 – 1.2 lb SO_2/MMBtu content. During the performance of the tests one of the DSI blowers

tripped on overheat for about 20 minutes (15:35 – 15:55) which reduced the injection of Trona by one/half for that period of time.

Attachment 3 shows the arrangement of the NolTec injection equipment and lances into the plant ductwork.

In accordance with the test program no measurements were made on Unit 5. On Unit 6, SO_2 and mercury were measured at the economizer outlet "before injection". Particulate matter (TM5) was measured before the ESP and fine particulate (PM_{10} and $PM_{2.5}$), mercury and SO_2 after the ESP. Coal was sampled the day/night before as it was being loaded into the coal bunkers by the autosampler located on the 33 conveyor.

Summary SO_2 data are shown in Table 3-5. Un-milled Trona was injected from 8:45 to 18:55 at varying rates (~3,000 - >13,000 lb/hr). The Trona injection information was compared to the Stack CEMs data to discern a trend. The Unit 6 SO_2 concentration before DSI was estimated based on the SO_2 concentration in the stack before and after DSI with one half of the SO_2 assumed to come from Unit 6. The results were graphed and are shown in Figure 3-1.

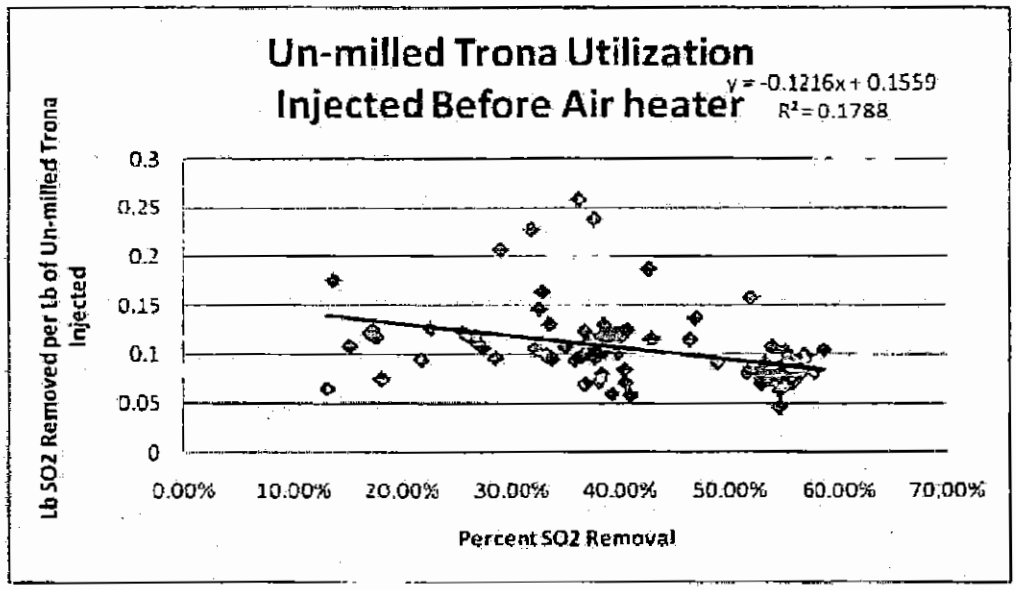

Figure 3-1 – Unmilled Trona Injection Utilization

The results indicate an overall removal efficiency range of 13 – 59% percent and with an efficiency ratio of 0.093 lb SO_2 removed per lb of sorbent injected at 50% SO2 removal.

Table 3-5 - Summary SO_2 Data, Un-milled Trona Injection Upstream of Air Heater June 7, 2010		
Measurement	**Unit**	**Value**
Average SO_2 Units 5 and 6 Before DS Injection during test	Lb/hr	3786
Average SO_2 (Unit 6), before DSI	Lb/hr	1893
Maximum Removal Efficiency Seen	Percent	59
Lb SO_2 Removed/Lb Sorbent at 50% removal	Ratio	0.093
Ton Trona/ Ton SO_2 Removed at 50% removal	Ratio	10.75

Summary particulate matter emissions data are shown in Table 3-6. The values presented are the averages of three one-hour runs. Data indicate overall ESP efficiency of 99.44 percent, somewhat better than the baseline efficiency.

Table 3-6 - Summary Particulate Matter Data, Un-milled Trona Injection Upstream of Air Heater June 7, 2010		
Measurement	**Unit**	**Value**
ESP Inlet (Unit 6)	Lb/hr	15,062
ESP Outlet	Lb/hr	84.70
Removal Efficiency	Percent	99.44

Total mercury emissions data are shown in Table 3-7. The values presented are the averages of three runs. Calculations, discussed in Attachment 1, indicate overall removal efficiency of 87.7 percent (based on coal mercury concentration). This removal efficiency is not necessarily comparable to the baseline since this is based on Unit 6 only and a comparison requires the assumption that unit 6 equals Unit 5 in emissions.

Table 3-7 - Summary Mercury (Total) Data, Un-milled Trona Injection Upstream of Air Heater June 7, 2010		
Measurement	**Unit**	**Value**
Coal	Lb/hr	0.0223
Coal	Lb/TBtu	9.4
ESP Outlet Unit 6	Lb/hr	0.00273
ESP Outlet Unit 6	Lb/TBtu	
Removal Efficiency	Percent	87.7

3.1.3 Trona, Milled Upstream of the Air heater

The purpose of this program segment was to document emissions and plant operating characteristics injecting milled (D50 of 26 microns) (milled on site) Trona upstream of the AH. Laboratory size analysis for the milled Trona can be found in Attachment 5.

The test occurred on 8 June. Milled Trona was injected from 9:10 to 16:40 at an average uniform rate of about 8600 lb/hr. The plant was burning coal from the East Thunder (Jacobs Ranch) mine with an approximate 0.9 – 1.2 lb SO_2/MMBtu content.

Attachment 3 shows the arrangement of the NolTec injection equipment and lances into the plant ductwork.

In accordance with the test program no measurements were taken on Unit 5. On Unit 6, SO_2 and mercury were measured at the economizer outlet "before injection". Particulate matter (TM5) was measured before the ESP and fine particulate (PM_{10} and $PM_{2.5}$), mercury and SO_2 after the ESP. Coal was sampled the day/night before as it was being loaded into the coal bunkers by the autosampler located on the 33 conveyor.

Summary SO_2 data are shown in Table 3-8. The Trona injection information was compared to the Stack CEMs data. The Unit 6 SO_2 concentration before DSI was estimated based on the SO_2 concentration in the stack before and after DSI with one half of the SO_2 assumed to come from Unit 6. The values presented are the average of the injection throughout the day. The values indicate an overall removal efficiency of 52.6 percent and with an efficiency ratio of 0.10 lb SO_2 removed per lb of sorbent injected. The ratio shows an improvement in removal efficiency over un-milled Trona.

Table 3-8 - Summary SO_2 Data, Milled Trona Injection Upstream of Air Heater June 8, 2010

Measurement	Unit	Value
Average SO_2 Units 5 and 6 Before DS Injection during test	Lb/hr	3273
Average SO_2 (Unit 6), before DSI	Lb/hr	1637
Removal Efficiency	Percent	52.6
Lb SO_2 Removed/Lb Sorbent	Ratio	0.10
Ton Trona/Ton SO_2 Removed	Ratio	10

Summary particulate matter emissions data are shown in Table 3-9. The values presented are the averages of three one-hour runs. Data indicate overall ESP efficiency of 98.68 percent, not quite as good as the baseline efficiency or that for un-milled Trona.

Table 3-9 - Summary Particulate Matter Data, Milled Trona Injection Upstream of Air Heater June 8, 2010		
Measurement	**Unit**	**Value**
ESP Inlet (Unit 6)	Lb/hr	12,774
ESP Outlet	Lb/hr	168.09
Removal Efficiency	Percent	98.68

Total mercury emissions data are shown in Table 3-10. The values presented are the averages of three runs. Calculations, discussed in Attachment 1, indicate overall removal efficiency of 84.1 percent (based on coal mercury concentration). This removal efficiency is not necessarily comparable to the baseline since this is based on Unit 6 only and a comparison requires the assumption that unit 6 equals Unit 5 in emissions..

Table 3-10 - Summary Mercury (Total) Data, Milled Trona Injection Upstream of Air Heater June 8, 2010		
Measurement	**Unit**	**Value**
Coal	Lb/hr	0.0387
Coal	Lb/TBtu	16.7
ESP Outlet Unit 6	Lb/hr	0.00615
ESP Outlet Unit 6	Lb/TBtu	3.8
Removal Efficiency	Percent	84.1

3.1.4 Trona, Milled Downstream of the Air Heater

The purpose of this program segment was to document the SO_2 emissions and plant operating characteristics injecting milled (D50 of 26 microns) (milled on site) Trona downstream of the AH.

The test occurred on morning of 9 June. Milled Trona was injected from 8:50 to 12:30 at an average injection rate of 14,493 lb/hr once the injection rate was stabilized. The plant was burning coal from the East Thunder (Jacobs Ranch) mine with an approximate 0.9 – 1.2 lb SO_2/MMBtu content.

Attachment 3 shows the arrangement of the NolTec injection equipment and lances into the plant ductwork.

In accordance with the test program no measurements were taken on Unit 5. On Unit 6, SO_2 was measured at the economizer outlet "before injection", and after the ESP. Coal was sampled during testing.

Summary SO_2 data are shown in Table 3-11. The Trona injection information was compared to the Stack CEMs data. The Unit 6 SO_2 concentration before DSI was

estimated based on the SO_2 concentration in the stack before and after DSI with one half of the SO_2 assumed to come from Unit 6. The values presented are from the morning run. The values indicate an average removal efficiency of 42.6 percent and with an efficiency ratio of 0.049 lb SO_2 removed per lb of sorbent injected. The ratio shows this scenario, injecting downstream of the AH, to be the least efficient of the Trona test alternatives.

Table 3-11 - Summary SO_2 Data, Milled Trona Injection Downstream of Air Heater
June 9, 2010

Measurement	Unit	Value
Average SO_2 Units 5 and 6 Before DS Injection during test	Lb/hr	3,339
Average SO_2 (Unit 6), before DSI	Lb/hr	1,670
Removal Efficiency	Percent	42.6
Lb SO_2 Removed/Lb Sorbent	Ratio	0.049
Ton Trona/Ton SO_2 Removed	Ratio	20.4

It was anticipated that this test scenario would be no be better, and probably worse than the injection before the AH due to the lower temperature of the flue gas. Thus no additional parameters were sampled. This was a CEMs only test.

3.1.5 Sodium Bicarbonate Downstream of the Air Heater

The purpose of this program segment was to document the SO_2 emissions and plant operating characteristics injecting SBC downstream of the AH.

The test occurred on afternoon of 9 June. SBC was injected from 14:40 to 16:00 with the feed rate ramping up from about 7000 lb/hr up to 11,750 lb/hr. The plant was burning coal from the East Thunder (Jacobs Ranch) mine with an approximate 0.9 – 1.2 lb SO_2/MMBtu content.

Attachment 3 shows the arrangement of the NolTec injection equipment and lances into the plant ductwork.

In accordance with the test program no measurements were taken on Unit 5. On Unit 6, SO_2 was measured at the economizer outlet "before injection"and after the ESP. Coal was sampled during testing.

Summary SO_2 data are shown in Table 3-12. The SBC injection information was compared to the Stack CEMs data. The Unit 6 SO_2 concentration before DSI was estimated based on the SO_2 concentration in the stack before and after DSI with one half of the SO_2 assumed to come from Unit 6. The results indicate an overall removal efficiency of 60 percent and with an efficiency ratio of 0.084 lb SO_2 removed per lb of

sorbent injected. The ratio and removal efficiency values were based on average 11,750 lb/hr reagent injection.

Table 3-12 - Summary SO_2 Data, SBC Injection Downstream of Air Heater June 9, 2010

Measurement	Unit	Value
Average SO_2 Units 5 and 6 Before DS Injection during test	Lb/hr	3,288
Average SO_2 (Unit 6), before DSI	Lb/hr	1,644
Removal Efficiency @11,750 lb/hr feed rate	Percent	60
Lb SO_2 Removed/Lb Sorbent	Ratio	0.084
Ton SBC/Ton SO_2 Removed	Ratio	11.9

3.1.6 Sodium Bicarbonate Upstream of the Air Heater Testing

The purpose of this program segment was to document emissions and plant operating characteristics injecting SBC upstream of the AH.

The test occurred on 10 June. SBC was injected from 8:30 to 16:55 at an average injection rate of 7,380 lb/hr The plant was burning coal with an approximate 0.9 – 1.2 lb SO_2/MMBtu content.

Attachment 3 shows the arrangement of the NolTec injection equipment and lances into the plant ductwork.

In accordance with the test program no measurements were taken on Unit 5. On Unit 6, SO_2 and mercury were measured at the economizer outlet "before injection". Particulate matter (TM5) was measured before the ESP and fine particulate (PM_{10} and $PM_{2.5}$), mercury and SO_2 after the ESP. Coal was sampled during testing.

Summary SO_2 data are shown Table 3-13. The SBC injection information was compared to the Stack CEMs data. The Unit 6 SO_2 concentration before DSI was estimated based on the SO_2 concentration in the stack before and after DSI with one half of the SO_2 assumed to come from Unit 6. The results indicate an average removal efficiency of 67.1 percent and with an efficiency ratio of 0.158 lb SO_2 removed per lb of sorbent injected. The ratio shows an improvement in removal efficiency over Trona and SBC injection after the air heater.

Table 3-13 - Summary SO_2 Data, SBC Injection Upstream of Air Heater June 10, 2010		
Measurement	**Unit**	**Value**
Average SO_2 Units 5 and 6 Before DS Injection during test	Lb/hr	3,474
Average SO_2 (Unit 6), before DSI	Lb/hr	1,737
Removal Efficiency	Percent	67.1
Lb SO_2 Removed/Lb Sorbent	Ratio	0.158
Ton SBC/Ton SO_2 Removed	Ratio	6.33

Summary particulate matter emissions data are shown Table 3-14. The values presented are the averages of three one-hour runs. Data indicate overall ESP efficiency of 97.80 percent, not quite as good as the baseline efficiency.

Table 3-14 - Summary Particulate Matter Data, SBC Injection Upstream of Air Heater June 10, 2010		
Measurement	**Unit**	**Value**
ESP Inlet (Unit 6)	Lb/hr	10,401
ESP Outlet	Lb/hr	228.96
Removal Efficiency	Percent	97.80

Total mercury emissions data are shown Table 3-15. The values presented are the averages of three runs. Data indicate overall removal efficiency of 85.8 percent (based on coal mercury concentration. This removal efficiency is not necessarily comparable to the baseline since this is based on Unit 6 only and a comparison requires the assumption that Unit 6 equals Unit 5 in emissions.

Table 3-15 - Summary Mercury (Total) Data, SBC Injection Upstream of Air Heater June 10, 2010		
Measurement	**Unit**	**Value**
Coal	Lb/hr	0.0321
Coal	Lb/TBtu	16.7
ESP Outlet Unit 6	Lb/hr	0.00455
ESP Outlet Unit 6	Lb/TBtu	2.33
Removal Efficiency	Percent	85.8

3.1.7 Sodium Bicarbonate Downstream of the Air Heater Parametric Testing

The purpose of this program segment was to document emissions and plant operating characteristics injecting SBC downstream of the AH. The amount of SBC added was adjusted throughout the day (9:10 - 19:35) to obtain a trend between SO_2 removal and

SBC injected. The SBC was added to both Units 5 and 6 from 3500 to about 16,000 lbs/hr (or from 1,750 – about 8,000 lb/hr/unit)

The test occurred on 11 June. The plant was burning coal from the East Thunder (Jacobs Ranch) mine with an approximate 0.9 – 1.2 lb SO_2/MMBtu content. During the performance of the tests both units 5 and 6 had temporary coal feeder issues that resulted in temporary minor reductions in plant output.

Attachment 3 shows the arrangement of the NolTec injection equipment and lances into the plant ductwork.

In accordance with the test program no measurements were taken on Unit 5. On Unit 6, SO_2 was measured at the economizer outlet "before injection"and after the ESP. Coal was sampled during testing.

The SBC injection information was compared to the Stack CEMs data to discern a trend. The Unit 5 and 6 SO_2 amount before DSI was estimated based on the SO_2 concentration in the stack before and after DSI. The results were graphed and are shown in Figure 3-2.

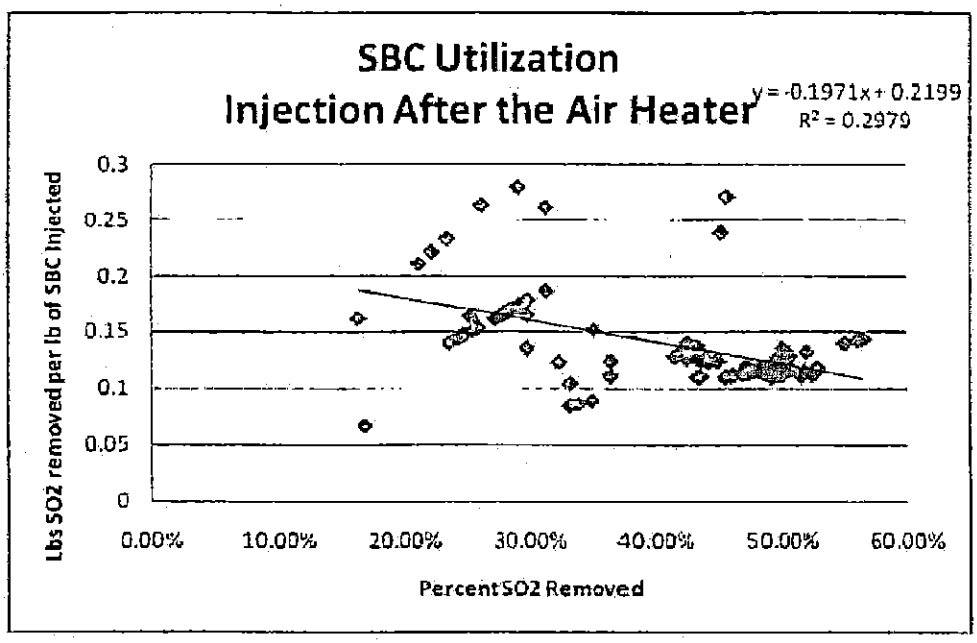

Figure 3-2 – SBC Utilization, Injection After the Air Heater

Summary SO_2 data are shown Table 3-16. The removal efficiency range of 16 - 53 percent was seen and with an efficiency ratio of 0.121 lb SO_2 removed per lb of sorbent injected at 50% SO2 removal.

Table 3-16 - Summary SO_2 Data, SBC Injection Downstream of Air Heater Units 5 and 6, June 11, 2010		
Measurement	**Unit**	**Value**
Average SO_2 Before DS Injection during test	Lb/hr	1983.3
Maximum Removal Efficiency Seen	Percent	53
Lb SO_2 Removed/Lb Sorbent at 50% SO_2 removal	Ratio	0.121
Ton SBC/Ton SO_2 Removed	Ratio	8.26

3.1.8 Sodium Bicarbonate Downstream of the Air Heater Units 5 and 6 Steady State Testing

The purpose of this program segment was to document emissions and plant operating characteristics injecting SBC downstream of the AH on a continuous basis.

The test occurred on 14 June. The plant was burning coal from the Belle Ayr mine with an approximate 0.6 lb SO_2/MMBtu content. This is a coal with a lower sulfur content than what the plant was burning during earlier test days. SBC was injected into both Units 5 and 6 from 10:00 – into June 15 at an average injection rate of 9,980 lb/hr after initial ramp up. The operation of the ESPs were impacted by the combination of the Belle Ayr coal and the SBC injection with lower power levels and an initial increase of 4-5% in opacity. This spike stabilized and the opacity trended down as the tests continued.

Attachment 3 shows the arrangement of the NolTec injection equipment and lances into the plant ductwork.

CEMs measurements were taken on Unit 5 and Unit 6, at the economizer outlet, before injection. The plant CEMs in #3 Tall Stack was used to measure SO_2 emissions. Coal was sampled during testing.

Summary SO_2 data are shown Table 3-17. The results indicate an overall removal efficiency of 54.7 percent and with an efficiency ratio of 0.112 lb SO_2 removed per lb of sorbent injected.

Table 3-17 - Summary SO_2 Data, SBC Injection Downstream of Air Heater Units 5 and 6, June 14, 2010		
Measurement	**Unit**	**Value**
Average SO_2 Before DS Injection during test	Lb/hr	2,036
Average SBC injection	Lb/hr	9,980
Removal Efficiency	Percent	54.7
Lb SO_2 Removed/Lb Sorbent	Ratio	0.112
Ton SBC/Ton SO_2 Removed	Ratio	8.93

3.1.9 Continued Sodium Bicarbonate Downstream of the Air Heater Units 5 and 6 Steady State Testing

The purpose of this program segment was to to continue to document emissions and plant operating characteristics injecting SBC downstream of the AH on a continuous basis.

The test occurred on 15 June and into 16 June. The plant was burning coal from the Belle Ayr mine with approximate 0.6 lb SO_2/MMBtu content. This is a coal with a lower sulfur content than was burned in the first two weeks of tests.

SBC was injected into Units 5 and 6 for all of June 15 and into June 16. Full load operation of Units 5 and 6 began about 6:25. The average SBC injection rate was about 9,960 lb/hr for both units during full load operation. This testing was curtailed when Unit 5 developed a tube leak resulting in the unit being taken out of service around 5:00 am on June 16.

Attachment 3 shows the arrangement of the NolTec injection equipment and lances into the plant ductwork.

On Unit 5 and Unit 6, CEMs measurements and mercury were sampled at the economizer outlet. On both units, particulate matter (TM5) was measured at the ESP inlet. Mercury, metals, acid gases, SO_3 and particulate were measured at the common #3 Tall Stack.

Summary SO_2 data are shown Table 3-18. The values indicate an overall removal efficiency of 54.7 percent and with an efficiency ratio of 0.113 lb SO_2 removed per lb of sorbent injected. This feed rate and removal efficiency continued into June 16 until Unit 5 was brought down at about 5 am. SBC injection continued at a reduced rate with just Unit 6 in operation with an average feed rate for Unit 6 of 4,950 lb/hr, with 52.9% SO_2 removal efficiency and a 0.109 Lb SO_2Removed/Lb Sorbent utilization.

Table 3-18 - Summary SO_2 Data, SBC Injection Downstream of Air Heater Units 5 and 6, June 15, 2010

Measurement	Unit	Value
Average SO_2 Units 5 and 6 Before DS Injection during test	Lb/hr	1055.7
Average SBC injection Rate	Lb/hr	9,960
Removal Efficiency	Percent	54.7
Lb SO_2 Removed/Lb Sorbent	Ratio	0.113
Ton SBC/Ton SO_2 Removed	Ratio	8.85

Summary particulate matter emissions data are shown Table 3-19. The values presented are the averages of three one-hour runs. Data indicate overall ESP efficiency of 99.02 percent, better than baseline efficiency. Although the efficiency is somewhat better than

the baseline, the real problem is the total particulate is 75 lb/hr more than measured with the baseline testing.

Table 3-19 - Summary Particulate Matter Data, SBC Injection Downstream of Air Heater June 15, 2010

Measurement	Unit	Value
ESP Inlet (Unit 5)	Lb/hr	10,367
ESP Inlet (Unit 6)	Lb/hr	12,822
Stack	Lb/hr	227.70
Removal Efficiency	Percent	99.02

Total mercury emissions data are shown Table 3-20. The values presented are the averages of three runs. Data indicate overall removal efficiency of 93.7 percent (based on coal mercury concentration), which is consistent with the baseline efficiency. The removal efficiency represents the combined removal of the DSI and PAC injection system.

Table 3-20 - Summary Mercury (Total) Data, SBC Injection Downstream of Air Heater June 15, 2010

Measurement	Unit	Value
Coal	Lb/hr	0.0186
Coal	Lb/TBtu	8.34
Stack	Lb/hr	0.00235
Stack	Lb/TBtu	0.65
Removal Efficiency	Percent	93.7

3.1.10 Comparison of Certain Metals Emissions, During Baseline and SBC Injection

Ten metals were measured in the stack during the baseline sampling and again when injecting SBC on the final day of testing. Different coals were burned between the two test days. Table 2-3 shows the analyses of the two coals during the test period.. From a visual review of the data, it is not evident that SBC had an impact on metals emissions, either positive or negative. There is some indication that SBC may have decreased the amount of nickel or selenium in the emissions.

3.1.11 Comparison of Acid Gas Emissions, During Baseline and SBC Injection

Hydrochloric acid and hydrofluoric acid gases were measured in the stack during baseline sampling and when injecting SBC on the final day of testing. The average emission rates are shown in Table 3-21. Different coals were burned between the two test days. Table 2-3 shows that the Jacobs Ranch coal had on average slightly greater concentrations of

chlorine than Belle Ayr coal, however, on the days tested the chlorine concentrations were similar. Fluorine concentrations were not sampled.

Assuming the Belle Ayr coal had similar concentrations of chlorine and the same or higher concentrations of fluorine, approximately 80% of the acid gases were removed when comparing the baseline test results with the SBC injection results.

Table 3-21 - Comparison of Acid Gas Emissions

Date	Test	Average HCl Lb/hr	Average HF Lb/hr
4-5-Jun (1)	Baseline	2.335	6.21
15-Jun(2)	SBC after the air heater	<0.53	1.23
	Removal (3)	>77.3%	80.2%

Notes:

1. Burned East thunder (Jacobs Ranch) PRB Coal
2. Burned Belle Ayr PRB Coal
3. Based on the assumption that the two coals have the same concentrations of chlorine and fluorine

3.1.12 DSI Impacts on NOx Emissions

The NOx emissions between the baseline sample dates and the DSI dates were reviewed to see if there was a discernable impact of DSI on NOx emissions. The data is included in Attachment 1. Little to no reduction in NOx emissions was seen with the injection of dry sorbent.

3.2 Comparison of Dry Sorbent Utilization

3.2.1 Dry Sorbent Utilization versus SO_2 Removal

A comparison of the amount of SO_2 removed against the amount and type of DSI was made to delineate the utilization efficiency of each of the dry sorbents used. Since the SO_2 concentration in the flue gas varied with time over the test runs a comparison of the dry sorbent utilized needs to be compared on an amount of SO_2 removed to amount of dry sorbent used. It should be noted that the SBC utilized during the test program was pre-milled. However, when it arrived portions of the SBC had clumped together resulting in unloading problems. This clumping may be indicative of a general degradation in the particle size (increase in particle size from the milled state) that could impact the SBC performance.

Table 3-22 provides a tabular comparison of the dry sorbent injected versus SO_2 removed.

The test results for SBC injection were graphed as provided in Figure 3-3 below.

Table 3-22 - SO_2 Removed Versus Dry Sorbent Utilization

Date	Injection Duration W/ Plant at Full Load	DS	Injection Location	Average Injection Rate (LB/Hr)	SO_2 Removal Efficiency	Lbs SO_2 Removed per Lb DS	Tons DS per Ton SO_2 Removed
7-Jun	8:45 – 18:35	Un milled Trona	Before air heater – Unit 6	3,000 - >13,000	13 – 59	0.093 @ 50% SO_2 removal	10.75
8-Jun	9:10 – 16:40	Milled Trona	Before air heater – Unit 6	8,600 +/-	52.6	0.10	10
9-Jun	8:50 – 12:30	Milled Trona	After air heater – Unit 6	14,493	42.6	0.049	20.4
9-Jun	14:40 – 16:00	Pre-milled SBC	After air heater – Unit 6	11,750	60	0.84	11.9
10-Jun	8:30 – 16:55	Pre-milled SBC	Before air heater – Unit 6	7,380	67.1	0.158	6.33
11-Jun	9:10 – 19:35	Pre-milled SBC	After air heater - Units 5 and 6	3,500 – 16,000	16 – 53	0.121 @ 50% SO_2 removal	8.26
14-Jun	10:00 – 24:00	Pre-milled SBC	After air heater - Units 5 and 6	9,980	54.7	0.112	8.93
15 - 16-Jun	6:25 - 4:55 (6-16)	Pre-milled SBC	After air heater - Units 5 and 6	9,960	54.7	0.113	8.85
16-Jun	5:35 – 6:30	Pre-milled SBC	After air heater - Unit 6	4,950	52.9	0.109	9.17

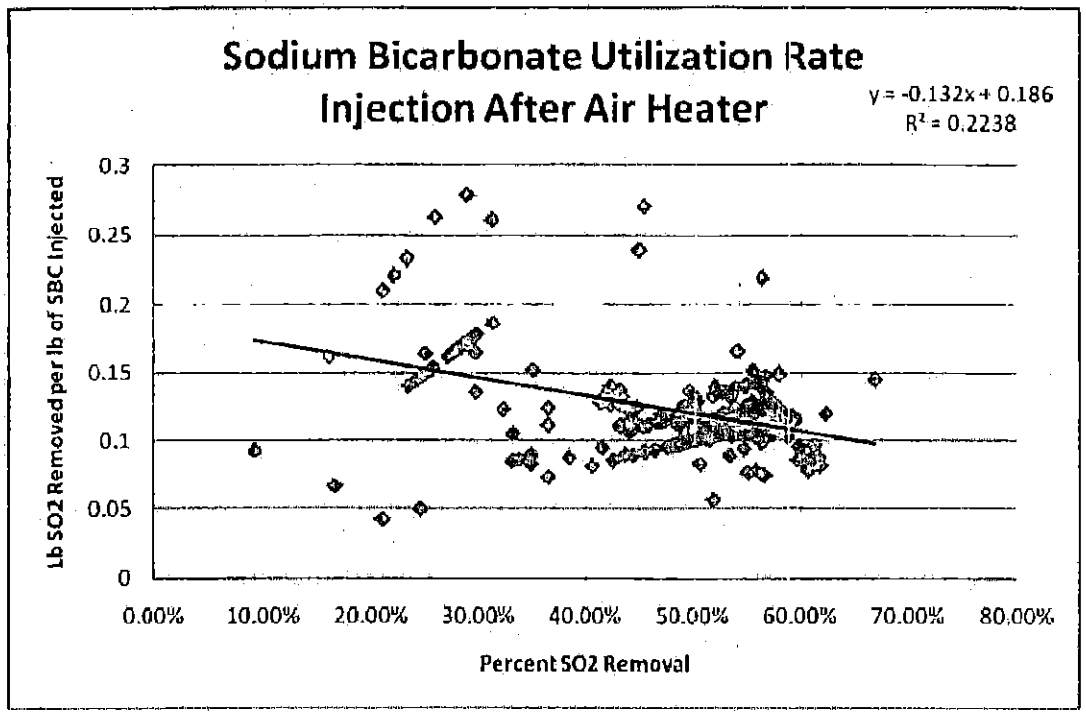

Figure 3-3 – Efficiency of SO_2 Removal Using SBC After The Air heater

Some general conclusions can be made from reviewing the comparisons provided in Table 3-22 and in Figure 3-3:

- Greater than 50% SO_2 removal was obtained with un-milled Trona, and milled Trona before the air heater and with SBC before or after the air heater
- 50% removal was not seen with milled Trona after the air heater
- SBC had a better utilization efficiency (0.158 lbs SO_2 removed per lb of dry sorbent) (6.33 tons of SBC/ton of SO_2 removed) than milled Trona (0.100 lbs SO2 removed per lb of dry sorbent) (10 tons of Trona/ton of SO_2 removed) when injection was before the air heaters.
- Milled Trona was more efficient than un-milled Trona in SO_2 removal (ratio averages 0.100 vs. 0.093, lbs SO2 removed per lb of dry sorbent respectively) (10 vs. 10.75 tons of Trona/ton of SO_2 removed) when injected before the air heater
- The injection location (whether before or after the air heater) impacts the efficiency of Trona and SBC utilization, with injection before the air heater having a significantly greater utilization efficiency (About half of the Trona was needed per lb of SO2 removed and about 75% of SBC was needed with injection before the air heater)
- The trend line for SBC utilization shows that the SBC utilization efficiency decreases with increased % SO_2 removal
- When using SBC for 50% SO_2 removal, a utilization rate of about 0.12 lbs SO_2 removed per lb of SBC is needed (8.3 tons of SBC/ton of SO_2 removed) with injection after the air heater and a significantly greater utilization (>0.158 lbs SO2 removed per lb of dry sorbent) (<6.33 tons of SBC/ton of SO_2 removed) if injection is before the air heater.
- Dry sorbent injection will reduce acid gases; DSI reduced HCl and HF acid gases by approximately 80% when the DSI system was operated at an SO2 removal efficiency of 50%.

3.2.2 Impacts of Dry Sorbent Utilization on Particulate Emissions

A comparison of the Unit 5 and 6 stack total particulate emissions during baseline testing (June 4-5, 2010) versus total particulate emissions during steady state SBC injection (June 15, 2010) are shown in Table 3-23. This comparison shows an increase in total particulates of 74.83 lbs/hr with the injection of dry sorbent. This equates to increase in total particulates of 295 tons/yr from Units 5 and 6 assuming a 90% capacity factor.

Table 3-23 - Comparison of Total Particulate Emissions							
Test Date	DSI	Injection Location	Total Particulate Inlet to ESP (lb/hr)		#3 Tall Stack Total Particulate Emissions (lb/hr)	ESP Collection Efficiency (Percent)	Outlet Particulate Emissions (lb/MMBtu)
6/4-5/2010 (1)	Baseline	NA	Unit 5	6,822			
			Unit 6	6,863			
			Total	13,685	152.87	98.88%	0.046
6/15/2010 (2)	Steady-State SBC @ 10,159 lb/hr avg)	Down Stream of Air Heater	Unit 5	10,294			
			Unit 6	12,822			
			Total	23,116	227.70	99.01%	0.060
Deltas				9,431	74.83	0.13%	0.014

Notes:

1. East Thunder PRB Coal burned
2. Belle Ayr PRB coal with approximately 15% lower ash than the East Thunder average burned on 6/4-5/2010

The type of dry sorbent utilized also affected the type of particulate emissions from the existing ESPs. Table 3-24 provides a comparison of the particulate emissions by size of particulate versus the June 4-5 baseline test data. In all cases the Unit was burning Jacobs Ranch coal. Table 3-24 also provides the average DSI rate.

Table 3-24 - Review of Average Particulate Emissions versus DSI on Unit 6							
Test Date	DSI	Average DSI Rate (lb/Hr)	Injection Location	Total Particulate Emissions (lb/hr)	PM>10 (lb/hr)	PM<10 (lb/hr)	PM<2.5 (lb/hr)
6/5/10	Base Test	NA	NA	81.32	13.48	67.84	17
6/7/10	Un-milled Trona	8,502	Upstream of Air Heater	84.7	5.14	79.56	13.63
6/8/10	Milled Trona	8,696	Upstream of Air Heater	163.99	9.14	154.85	31.75
6/10/10	Pre-milled SBC	7,150	Down Stream of Air Heater	228.96	8.61	220.35	20.69

Reviewing the results provided in Tables 3-23 and 24 show that the addition of DSI to the flue gas stream increases the total particulates leaving the ESP with the majority of increase being PM<10 microns. Injecting milled dry sorbent has the most impact on the increase of fine particulates with the pre-milled SBC having a greater impact than the milled Trona, though the results from the testing on June 10 are suspect since they are greater than what was measured on June 15 for the combined Unit 5 and 6 emissions with SBC injection. The least impact on particulate emissions was the injection of un-milled Trona which had the largest particle size of all of the test runs. It should be noted that with the addition of dry sorbent no impacts on the operation of the ESP or opacity were observed when firing Jacobs Ranch coal. The Opacity and ESP performance (i.e. spark rates, secondary current, etc.) did change with SBC injection when firing the Belle Ayr coal with an increase in opacity of several percent. This increase did not cause the plant any issues with meeting the plant's opacity limits.

3.2.3 Impacts of DSI Utilization on Mercury Emissions

The removal efficiency of mercury during injection of DSI was reviewed and is included in Attachment 1. The results indicate a baseline removal efficiency of 93% with the injection of a minimum of 5 lbs activated carbon per million acf. During DSI the mercury removal varied from 84.1 – 93.7% with 93.7% removal occurring during SBC injection to both units. This removal efficiency is based on the concentration of mercury in the coal burned. Throughout the DSI test the activated carbon injection rate was unchanged. Based on the low values of mercury analyzed and the 10% variability of removal during injection, it is difficult to state whether DSI had any real impact on mercury removal.

3.2.4 Impacts of DSI Utilization on Carbon Dioxide Emissions

The use of Trona or SBC to remove SO_2 and acid gases will evolve CO_2 as part of the chemical reactions. Due to the chemical makeup of the two dry sorbents the utilization of SBC will evolve more CO_2 than Trona on a pound per pound sorbent basis. Based on 50% SO_2 removal and a 90% capacity factor, the use of Trona at Joppa will evolve about 26,000 – 40,000 tons per year while the use of SBC will evolve between 41,000 – 49,000 tons/yr based on injection location (before or after airheater).

EXHIBIT 3

Comments of Kimberly Gray (August 1, 2012)

BEFORE THE ILLINOIS POLLUTION CONTROL BOARD

AMEREN ENERGY RESOURCES	)	
	)	PCB 12-126
Petitioner,	)	(Variance - Air)
v.	)	
ILLINOIS ENVIRONMENTAL PROTECTION AGENCY,	)	
Respondent	)	

PC# 921

NOTICE OF FILING

To: Attached Service List

PLEASE TAKE NOTICE that on August 1, 2012, I filed with the Clerk of the Pollution Control Board of the State of Illinois **COMMENTS OF KIMBERLY GRAY,** a copy of which is attached hereto and herewith served upon you.

Respectfully submitted,

Faith E. Bugel

Faith Bugel
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Feasibility of Dry Sorbent Injection for SO_2 Control from Ameren's Coal-fired Power Plants

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Dry Sorbent Injection (DSI) is emerging as a pollution control technology to address sulfur dioxide (SO_2) emissions. Specifically, for Ameren's fleet of coal fired electric power plants (particularly, the E. D. Edwards and Joppa plants) DSI represents a technically and economically feasible strategy to reduce SO_x and other acid gases (e.g., HCl and HF).

DSI systems do not require major capital investment and are very robust and flexible in design. SO_2 reductions in the range of 50-80% can be achieved and reductions of as high as 95% have been documented. Further, simply by adjusting the dry sorbent feed rate, removal rates can be tuned to changes in operating conditions (i.e., changes in fuels, loads, regulations, etc.).

Our analysis of the estimated performance of DSI at the E.D. Edwards and Joppa plants reveals that, by employing DSI to achieve just 50% SO_2 removal efficiency at the Edwards and Joppa plants, Ameren should be able to achieve a fleetwide average of 0.25lbs/MMBtu SO_2. Furthermore, the capital costs of DSI for both plants are estimated to be less than $200M (approximately $50M at Edwards and $145M at Joppa).

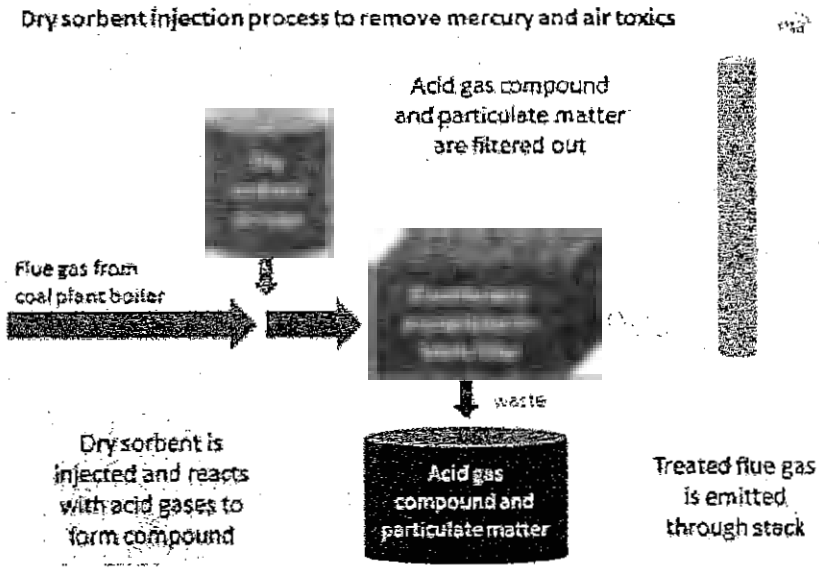


Figure 1. Schematic of DSI injection and removal system. Source – US Energy Information Agency. (http://www.eia.gov/todayinenergy/detail.cfm?id=5430)

1. Flue Gas Desulfurization

Flue-gas desulfurization (FGD) is a set of technologies used to remove sulfur dioxide (SO_2) and other acid gases from the exhaust flue gases of fossil-fuel power plants, and other SO_x-emitting

processes. A variety of sorbents are used in either wet or dry FGD processes. Depending on the way in which spent sorbents are treated, FGD processes can be further divided into once-through process or re-generable process. The costs of the re-generable technologies, however, are more expensive compared to that of the once-through technologies; thus, the re-generable processes are not widely used to remove SO_2.

An example of a typical wet, lime/limestone FGD system is illustrated in Figure 2 and consists of three major sub-systems: 1) reagent (lime or limestone slurry) preparation; 2) scrubber/SO_2 absorber and mist eliminator; 3) slurry/solid waste disposal systems.

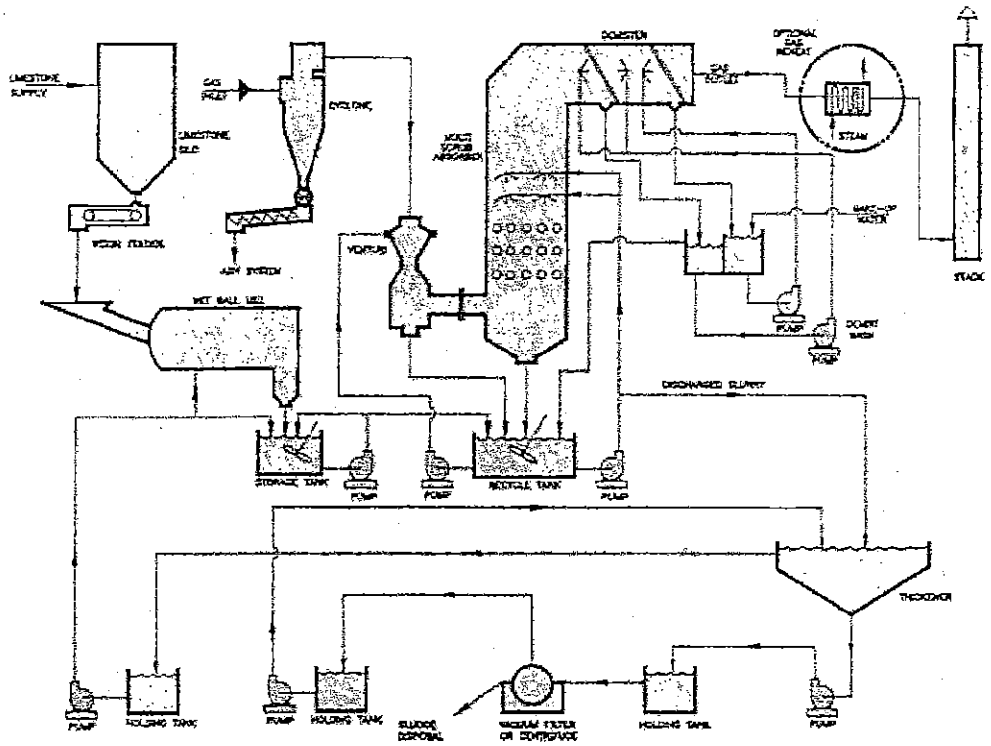


Figure 2. Clean Gas Systems, Inc. Wet Flue Gas Desulfurization process train. (http://www.cgscgs.com/ga_fgd.htm)

Nearly 90% of the electricity capacity in the U.S. is generated by plants using wet FGD. Although wet FGD systems clearly predominate over dry sorbent injection (DSI) systems, which are discussed further below, the capital costs can be as much as 10 times greater. Table 1 compares the key features of wet FGD and DSI. The major advantages of wet systems is that very high SO_2 reduction efficiencies are achieved, in the range of 95-98%, whereas removal efficiencies between 50-80% are typically attained by DSI systems. Furthermore, the alkaline sorbent demand of wet FGD is approximately 2-3 times less than that of DSI. DSI has a number of advantages over wet FGD, however. DSI produces dry wastes that are generally easier to dispose of than the wet wastes generated by wet FGD, which in some cases require wastewater treatment prior to discharge. Power consumption, pumping requirements, and pressure drop across absorbers for DSI systems are lower than those for wet FGD system. Other advantages of DSI include: shorter residence times are necessary than with wet FGD, solids are less likely to agglomerate or deposit on internal supports, and the high resistivity problems associated with many alkali materials are

avoided. Perhaps the biggest advantage of DSI is lower cost compared to wet FGD, with DSI averaging 10-25% of the cost of wet FGD.

	Wet FGD	Dry Sorbent Injection
Capital Cost	$200-400/kW	$40-50/kW
Coal Sulfur Content for Best Application	>2%	<1.5%
SO_2 Reduction Efficiency	95-98%	50-80%
Power Consumption, % of electric generation	1.0 - 2.5%	0.1 - 0.5%
Byproducts	Gypsum solid or $MgSO_4$ solution for use or disposal	Collected with fly ash
Alkaline Reagent or Sorbent Consumption, kg/kg SO_2 in flue gas	~2	~3-7
Water consumption, m^3/hr/MW	0.2-0.3	None
Wastewater treatment required?	Yes	No
Flue gas reheating required?	Yes	No
Ease of retrofit to existing power station	Very difficult	Easy

Table 1: Comparison of different parameters for wet and dry FGD systems. (http://www.mobotecusa.com/mb/technology/dry-sorbent-injection.htm)

Our analysis of the estimated performance of DSI at the E.D. Edwards and Joppa plants is consistent with the data shown in Table 1. Conservatively, employing DSI to achieve 50% SO_2 removal efficiency at the Edwards and Joppa plants, Ameren should be able to achieve 0.25lbs/MMBtu. Furthermore, the capital costs of DSI for both plants are estimated to be less than $200M (approximately $50M at Edwards and $145M at Joppa).

2. Dry Sorbent Injection

In DSI systems, calcium-based dry sorbents such as limestone ($CaCO_3$) or hydrated lime ($Ca(OH)_2$) are injected into the upper portion of a coal-fired boiler where combustion gas temperature is optimal for SO_2 capture. SO_2 reacts rapidly with the calcium-based sorbent to form stable calcium sulfate solid. Sodium-based dry sorbents such as trona or soda ash can be injected directly into the hot flue gas at multiple points as illustrated below in Figures 4 and 6.

Most dry desulfurization systems use calcium-based alkali, such as lime and limestone, as sorbent for reduction of SO_2 from flue gas since these alkaline materials have a relatively lower unit price. However, since calcium-based alkali injection process has very low sorbent utilization capacities, high sorbent injection rates are required to achieve significant SO_2 reduction from flue gas from coal-fired power plants, resulting in high operating and maintenance costs[2].

According to previous studies, sodium-based compounds have higher reactivity against SO_2 compared to calcium-based sorbent[3]. Of sodium-based sorbents, sodium bicarbonate ($NaHCO_3$) is more efficient in removing SO_2 compared to sodium carbonate (Na_2CO_3)[4]. This is due to the additional reactive surface area that is created as sodium bicarbonate converts to sodium carbonate in a hot gas stream prior to reaction with SO_2[5]. This thermal decomposition reaction can improve

the utilization of sodium bicarbonate for SO_2 removal compared to sodium carbonate by as much as 40%. However, since $NaHCO_3$ is much more expensive than lime as shown in Table 2, use of $NaHCO_3$ as sorbent creates higher operating and maintenance costs than does lime.

Sorbent	Cost (per ton)
Dry hydrated lime	$ 40 - $ 70
Sodium Bicarbonate ($NaHCO_3$)	$ 260
Nahcolite ($NaHCO_3$)	$ 200
Trona ($Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O$)	$ 70

Table 2: Comparison of various sorbents and their costs.

3. Trona

Trona (trisodium hydrogendicarbonate dihydrate), ($Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O$) is a naturally occurring, evaporite mineral. Figure 3 shows microscopic images of trona powders. Although the principal use of trona is to produce soda ash for glass and powdered detergent[6], research has demonstrated that it is effective in reducing the SO_x and other acid gas emissions from power plants[7].

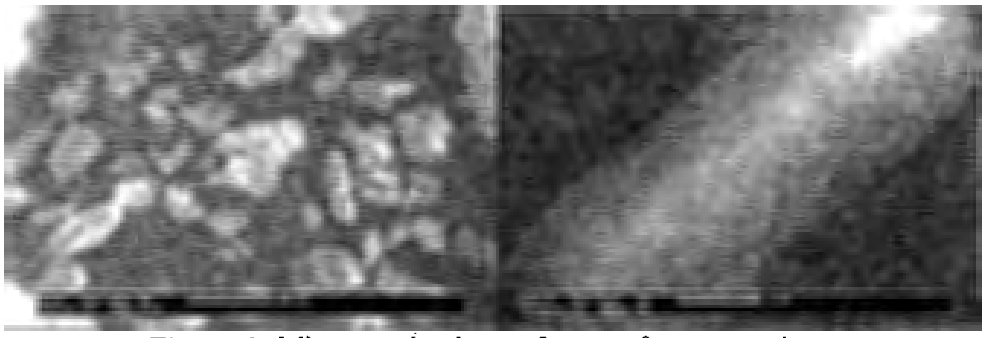


Figure 3: Microscopic views of trona after processing.

Trona consists of both sodium carbonate and bicarbonate (Table 3) and due to its lower cost, it has the potential to replace lime and limestone as the most widely used sorbent in the desulfurization processes. It is already the most common sodium-based dry sorbent in use.

Constituent	Percent (%)
Na_2CO_3	46
$NaHCO_3$	36
H_2O	16
SiO_2	< 0.4
H_2O insoluble	< 2

Table 3: Composition of trona

3.1 Mining

Trona is mined underground and processed into soda ash or bicarbonate of soda for a variety of uses. Wyoming has the world's largest deposit of trona, found at depths from 600 to 3500 ft over an area of approximately 2500 square miles. Wyoming supplies about 90% of the nation's soda ash[8]. Today four companies, FMC, OCI, Solvay and Green Chemical, currently mine trona in the Green River Basin, but only two, Solvay Chemicals and FMC, market trona for SO_2 control[9].

3.2 Processing

Trona can be processed into soda ash or sodium bicarbonate. Trona decomposes by calcination at any temperature over 70°C, but most manufacturers prefer to use 130°C. The calcined material is dissolved, clarified, filtered and re-crystallized. It is then centrifuged to remove excess water and dried. The dried product is shipped as either a bagged or bulk product.

4. Trona Injection & SO_2 emission control

4.1 Trona Injection

In a DSI system, trona is injected directly into hot fluc gas (> 275°F) as shown in the Figure 4.

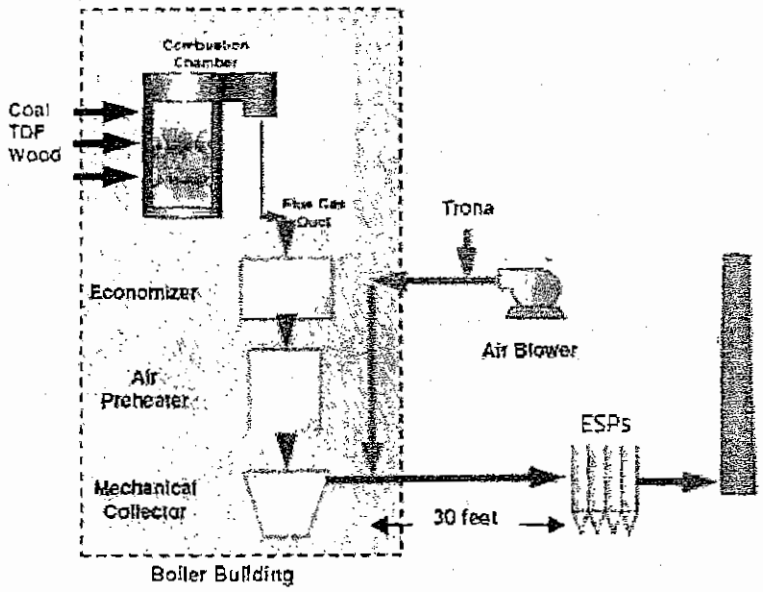


Figure 4: A coal power plant system with trona injection.

After injection, the sorbent is calcined into porous sodium carbonate as shown in Figure 5. Upon decomposition to sodium carbonate, a significant increase in the surface area of the particle is produced in what is commonly referred to as the "popcorn effect". The high surface area enables fast gas-solid reactions between trona and SO_2. The product Na_2SO_3 is then collected either by electrostatic precipitators or fabric filters. The chemical reactions are shown below.

Trona calcination:

$$2(Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O)(s) \rightarrow 3Na_2CO_3(s)+5H_2O(g)+CO_2(g) \qquad (1)$$

SO_2 adsorption:

$$Na_2CO_3 + SO_2 \rightarrow Na_2SO_3 + CO_2 \quad (2)$$

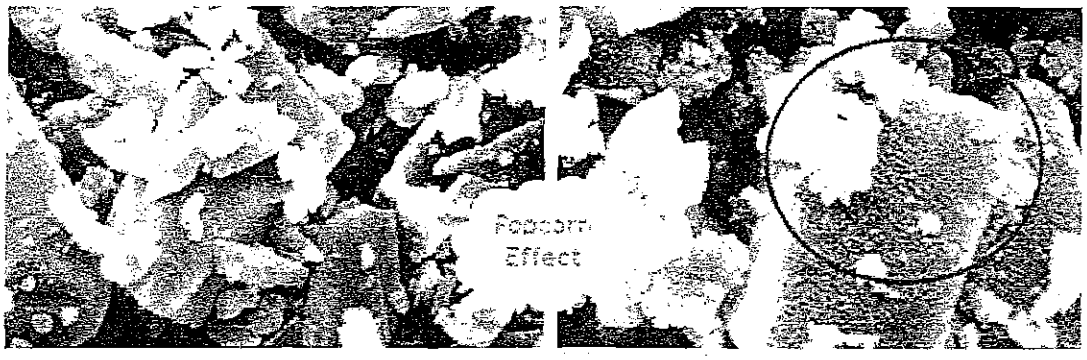


Figure 5: Sorbent is calcined into porous sodium carbonate- Popcorn effect

Trona can be injected at almost any location in the gas stream (Figure 6) but each location has its own advantages and disadvantages.

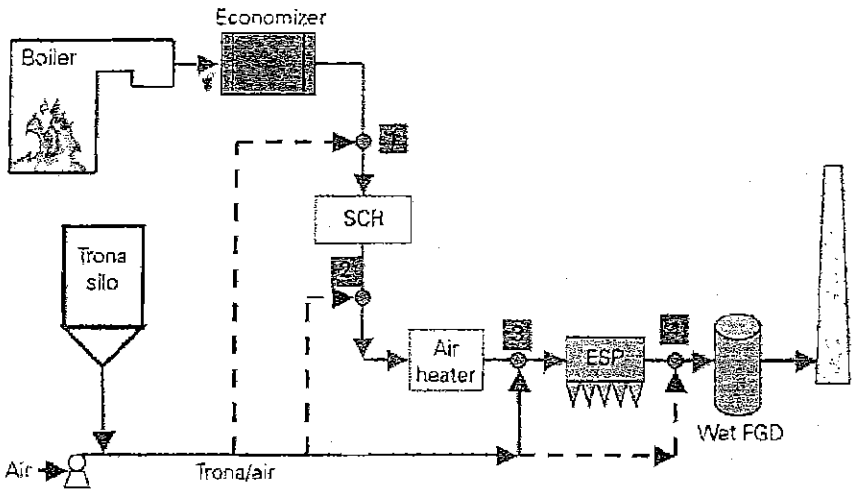


Figure 6: Different locations for Trona injection.

Upstream of the SCR (Location 1)

- Injecting trona at this location can remove most SO_3 ahead of the SCR to eliminate the formation of NH_4HSO_4, or ammonium bisulfate, inside the catalyst and consequently lower the minimum operation temperature.
- This is the preferred location if there is a hot-side electrostatic precipitator (ESP) upstream of the SCR catalyst.

Between the SCR and Air Heater (Location 2)

- Injecting trona at this location removes SO_3 ahead of the air heater so that it can run at lower temperatures, resulting in higher plant thermal efficiency.

Between the Air Heater and ESP (Location 3)

- This is the most common location to inject trona to eliminate the blue plume caused by SO_3.

Between the ESP and Wet Flue Gas Desulfurization (Location 4)

(i) Injecting trona at this location is effective in mitigating SO_3.

(ii) A wet scrubber is needed downstream to capture the reaction product (Na_2SO_4) and unreacted sorbent (Na_2CO_3).

(iii) Na_2CO_3 will enhance the performance of SO_2 removal in the wet scrubber.

4.2 SO_2 emission control

A number of researchers have investigated the efficiency of trona to control SO_2. In one study, Cho conducted modeling and experimental studies in order to optimize trona's reactivity with SO_2 in DSI[1].

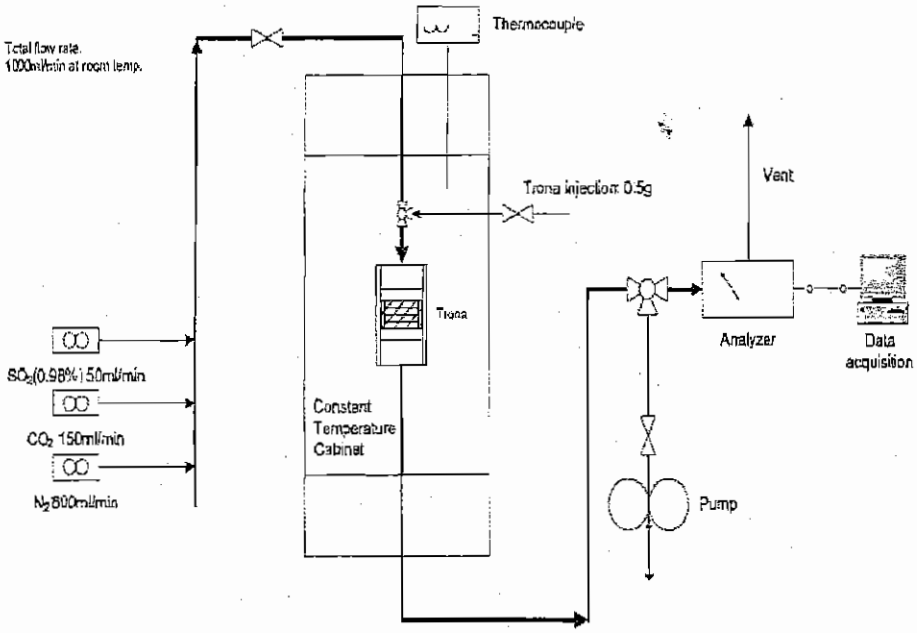


Figure 7: A schematic diagram of fixed bed reactor

A schematic diagram of fixed bed reactor is shown in Figure 7. For Cho's study, the reactor was brought in steady condition prior to trona injection. The exhaust gas was monitored continuously for SO_2 in real time by an infrared gas analyzer. Experimental conditions in the fixed bed reactor were as follows: the flue gas temperature was 150°C; flue gas SO_2 concentration was 510-530ppm; and flow rate was 1000ml/min. Trona could reduce 60-80% of the SO_2 gas (Figure 8). Water is essential for the reaction of trona. Water vapor had a high influence and caused 38-53% change in the reaction.

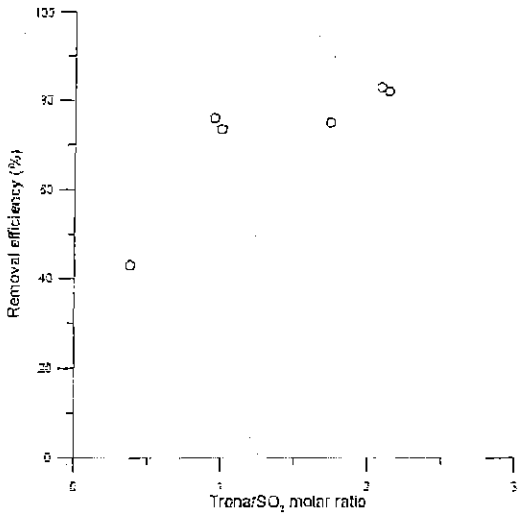


Figure 8: Plot describing the removal efficiency in variation with trona and SO_2 molar ratio

As shown in Figure 8, removal efficiency increased with increasing trona concentration and decreased with an increase in SO_2 gas.

The conversion/reactivity of trona (X_t) can be theoretically calculated by:

$$X_T = 1 - \frac{{}^4/_3 \times \Pi \times \tau_c^3}{{}^4/_3 \times \Pi \times R^3} = 1 - \left(\frac{\tau_c}{R}\right)^3 = 1 - \left(1 - \frac{u}{\tau_B}\right)^3 \qquad (3)$$

Where,
R= Radius of the particle
R_c= Radius of trona particle
T_b= Time required to complete the conversion of trona
X_t= conversion of trona
u = velocity (cm.sec)

Figure 9 shows the positive effect of temperature on removal efficiency.

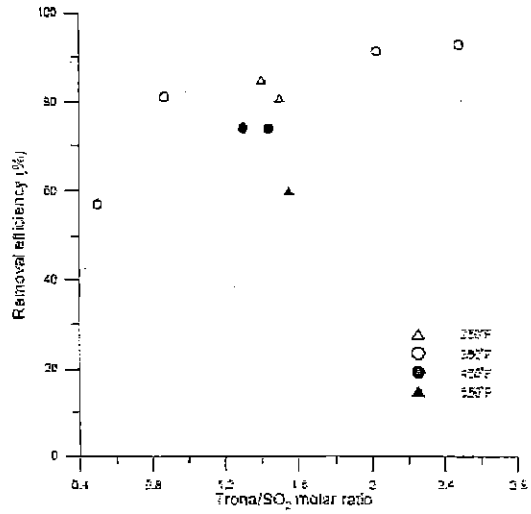


Figure 9: Plot describing the removal efficiency in variation with trona and SO_2 molar ratio with different temperatures.

Figure 10 illustrates the effect of size of trona on removal efficiency, where smaller particles of trona treat more SO_2 compared to larger-sized particles.

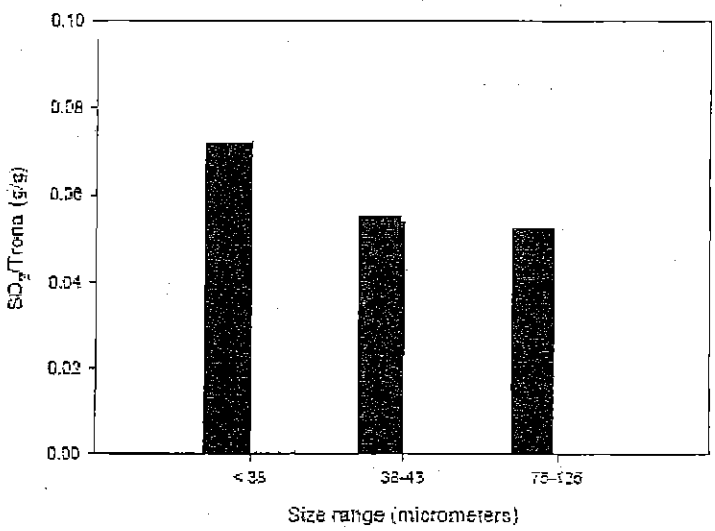


Figure 10: Effect of size of trona on removal efficiency

5. ESP Upgrades

5.1 Electrostatic Precipitators

Particulate matter (PM) is a by-product of fossil fuel combustion used to generate steam for industrial processes. Electrostatic precipitators (ESP) are one of the major particulate collection devices used today. They can handle large gas volumes with a wide range of inlet temperatures, pressures, dust volumes, and acid gas conditions. They can collect a wide range of particles in dry and wet compositions. For many industries, the collection efficiency can be as high as 99%.

As flue gas passes across a series of electrically charged plates and wires, PM (ash and injected sorbents) becomes statically charged. These charged particles collect on the electrically grounded plates. The plates are periodically "rapped" to dislodge PM, which is then collected and disposed as shown in Figure 11 [10].

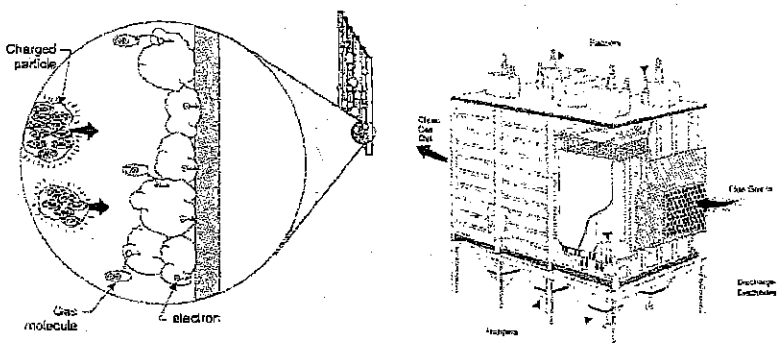


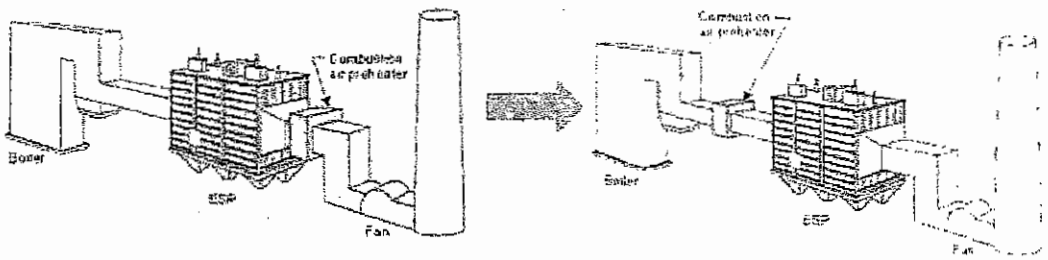
Figure 11: Design of ESP, showing the particle capture

In order to accommodate the additional PM loaded to the ESPs from trona and to improve the control efficiency of the ESPs, some modification of existing ESPs may be required, such as changing the location of the combustion air preheater ("hot-side" to "cold-side" ESP design) and/or installing high frequency transformer rectifier sets on ESPs.

5.2 Hot-side Versus Cold-side ESPs

In describing ESPs installed on industrial and utility boilers, *cold-side* and *hot-side* refers to the placement of the ESP in relation to the combustion air preheater. The air preheater in a cold-side ESP is located *before the ESP*, whereas in a hot-side ESP it is located *after the ESP*[11] as shown in Figure 12.

The air preheater is a tube section that preheats the combustion air used for burning fuel in a boiler. When hot flue gas from an industrial process passes through an air preheater, heat exchange occurs whereby heat from the flue gas is transferred to the combustion air stream. The flue gas is therefore "cooled" as it passes through the combustion air preheater. The warmed combustion air is sent to burners, where it is used to burn gas, oil, coal, or other fuel including garbage[12].



"Hot-side" ESP "Cold-side" ESP

Figure 12: Schematic diagram of hot-side and cold-side ESP

Although the use of hot-side precipitators can help reduce corrosion and hopper plugging, there are also some disadvantages. In a hot-side ESP the temperature of the flue gas is higher, and hence, the gas volume treated in the ESP is larger. Consequently, the overall size of the precipitator is larger, making it more costly. Other major disadvantages include structural and mechanical problems that occur in the precipitator shell and support structure as a result of differences in thermal expansion.

With cold-side ESPs, in contrast, the volume of flue gas that is handled is reduced in comparison to hot-side ESPs because cold-side ESPs are operated at lower temperatures. Thus, the overall size of the unit can be relatively smaller, making it less costly. The decreased gas volume also increases the gas residence time in the ESP, thus increasing the control efficiency of the ESP. In addition, injection of sodium-based dry sorbents may reduce the resistivity of the fly ash resulting in improved ESP effectiveness. Experimental results shown in Table 4 demonstrates the better control achieved by cold-side ESPs[13].

Emissions before and after cold-side conversion		
Emission	**Hot-side**	**Cold-side (Estimated)**
Opacity (%)	7-20	10
Particulate (lb/mm btu	0.063	0.03
SO_2 (lb/mm btu)	0.63	0.63
NO_x (lb/mm btu)	0.34	0.34

Table 4: Emissions before and after cold-side conversion from Midwest Power's Council Bluffs Energy Center experiment.

One of the disadvantages of converting ESPs from hot-side to cold-side operations, however, may be an increase in the ash loading on the air heater. The increased loading occurs because 100% of the fly ash will pass through the air heater. Since replacement and cleaning work could be difficult, it is recommended that dense pack baskets be replaced with loose pack baskets.

Finally, the burning of low-sulfur coal makes fly ash collection by cold side ESPs alone ineffective. Fly ash produced from low sulfur coal-fired boilers has high resistivity, making it difficult to collect. Therefore, in general, cold-side ESPs are used along with conditioning agents when burning low sulfur coal.

5.3 Transformer Rectifiers Sets

Transformer rectifiers supply DC voltage and current to ESPs. High-frequency transformer rectifiers supply high power, voltage and current to ESPs and, thus, may improve the dust collection efficiency of ESPs. Such enhancements to ESPs at existing plants appear sufficient to address the increased PM load that trona systems generate, rendering additional PM control devices, such as fabric filters, unnecessary.

5.4 Effect of trona on PM

With the use of trona, the control efficiency of ESPs improves. Data from trona injection tests (Mirant's Potomac River Station on Unit 1 between November 12 and December 23, 2005[14]), indicated that ESP performance improved with trona injection, even though trona reaction with SO_2 leads to PM formation. The reason for this has not been studied yet, but it likely results from a lower resistivity of PM after the injection of trona.

6. Feasibility Study of trona injection to other plants

6.1 Existing coal power plants

There are a number of the existing power plants that use DSI in the form of trona injection:

(i) **GenOn Energies** - GenOn Energies employs trona to achieve 40-60% of SO_2 emissions reduction. A dry powder form of trona is injected into the exhaust gas stream where it neutralizes and bonds with the SO_2. The dry byproduct is then removed in the particulate emissions control equipment and collected with ash[15].

(ii) **American Electric Power (AEP) -** American Electric Power (AEP) tested several sorbents and sorbent systems and selected trona as the best solution for their fleet of plants. They developed a reliable and cost-effective trona handling, conveying and injection system. Positive results include a substantial reduction in SO_3 and enhanced performance of the existing dry ESPs. Additionally, operational and maintenance costs were minimized[16].

(iii) **Dominion Resources** - Kincaid Generation LLC, a subsidiary of Dominion Resources Inc., awarded the KBR Power & Industrial Group a contract to provide engineering, procurement, and construction services for a DSI system to reduce sulfur dioxide emissions at its 1,158 MW Kincaid coal-fired power plant in Illinois. The project is scheduled for completion in late 2013[17].

6.2 Case Studies

(i) **Mirac Potomac River generating station** – A series of 32 experiments were conducted at the Mirac Potomac River generating station to test the performance of trona obtained from the Green River, WY mine. A Continuous Emission Monitoring System (CEMS) was installed to monitor SO_2 emissions and 80% sulfur removal was consistently achieved. Figure 13 illustrates the percent of SO_2 removal as a function of trona feed stoichiometry[18].

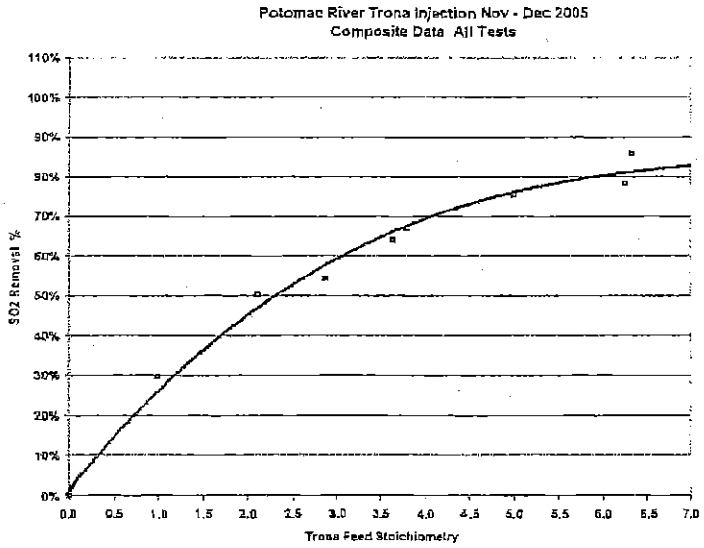


Figure 13: Plot showing direct relationship between SO_2 removal and trona dose.

(ii) **Nalco Mobotec -** Most Nalco Mobotec solutions require only minimal modification of existing furnaces and associated systems and can be implemented at a fraction of the cost of installing alternative air pollution control equipment. They offer furnace and post-furnace sorbent injection systems that are very easy to retrofit to existing power plants. Power consumption is low—less than 0.5% of generating capacity. They have their own design for sorbent injection system as shown in Figure 14, which consists of independent feed hoppers, various types of feed equipment, and a bin vent filtration system. This system includes several equipment advancements to ensure consistent sorbent flow-ability and accurate sorbent injection rates[19].

Figure 14: Design of sorbent injection system by Nalco Mobotec

6.3 Commercialization of trona

Trona is commercialized by a variety of industries such as:

(i) Babcock and Wilcox provides an SO_3 mitigation technology through a license with AEP ProServ, Inc., a subsidiary of American Electric Power (AEP)[20].

(ii) Tata Chemicals (Soda Ash) with Church & Dwight Company and FMC Corporation have signed a definitive agreement to form a partnership to manufacture and market sodium-based dry sorbents for air pollution control in electric utility and industrial boiler operations. Natronx will produce, sell and distribute sorbents to users of DSI technology. USEPA estimates that DSI technology will likely be employed by nearly 20% of US coal-fired electric generation capacity as part of compliance with air pollution regulations recently issued in March 2011. Natronx intends to invest approximately $60 million to construct a 450,000 tons-per-year facility to produce trona sorbents by the fourth quarter of 2012[21].

(iii) Solvair Solutions markets trona not only in coal-fired power plants but also in energy-from-waste plants, industrial boilers, municipal waste incinerators and other industries.

6.4 Effect of trona injection on other contaminants

Trona injection is also an effective technology for the removal of other coal combustion contaminants, such as SO_3, HCl and mercury (Hg).

(i) **Field Tests** - Trona removes SO_2, SO_3, mercury (Hg), HCl and HF at higher rates than lime and costs less than sodium bicarbonate. Field testing by SOLVAir Solution Company showed the removal rates of SO_2 as 90%. It has routinely achieved HCl removal of 95-99%. In addition, it is able to remove 20-70% of Hg used alone, and over 90% in combination of activated carbon[22].

$$Na_2CO_3 + SO_3 \rightarrow Na_2SO_4 + CO_2$$

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$$

$$Na_2CO_3 + 2HBr \rightarrow 2NaBr + H_2O + CO_2$$

HCl and HBr can oxidize mercury, thus enhancing mercury removal.

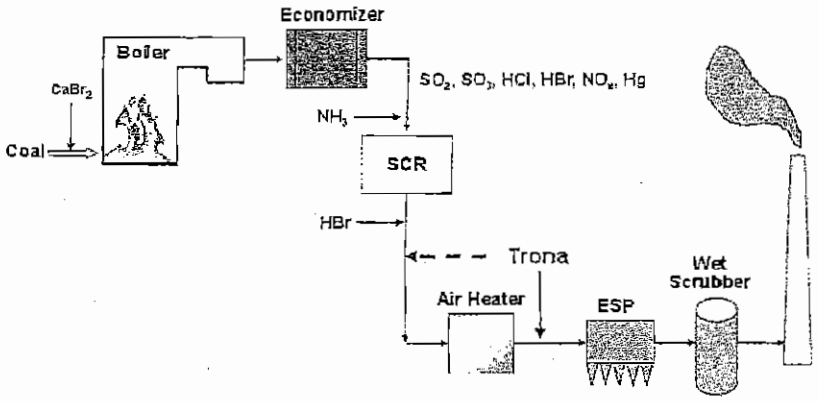


Figure 14: Schematic diagram of other contaminant removal by trona.

(ii) **Trona's effect on NO_X** - Coal-fired power plant use selective catalytic reduction (SCR) systems to reduce the emissions of nitrogen oxides (NO_x). But for many plants, adding an SCR system has unintended consequences: greater oxidation of SO_2 to sulfur trioxide (SO_3), and a rise in stack opacity. This problem can be solved by combining trona injection with SCR systems, which results in considerable reduction of NO_X. This combination is already being used in Dunkirk generating station, CR Huntley generating station and Indian River generating station[23].

6.5 Potential health effects related to trona exposure

The Virginia Department of Health investigated the possible health effects of trona[24]. Since trona is a caustic substance, it can have an irritant effect on the respiratory system, mucous membranes, eyes, and skin. Excessive levels of airborne dust may irritate the mucous membranes and upper respiratory tract. Aside from these irritant effects, no chronic loss of lung function is attributed to trona in the studies examined, and interventions to reduce dust levels improved respiratory and/or skin-related symptoms. Beyond the occupational setting, available data suggest that trona is only a transient irritant. Yet, to date, there are no published epidemiologic studies of populations living near power plants where trona is used for air pollution control, nor studies examining the health effects as a result of exposure to trona dust among the general population or among special populations that may be at increased susceptibility to airborne irritants. As a food substance, refined trona is commonly added to animal feed to increase the milk yield and double-refined trona is designated by the Food and Drug Administration as safe when used appropriately.

6.6 Conclusion

This review of the literature and practice, in addition to our own analyses, supports the position that DSI is an efficient, robust, flexible, and cost-effective strategy to retro-fit selected Ameren plants, specifically E. D. Edwards and Joppa, in order to bring their fleet into compliance with the Illinois Multi-Pollutant Standard. Laboratory and full-scale tests have demonstrated that trona typically achieves 60-95% reduction in SO_2 emissions. Trona is particularly well suited for this application and is easily integrated into the flue-gas and the cold-side ESP system of Ameren's plants. If Ameren were to employ DSI to achieve just 50% SO_2 removal efficiency at

the Edwards and Joppa plants, it should be able to meet its fleetwide SO_2 limits of 0.25lbs/MMBtu with a total estimated capital cost of less than $200M.

Qualifications of Professor Kimberly A. Gray

Kimberly A. Gray is an environmental engineer with over 30 years of experience. Since 1995 she has been a professor of Environmental Engineering in the Department of Civil and Environmental Engineering at Northwestern University. Previously, she held a similar academic post at the University of Notre Dame. She worked in industry in Paris, France and Miami, FL., and continues to work with a wide range of industrial partners on research and consulting projects. She is a qualified expert in the areas of emissions treatment technologies, environmental testing and analytical chemistry, contaminant fate, environmental quality and public health. She studied the formation and control of detached plumes in Portland Cement manufacturing plants and has provided technical assistance to the Chicago Legal Clinic on over 60 environmental projects in the Chicago area. Of these, about 20% focused on air quality issues associated with fossil fuel combustion and in many cases, specifically the SO_x, NO_x and CO_2 emissions from coal-fired electric power generation. Gray is an internationally recognized scholar in the areas of physicochemical processes in environmental systems and the development of photocatalytic treatment technologies for air and water remediation. She is the author of over 100 scholarly papers and reports, holds patents for photocatalyst synthesis and application, and lectures widely on energy, environmental and urban sustainability issues.

References

1. Cho, K. J. (2007). "A modeling and experimental study of the conversion of Trona to increase its reactivity with SO_2 in dry injection systems,", PhD Dissertation (Environmental Engineering), University of Cincinnati, http://etd.ohiolink.edu/view.cgi/CHO%20KYUNGMIN%20JACOB.pdf?ucin1185822434
2. Dogu, T., *Effect of port structure on the mechanism of SO_2 sorption on activated soda.* (Wiley: New York, 1984); p 152-162.
3. E.A. Samuel, D. A. F., R.L. Ostop, SO2 removal using dry sodium compounds. *Am. Inst.Eng. Semp.* **1981,** 77, (211).
4. Keener, T. C.; Davis, W. T., Study of the reaction of SO2 with NaHCO3 and Na2CO3.*Journal of the Air Pollution Control Association* **1984,** 34, (6), 651-654.)
5. Bares, J.; J., M.; Mocek, M.; Erdös, E., Kinetics of the Reaction between the Solid Sodium Carbonate and the Gaseous Sulfur Dioxide. III. *Coll. Chech. Chem. Commun.* **1970,** 35.
6. http://www.mii.org/minerals/photoTrona.html
7. http://www.netl.doe.gov/technologies/coalpower/cctc/resources/pdfs/pscol/netl1160.pdf
8. http://www.wma-minelife.com/Trona/tronmine/tronmine.htm
9. http://www.wma-minelife.com/Brochures/Trona_08.pdf
10. http://www.precip.com/index.php?option=com_content&view=article&id=49&Itemid=60
11. http://yosemite.epa.gov/oaqps/eogtrain.nsf/b81bacb527b016d785256e4a004c0393/
12. APTI Course SI: 428A *Introduction to Boiler Operation* describes boilers and heat recovery equipment in greater detail.
13. http://www.isesp.org/ICESP%20V%20PAPERS/ICESP%20V%20Papers%2003%20ESP%20USER%20EXPERIENCE%20AND%20FIELD%20STUDIES.htm
14. http://energy.gov/oe/downloads/Trona-injection-tests-mirant-potomac-river-station-unit-1-november-12-december-23-2005
15. http://www.genon.com/company/env-Trona.aspx
16. http://www.coalpowermag.com/plant_design/SO3-Control-AEP-Pioneers-and-Refines-Trona-Injection-Process-for-SO3-Mitigation_29.html
17. http://www.kbr.com/Newsroom/Press-Releases/2012/05/07/KBR-Power-and-Industrial-Group-Awarded-Dominion-Resources-Inc-EPC-Contract/
18. http://oldtownalexandria.patch.com/topics/Potomac+River+Generating+Station
19. http://www.nalcomobotec.com/mb/technology/dry-sorbent-injection.htm
20. http://www.babcock.com/library/brochures-environmental.html
21. http://www.4-traders.com/TATA-CHEMICALS-LIMITED-9058951/news/Tata-Chemicals-Limited-Tata-Chemicals-Church-Dwight-and-FMC-announce-joint-venture-for-air-pol-13808631/
22. http://www.solvair.us/EN/products/select200/solvairirselect200and150Trona.aspx
23. http://www.coalpowermag.com/plant_design/SO3-Control-AEP-Pioneers-and-Refines-

Trona-Injection-Process-for-SO3-Mitigation_29.html

24. Virginia Department of Health, Office of Epidemiology & Office of Environmental Health (June 2007). "Health Effects Associated with Exposure to Trona: A Review of the Biomedical Literature," http://www.atsdr.cdc.gov/hac/pha/MirantHC/AppendixF-TronaSummary.pdf

Under penalties as provided by Illinois law, the undersigned certifies that the statements set forth in this instrument are true and correct.

Executed this 31 day of July, 2012 in Chicago, Illinois.

Kimberly Gray
Professor of Civil and Environmental Engineering
Northwestern University

CERTIFICATION

Kimberly Gray appeared before me and subscribed, and swore or affirmed that the foregoing Affidavit is true, correct and executed as a knowing, free and voluntary act for the purposes stated this 31 day of July 2012.

Fidelia Gaines-Mitchell

NOTARY PUBLIC

OFFICIAL SEAL
FIDELIA GAINES-MITCHELL
NOTARY PUBLIC - STATE OF ILLINOIS
MY COMMISSION EXPIRES:08/28/13

My Commission expires:

08 / 28 / 2013.

CURRICULUM VITAE

Kimberly Ann Gray

(07/12)

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EDUCATION

1988	Ph.D., Department of Geography and Environmental Engineering The Johns Hopkins University, Baltimore, MD Thesis Title: The Formation, Characterization, and Use of Inorganic Iron(III) Polymers for Coagulation in Water Treatment Advisor: Dr. Charles R. O'Melia
1983	M.S., Department of Civil Engineering University of Miami, Coral Gables, FL Advisor: Dr. Thomas D. Waite
1978	B.A., Biology, Minor Biochemistry Northwestern University, Evanston, IL

PROFESSIONAL EXPERIENCE

2012-2013	Senior Sabbatical Fellowship – Public Interest Scientist, Environmental Law and Policy Center, Chicago, IL.
2006-present	Professor, Department of Civil and Environmental Engineering, Northwestern University
2008-present	Northwestern Institute of Sustainable Practices, Director.
2009 – present	Global and Ecological Health Engineering Program, co-Director with Matthew Glucksberg
2003-2010	Director, Environmental Science, Engineering & Policy Program (WCAS); Coordinator of Environmental Engineering and Science (MEAS), Northwestern
2002-present	Member, Transportation Center, Northwestern University
1999-present	Member, Institute of Policy Research Northwestern University
1998-2005	Associate-Director, Institute of Environmental Catalysis, Northwestern University
1997-present	Member, Center for Catalysis and Surface Science, Northwestern University
1996-present	Courtesy Appointment in the Department of Chemical & Biological Engineering, Northwestern University

1995-2006	Associate Professor, Department of Civil and Environmental Engineering, Northwestern University
1989-1995	Assistant Professor, Department of Civil Engineering and Geological Sciences, University of Notre Dame (promoted to Associate Professor)
1987-1989	Research Engineer, Lyonnaise des Eaux, Laboratoire Central, Le Pecq, France.
1983-1987	Research Assistant, Department of Geography and Environmental Engineering, The Johns Hopkins University.
1984-1985	Instructor, Part-Time Engineering, The Johns Hopkins University.
1982-1983	Instructor and Research Assistant, Department of Civil Engineering, University of Miami.
1981-1982	Environmental Engineer, Carr Smith and Assoc., Coral Gables, FL.
1980-1981	Research Hydrologist, Everglades National Park, Homestead, FL.
1979-1980	Research Assistant, Smithsonian Institution Foreign Currency Program in India.

PROFESSIONAL MEMBERSHIPS

American Chemical Society
American Society of Civil Engineers
Association of Environmental Engineering and Science Professors

HONORS

2011 – Invitee, 9th Annual National Academies Keck *Futures Initiative* (NAKFI), *Ecosystem Services*

2009-2010, 2010-2011 Northwestern Faculty Honor Roll

2009 Distinguished Scientist, Trinity University, San Antonio, Texas

Aldo Leopold Leadership Fellow, 2008, Woods Institute for the Environment, Stanford University

Sigma Xi Distinguished Lecturer, 2008-2010

2007 McCormick Excellence Award in Research, Teaching, & Citizenship

Presidential Young Investigator, National Science Foundation, 1991-1996.

Graduate School Award for Best Dissertation in the College of Engineering; Dissertation Director of Roger J. Hilarides, 1994.

Second Place, Montgomery-Watson and Assoc. of Environmental Engineering Professors Master Thesis Award and Honorable Mention in AWWA Academic Achievement Award Competition, Thesis Advisor of David Widrig, 1993.

Stanley E. Blumberg Alumni Association Scholarship, The Johns Hopkins University, 1986-1987.

Hattie Strong Foundation Fellowship, 1986-1987.

American Chemical Society Graduate Student Award in Environmental Chemistry, 1986.

American Association of University Women Fellowship, Alternate, 1986.

American Water Works Association, Chesapeake Section, Student Paper Award, 1986.

PROFESSIONAL ACTIVITIES

Panel Moderator for Infrastructure, Policy and Regulatory Considerations at The Electrification of Transportation - A Look at the Road Ahead Workshop, NU Transporatation Center, Allen Center, 18 April 2012.

2012 - Reach the Decision Makers Program, UCSF Program on Reproductive Health and the Environment

2011 – Consultant, Academic Affairs Division of the Texas Higher Education Coordinating Board, evaluation of the Environmental Engineering program at Texas A&M University at Kingsville

Member, Board of Directors, International Association for Urban Environment, 2009-present.

Member, Editorial Board, The International Journal of Sustainable Development & World Ecology, 2008-present.

Member, Panel Discussion on Energy: Chicago's Energy Needs in 2020, Major Donor Recognition Event with Ira Flatow for WBEZ, Chicago Public Radio, April 28, 2010.

Panel Member, *Environmental Racism: Poverty and Pollution in Minority Communities*, 2010 Martin Luther King Celebration, NU School of Law, January 12, 2010.

Science, Ethics, and Appropriate Uses of Technology: A U.S.-France-Iran Workshop, National Academy of Science, Fondation des Treilles, Tourtour, France, Nov. 7-12, 2009.

"Energy & Sustainability" symposium (Panel member with Thomas L. Friedman) as part of President Morton Schapiro's Inauguration, 9 October 2009.

Member, CBEN NSEC Site Visit Review Panel, Rice University, 29 July, 2009.

Member, Strategic Planning Panel for the Shedd Aquarium, Sustainable Place, Practices, People, Chicago Oct. 8, 2008.

Panel Member, Sustainable Water and Land Management, Clean Technologies & Sustainability: Global Perspectives & Opportunities, Federal Reserve Bank of Chicago, Sept. 9, 2008.

Member, Steering Committee, International Institute of Nanotechnology, Northwestern University, 2008-present.

Panel Moderator, Sustainable Manufacturing: Balancing Environmental Benefits with Economic Costs, 2007 Manufacturing Business Conference, Evanston, IL, May 12, 2007.

Invited Participant, Business, Engineering, & Sustainability: Collaborative Programs for Innovation, 2007 Planning Workshop, University of Maryland, College Park, MD, Feb. 16-17, 2007.

Panel Moderator, Next Generation Strategies for Creating Value through Sustainable Product Design and Manufacturing, 2006 Net Impact Conference, Oct. 28, 2006.

Panel Member, University of Chicago Review of Environmental Science Division, Argonne National Laboratory, Sept. 18-20, 2006.

International Association for Great Lakes Research, Session Organizer and Chair, Integrative Approaches to Ecosystem Modeling, May, 2005.

Canadian Foundation for Innovation, Review panel, October, 2003.

Board of Directors, Chicagoland Redevelopment Initiative (REDI), 2002-2006; Community Advisory Board, Great Lakes Redevelopment Initiative Fund, 2004-present.

American Chemical Society, Division of Environmental Chemistry, Symposium Organizer and co-Chair (with Bruce Logan), Analysis of Environmental Phenomena at Molecular Scales, August, 2001.

Association of Environmental Engineering Professors, Board of Directors, 1996-2000; Vice-President, 1997-98; President, 1998-1999, Past-President, 1999-2000.

National Research Council Water Science and Technology Board, Member of Committee on USGS Water Resources Research, 1996-1999.

National Science Foundation Review Panels: Environmental Engineering, 2010, 2011; Career Award, 1998, 2004, 2005, 2006; NSF Young Investigator Award, 1992; IGERT, 2004, 2005, 2007; Small Business Innovation Research Grant Proposals, 1990, 1994, 1996; BES 2000, 2001, 2002; Division of Undergraduate Education (UCD & ILI), July, 1993, January & July, 1994; Advisory Panel, Environmental Technology, 1995; Committee of Visitors (BES review), 2002.

Organized Workshop at the AEESP Research Needs Conference, "Gender, Diversity and Family Issues," Pennsylvania State University, July 31, 1999.

Organized 1998 Annual Meeting of the Center of Catalysis and Surface Science, "New Frontiers in Environmental Catalysis," Sept. 9, 1998.

Panel Member, NSF-AEEP Frontiers in Environmental Engineering Workshop, Monterey, California, Jan. 14-16, 1998.

Panel Member for "Photodetoxification and Purification of Water and Air" at the DOE Workshop on Research Opportunities in Photochemistry, Estes Park, Colorado, 5-8 February 1996.

Panel Member for NSF Workshop, "Application of Ionizing Radiation for Decontamination of Environmental Resources," Miami, FL, June 1-3, 1994.

Environmental Protection Agency and American Academy of Environmental Engineers WASTECH Task Group 1992-1994, coauthor of monograph, "Chemical Treatment: Innovative Waste Treatment Technologies".

Environmental Protection Agency, Member of Bioremediation Education Subcommittee, 1991-1993.

American Water Works Research Foundation, Project Advisory Committee for "Destruction of Toxic Organics Using Adsorption and Photocatalytic Regeneration with Sunlight or Low Intensity Artificial Lights," 1991-1993.

American Water Works Association, Organic Contaminants Research Committee 1994-present, Coagulation Research Committee 1989-1991.

American Institute of Chemical Engineers, Session Chair and Organizer: Theory and Application of Radiation Processes for the Destruction of Hazardous Compounds, 1990, 1991, 1993; Chemical and Biological Treatment of Waste, 1992; Physical and Chemical Treatment to Enhance Bioremediation of Hazardous Waste, 1994; Photochemical and Radiolytic Treatment Processes, 1996.

Program Development Council and Superfund Subcommittee for Hazardous Materials Control Resources Institute 1994-1996; Session Chair, "Laboratory & Analytical Methods" at 1994 Superfund XV Conference and Exhibitor.

Midwest Environmental Chemistry Workshop, Conference Organizer, University of Notre Dame, October 17-18, 1993.

Fine Particle Society, Division of Aerosols, Health and Environment, Session Chair and Organizer, "Free Radical Processes for Contaminant Destruction in Heterogeneous Systems," 1993.

American Chemical Society, Symposium Organizer, "Polysaccharide Chemistry in Environmental Processes," April, 1992.

Reviewer: Chemistry of Materials, Journal of Catalysis, Applied Catalysis A & B, ACS Catalysis, Coordination Chemistry Reviews, Environmental Science & Technology, Angewandte Chemie, Journal American Chemical Society, Journal of Physical Chemistry, Langmuir, Physical Chemistry Chemical Physics, Energy & Fuels, Nanoscale, Carbon, Catalysis Communication, Catalysis Letters, Transportation Research, Thin Solid Films, Journal of Material Science, Journal of Colloid and Interface Science, Colloids and Surfaces, Journal of Membrane Science, Journal of Applied Microbiology, Aquatic Ecology, Chemistry and Ecology, Journal of Applied and Analytical Pyrolysis, Science of the Total Environment, Water Research, Water Quality Journal of Canada, Water Environment Research, Environmental Toxicology and Chemistry, Journal AWWA, Biodegradation, ASCE Journal of Environmental Engineering, CRC Critical Reviews in Environmental Science and Technology, Chemosphere, Waste Management, Industrial & Engineering Chemistry Research, Research on Chemical Intermediates, Israel Journal of Chemistry, Journal of Solar Energy Engineering, Biotechnology Progress, Environmental Progress, Solar Energy, Journal of Advanced Oxidation Technology, Journal of Hazardous Materials, ACS Symposium Series, New York Sea Grant Program, National Research Council, USGS - Water Resources Center, Dept. of Energy BES, DOD – DEPSCoR, Journal of Molecular Catalysis, Journal of Solid State Chemistry.

COURSES TAUGHT

Undergraduate:
Sustainability: Issues and Action, Near and Far, CEE 395 (2006-present)
Energy and the Environment: The Automobile, Envr Sci 203 (2005-2010)
Community Based Design, CEE-398 – 1, 2 (1996 – present)
Urban Neighborhoods: Issues and Action, Soc-376 (co-taught, W. Espland; Cross School Initiative, 2002)
Environmental Engineering Analysis CE 261 (co-taught, B. Rittmann, J-F Gaillard)
Introduction to Water Chemistry and Treatment (UND)
Water and Wastewater Treatment Design (UND)
Water Quality Management (UM)

Graduate:
Sustainability Practicum, CEE 395 (co-listed with Law School, PPTY TORT 616 SEC 1 Practicum: Sustainability Solutions & ISEN 440)
Sustainable Product Design and Development, DSGN 495 (2009, 2010)
Physicochemical Processes in Aquatic Systems, CE-444 (NU & UND)
Physical Principles in Environmental Systems CE-440 (co-taught, J-F. Gaillard)
Unit Operations in Environmental Systems CE-445
Environmental Analytical Chemistry CE-446 (co-taught, J-F. Gaillard)
Sustainable Manufacturing, IEMS-497-40 (2005, 2006, 2007, 2008 MMM)
Energy and the Environment IPLS -492 (2009)
Changing Views of Nature MALS- 403 (2006, 2012)
Cities and the Environment: Past, Present and Future, MALS-403 (2004)
The Environmental Legacy of Modern Industrialized Societies, MALS-403 (2001)
Aquatic Chemistry/Advanced Aquatic Chemistry (UND)
Water and Wastewater Treatment Design (JHU)
Water Supply and Drainage (JHU)

DOCTORAL STUDENTS ADVISED - CURRENT

Todd Eaton (2010 – present): TiO_2/SiO_2 Nanocomposites for CO_2 Photoreduction: Synthsizing and characterizing novel interfacial structures.

Kevin Schwarzenberg (2010 – present) – Characterizing adsorption affinity of CO_2 and it effect on photocatalytic reduction.

Tiezheng Tong (2010 – present): Unintended effects of nanotitania in benthic systems.

Sarist Macksasitorn (2010 – present): Biomagnification of persistent organic chemicals in the food webs of Green Bay.

Daniel Finkelstein-Shapiro (2008-present, Dept. of Chemistry): The effect of defect site structure on photocatalytic efficiency.

DOCTORAL STUDENTS ADVISED – COMPLETED

Katie Kalscheur (June, 2012): Characterizing the Effects of Organic Quality on the Structure and Function of Periphyton in Urbanized Streams.

Paul Desario (June, 2011): Cation Doped TiO_2 Thin Films Prepared by Reactive Sputtering: Synthesis, Characterization, and Applications for Environmental Catalysis.

Marshall Lindsey (December, 2010, Dept. of Chemical and Biological Engineering): Location, Vehicle Miles of Travel, and the Environment: A Chicago Case Study.

Shannon Ciston (June, 2009, Dept. of Chemical and Biological Engineering): Photo-active Ceramic Membranes for the Prevention of Biofouling: Synthesis, Characterization & Testing

Yuan Yao (Feb., 2009, Dept. of Mechanical Engineering; co-advised with Prof. Richard Lueptow): Synthesizing TiO_2-Carbon Nanotube Composite Materials for Photocatalysis.

Le Chen (September, 2008): "Synthesizing Mixed Phase Titania Nanocomposites by Reactive DC Magnetron Sputtering to Enhance Photoactivity and Photoresponse." (161 p.)

Carla Ng (May, 2008); Dept. of Chemical and Biological Engineering): "Integrative modeling of the cumulative effects of chemical and biological stresses on aquatic food web structure to predict contaminant transfer." (135 p.)

Jill Kostel (June, 2006): "Periphyton Community Structure in Lotic Systems: The Interactions of Metals, PCBs, and Environmental Variables." (451 p.)

Cari Ishida (September, 2005): "Strategies to Enhance Denitrification Rates in Restored Wetlands: Hydrology, Ecology, and Microbiology." (194 p.)

Mary Finster (May, 2005): "Phytoremediation of Lead in Urban Residential Soils: A Study of Application, Feasibility and Effectiveness in Chicago."

Alexander Agrios (May 2003): "Visible Light Photocatalysis: Adsorption, Complexation, and Reaction of Chlorophenols on Titanium Dioxide." (168 p.)

Tanita Sirivedhin (May, 2002): "Monitoring the Behavior of Organic Carbon in Surface Waters using Pyrolysis/GC/MS." (365 p.)

G. Adam Zacheis (August, 2000): "Degradation of Contaminants Adsorbed to Heterogeneous Surfaces Using Ionizing Radiation." (296 p.)

Allen Simpson (May, 1997): "Interpretation of PY-GC-MS Data to Evaluate the Behavior of Natural Organic Material in Aquatic Systems." (214 p.)

Daniel C. Schmelling (May, 1996): "The Photocatalytic Behavior of 2,4,6-Trinitrotoluene in Titanium Dioxide Systems: Photochemical, Electrochemical and Radiolytic Investigations." (138 p.)

Hong Wang (May, 1996): "The Response of a Laboratory Stream System to PCB Exposure: Study of Periphytic and Sediment Dynamics." (233 p.)

Melissa Dieckmann (May, 1995): "The Sensitized Photocatalytic Degradation of Colored Aromatic Pollutants using TiO_2." (192 p.)

Ulick Stafford (Oct., 1994): "Mechanistic Study of Photocatalytic Degradation of Chlorinated Phenols on TiO_2." (223 p.)

Roger J. Hilarides (May, 1994): "Destruction of 2,3,7,8-Tetrachlorodibenzo-p-dioxin on Soil using Cobalt-60 Gamma Radiation." (249 p.)

MASTER'S STUDENTS ADVISED – COMPLETED

Tracy Yang (March 2012): "Mobile Testing in the Thar Desert: Assessing water quality with limited resources."

Blake Chastain (June 2012, MALS): "The Creation Care Bubble and Evangelical Politics."

Ke Gong (March 2012): "Ecotourism"

Ritu Gopal (June, 2011): Aroclor analysis of Green Bay fish and sediments.

David Petrone (May, 2011; Dept. of Chemical and Biological Engineering): "An Application and Evaluation of theEPA Greenhouse Gas Inventory Reporting Rule."

Erin Himmelspach (Sept., 2010; Dept. of Chemical and Biological Engineering): "Investigation of Titania-Silica Nanocomposites: Probing Interfacial Catalytic Hot Spots for the Photocatalytic Reduction of Carbon Dioxide."

Kevin Schulte (June, 2009): "Synthesis and Characterization of TiO_2 Nanotubes for CO_2 Reduction."

Debra Weissman (June, 2006): "Nutrient Dynamics in Riparian Wetlands."

M. Christina Vicario (July, 2001, Dept of Chemical Engineering): "Novel VUV Photocatalytic Reactor."

Y. Mwende Munyasya (November, 2000): "The Effects of Catalyst Loading, Light Wavelength, and Oxygen on the Photocatalytic Transformation of 2,4,5-Trichlorophenol."

Mary Finster (October, 1999, Dept. of Chemical Engineering): "The Urban Heat Island, Photochemical Smog, and Chicago: Local Features of the Problem and Solution."

David Widrig (November, 1992): "Preozonation to Enhance Coagulation: The Effect of Algal Species and Water Quality on the Removal of Dissolved Organic Carbon" (172 p.).

Jonathan Noris (August, 1994): "Treatment of High Selenium Waters" (102 p.).

POST DOCTORAL FELLOWS – CURRENT

Dr. Anas Shereef (2011 – present)

POST DOCTORAL FELLOWS - COMPLETED

Dr. Olga Lyandres (2009-2011)
Dr. Baiju Vijayan (2008-2011)
Dr. Gonghu Li (2005-2007)
Dr. Shai Arnon (2004-2006, co-advised with Aaron Packman)
Dr. Deanna Hurum (1999-2004)

Dr. Sung Il Chang (2001-2003)
Dr. Usha Rao (1997-1999, co-advised with Dave Hollander)
Dr. Robert Bornick (1995-1997)
Dr. Ann St. Amand (1990-1992)

RESEARCH GRANTS AND CONTRACTS – CURRENT or PENDING

"Northwestern University Superfund Research Center in Reproductive Health Hazards," co-PI with Teresa Woodruff, Superfund Research Program, National Institute of Environmental Heath Services, NIH, in preparation for April submission (approx. $ 7M/4 years).

"The Energy Highway," in collaboration with Dr. Gayathri Gopalakrishnan (ANL) to National Academy Keck Future Initiatives, $100,000, 06/12 – 06/14.

"Ecological Goods and Services in Urban Development in the Asia Pacific Rim Countries," Asia Pacific Economic Forum, Business Advisory Committee, Summa Capital, Ltd. $162,000, 4/15/11 – 12/31/11.

"The Unintended Ecological Consequences of Nanomaterials: Effects of nanotitania in benthic systems," NSF, $357,539, 04/11-04/14.

"Science Master's Program in Engineering and Global Health Technologies," NSF (with Matt Glucksberg, PI), $700,000, 09/01/10-9/01/13.

"Ecological Forecasting: Framework to evaluate the effects of multiple stresses in Lake Michigan foodwebs and guide remediation," NOAA, $999,000, 09/09-03/13.

"The Chicago Transformation Teacher Institutes," NSF (with UIC), $436,768, 01/10-12/14.

"Institute for Environmental Catalysis", DOE, co-PI (CO_2 Reduction Subtask Leader) with Peter Stair (PI), $4M, 09/05-09/12; individual allocation, ~ $700,000;(currently under renewal review).

Dow Sustainability Innovation Competition, $350,000, 12/08—06/15.

"Tailoring titania nanocomposites to LED illumination for gas phase reactions," Honeywell Corporation, $300,000, 8/1/08-12/31/11.

"TiO_2-based nanocomposites for solar fuel production: *Engineering the solid-solid interface for specialized photocatalytic function*," NSF. $400,000 09/08-09/12.

"Second Generation Photocatalysts: TiO_2-based nanocomposites by dc reactive sputtering," National Science Foundation, $240,000, 07/07-12/11.

"Collaborative Research. Mediation of denitrification by algal/bacterial interactions in stream periphyton: role of successional development and species identity," National Science Foundation, $292,240, 08/07-08/12.

RESEARCH GRANTS AND CONTRACTS – COMPLETED

"Reactor and Reaction Optimization for the Photocatalytic Reduction of CO_2," Boeing Corporation, $95,000, 08/08 – 12/08.

"Reactive Membrane Technology for Water Treatment," National Science Foundation, $400,000, 10/04-12/08 (PI, Richard Lueptow).

"Deterioration of Zinc Potassium Chromate Pigments: Elucidating the effects of pigment mixture and environmental conditions on changes in color and chemical speciation," Mellon Foundation, $29,716, 10/06-06/08.

"Engineering Riparian Flood Events: Baseline Monitoring," U.S. Army Corps of Engineers, $41,160, 05/05-01/07.

"GAANN: Community-Based Urban Environmental Issues," Dept. of Education, $ 495,850, 8/03-8/07 (PI, co-PIs – Aaron Packman and J-F Gaillard).

"Engineering an Artificial Substrate System to Accelerate the Denitrification of Agricultural Runoff by Periphyton," $324,000, 8/02-8/06 (PI, co-PI-Aaron Packman).

"Titania Coated Shikkui Tiles: Determining the Role of the Support," Fukuoka University Institute for Recycling and Environmental Control Systems, $30,000, 11/05-04/06, *FastScience*.

FastScience, Characterization of Titania Coatings by EPR for Sundecor and Professor Katsuyuki Nakano, Fukuoka University, and the Institute for Recycling and Environmental Control Systems, Phase I, $10,000, Phase II, $15,000, Phase III, $10,000, 3/04-3/05.

"Hydraulic Effects on Biological Diversity in Wetlands," U.S. Army Corps of Engineers, $356,160, 11/01-11/04.

"The Fate of Carbon and Nitrogen in an Experimental Marsh," The Wetlands Initiative, $44,000, 01/99-08/02, $25,005, 08/03-12/05.

"Collaborative Learning Communities," Cross-School Initiative, Northwestern University, $100,000, 09/00-6/03.

"Safer Yards – Phytoremediation of Lead-Contaminated Soils," Housing and Urban Development, $171,073, 02/00-02/03.

"Technical Assistance to Community Groups through the Chicago Legal Clinic," USEPA, Region V, $26,250, 9/00-1/02

"Radiolysis on Oxide Surfaces," National Science Foundation, $77,269, 2/00-3/01.

"Radiation-Induced Catalysis on Metal Oxide Surfaces: Preliminary Investigation of Basic Phenomena and Potential Applications," Center for Catalysis and Surface Science, Seed Proposal, $25,000/1 year 6/98-6/00.

"Pavement Analysis and the Urban Heat Island Effect," USEPA, Atmospheric Pollution Prevention Division, $111,121, 7/98-6/99.

"Institute of Environmental Catalysis", NSF, Environmental Molecular Science Institute Program, Assoc. Director and co-PI with Peter Stair, $7,982,692/5 yrs total; individual expenditure, $516,000, 9/1998-12/2004.

"Community Based Projects for Teaching Environmental Engineering Design," Murphy Society, $40,916, 1/99-9/99, $54,069, 01/01-01/02.

"Technical Assistance to Community Organizations: Brownfield Cleanup using Wetlands," USEPA, Region V, $15,000, 1/98-1/99.

"Community Based Projects for Teaching Environmental Engineering Design," Mitsubishi Foundation, $10,000, 1/98-1/99.

"Detached Plume Study in Portland Cement Manufacturing Plants-Part I," Portland Cement Association, $122,500, 7/98-9/99.

"Carbon Cycling in a Riparian Wetland of the Des Plaines River," Wetlands Research, Inc., $13,000, 6/97-6/99; Evaluation of the Denitrification Potential of Wetlands, $55,000, 6,99-6/00.

"Photocatalysis for Space Mission and Aircraft Applications," Allied Signal, $20,000/9/97-8/98.

"Environmental Stress in Ecosystems: Linking Ecology and Engineering", Co-PI with Gary Lamberti (UND), NSF Research Training Group in Environmental Biology, $537,500/(9/95-6/2000).

"Macrocosm Total Organic Carbon Analysis using Pyrolysis-GC-MS", Orange County Water District, $50,000 (8/94-3/96); Monitoring the Organic Quality of the Santa Ana River and Anaheim Lake by Pyrolysis-GC-MS, $50,000 (8/96-6/97).

"The Use of Pyrolysis-GC-MS to Evaluate Drinking Water Treatment Processes", U.S. EPA, $232,813/2 years (1993-1995). Extended to 6/97.

"Instrumentation and Laboratory Improvement for Undergraduate Environmental Analytical Chemistry", with Co-PI, Jean-Francois Gaillard, NSF, $137,512/3 years (6/15/93-11/95).

"Removal of DBP Precursors by Granular Activated Carbon Adsorption", American Water Works Research Foundation, $40,000 (1/93-8/95).

"Radiolytic Destruction of Organic Compounds", Occidental Chemical Corporation, $65,138/1 year , with co-PI: R.L. Irvine (5/92-12/93), $73,766 as sole PI (1/94 - 12/94), $55,231 (1/95-6/97).

"Pilot and Laboratory Scale Studies of KDF Electrochemical Media", KDF Fluid Treatment Inc., $6,200/1 year (1994).

"Characterization and Performance of Polyferric Sulfate Coagulants", Midland Resources, Inc., $7,000 (1/91-12/91).

"The Role of an Attached Algae Mat in the Fate of PCBs in Artificial Stream Ecosystems", The Jesse H. Jones Faculty Research Fund, $8,500/1 year (7/91-7/92); NSF Planning Grant, $26,182/1 year (4/91-4/92).

Presidential Young Investigator Award, "Physiocochemical Processes in Aquatic Systems", NSF, $500,000/5 years (7/91-7/96), ($312,500 from Sponsor/non Federal Matching Funds in excess of $187,000 have been obtained). Extended to 12/97.

"Mechanistic Studies of Photocatalytic Degradation of Hazardous Organic Compounds in Semi-conductor Systems", NSF, $69,964/2 years, approved; declined due to PYI Award (1991).

"Coagulation Performance of Aqualenc", Phone-Poulenc Chemical Company, $20,000 (1/90-6/91).

"Removal of Algal Material: Treatment Techniques and Mechanisms", Lyonnaise des Eaux, Paris, France, $116,400 (4/90-12/93).

"Request for Purchase of Combined Electrophoresis and Submicron Size Analyzer", Jesse H. Jones Faculty Research Equipment Fund, University of Notre Dame, $19,050 (4/90-4/91).

INVENTION DISCLOSURES/PATENT APPLICATIONS

1. Photocatalytic Composite (TiO_2/SWCNT) for Organic Chemical Oxidation (provisional patent application NU 27068, filed), Y. Yao, R. Lueptow, K.A. Gray.

2. Mixed-phase nano-structured TiO_2 composite photocatalyst for energy and energy efficiency applications, (provisional patent application NU 27093) G. Li & K.A. Gray.

3. Reactively sputtered TiO_2 nanocomposite thin films for photoreduction and photooxidation applications under UV and visible light, (Patent No. US 8,202,820 B2 issued 06/19/12) L. Chen, M. Graham, K.A. Gray

4. Solvent-Exfoliated Graphene-Titania Nanocomposite Photocatalysts, (provisional patent application NU2011-059), Yu Teng Liang, Baiju Vijayan, Kimberly Gray, Mark Hersam.

JOURNAL and PEER-REVIEWED PUBLICATIONS

93. Daniel Finkelstein-Shapiro, Charlie Y.-H. Tsai, Shuyou Li, Kimberly A. Gray (2012). "Synthesis of high-energy anatase nanorods via an intermediate nanotube morphology," *CPLETT*, DOI 10.1016/j.cplett.2012.07.039.

92. Kathryn N. Kalscheur, Miguel Rojas, Christopher G. Peterson, John J. Kelly, Kimberly A. Gray (2012). "Algal Exudates and Stream Organic Matter Influence the Structure and Function of Denitrifying Bacterial Communities, " *Microbial Ecology*, in press.

91. Olga Lyandres, Pongkarn Chakthranont, Daniel Finkelstein Shapiro, Michael Graham, Kimberly Gray (2012). "The effects of preferred orientation in sputtered TiO_2 thin films on the photooxidation efficiency of acetaldehyde," *Chemistry of Materials*, in press.

90. Y.T. Liang, B. Vijayan, O. Lyandres, K.A. Gray, M.C. Hersam (2012). "The effect of dimensionality on the photocatalysis of carbon-titania nanosheet composites: Charge transfer at nanomaterial interfaces," *Journal of Physical Chemistry Letters*, 3:1760–1765.

89. K.N. Kalscheur, R.R. Penskar, A.D. Daley, S.M. Pechauer, C.G. Peterson, J.J. Kelly, K.A. Gray (2012), "Effects of anthropogenic inputs on the organic quality of urbanized streams," *Water Research*, 46: 2515-2524 DOI: 10.1016/j.watres.2012.01.043.

88. K. Schwartzenberg, K.A. Gray (2012). "Nanostructured Titania: The Current and Future Promise of Titania Nanotubes," *Catalysis Science and Technology*, 2 (8), 1617 – 1624; DOI: 10.1039/C2CY00538G.

87. Baiju K. Vijayan, Nada M. Dimitrijevic, Daniel F. Shapiro, Kimberly A. Gray (2012). "Coupling titania nanotubes and carbon nanotubes to create photocatalytic nanocomposites," *ACS Catalysis 2*, 223–229.

86. P.A. DeSario, J. Wu, M.E. Graham, K.A. Gray (2012). "Nanoscale structure of $Ti_{1-x}Nb_yO_2$ mixed phase thin films: Distribution of crystal phase and dopants," *Journal of Materials Research*, 27:944-950 (DOI:10.1557/jmr.2011.449).

85. Alon Danon, Kaustava Bhattacharyya, Baiju K. Vijayan, Junling Lu, Dana J. Sauter, Kimberly A. Gray, Peter C. Stair, and Eric Weitz (2012). "The Effect of Reactor Materials on the Properties of Titanium Oxide Nanotubes," *ACS Catalysis*, *2* (1), 45–49.

84. D. Finkelstein-Shapiro, A.M. Buchbinder, B. Vijayan, K. Bhattacharyya, E. Weitz, F.M. Geiger, K.A. Gray (2011). "Elucidation of several types of binding sites for the adsorption of acetaldehyde on the surface of titania nanorods," *Langmuir*, 27, 14842–14848.

83. N.M. Dimitrijevic, T. Rajh, B. Vijayan, K.A. Gray (2011). "Photocatalytic Reduction of CO_2: Probing Structure of Photocatalysts and Mechanism of CO_2 Transformation," *ECS Transactions*, 35 (25) 167-171.

82. Y. T. Liang, B. Vijayan, K.A. Gray, M.C. Hersam (2011). "Minimizing Graphene Defects Enhances Titania Nanocomposite-Based Photocatalytic Reduction of CO_2 for Improved Solar Fuel Production" *Nano Letters*, 11, 2865–2870.

81. P.A. DeSario, K.A. Gray (2011) "Passive Systems: Using every surface in the built environment," in **Handbook of Metropolitan Sustainability: Understanding and Improving the Built Environment**. F. Zeman, ed. (Woodhead Publishing Ltd), Ch. 15, in press.

80. C.G. Peterson, A.D. Daley, S.M. Hell, K.N. Kalscheur, M. Sullivan, S.L. Kufta, K.A. Gray, J.J. Kelly (2011). "Development of microalgal/bacterial-denitrifier associations in streams of contrasting anthropogenic influence," *FEMS Microbiology Ecology*, 77, 477–492.

79. J. Wu, S. Lo, K. Song, B. Bijayan, K.A. Gray, V.P. Dravid (2011). "Growth of rutile TiO_2 nanorods above anatase TiO_2 thin films on Si-based substrates," *Journal of Materials Research*, 26:1646-1652.

78. Luciana Zanella, Francesca Casadio, Kimberly A. Gray, Richard Warta, Qing Ma and Jean-François Gaillard (2011). "The Darkening of Zinc Yellow: XANES Speciation of Chromium in Artist's Paints after Light and Chemical Exposures," *Journal of Analytical Atomic Spectrometry*, 6, 1090-1097.

77. P. Desario , L. Chen, M.E. Graham, K.A. Gray (2011) "The effect of oxygen deficiency on the photoresponse and reactivity of titania thin films," *JVST A*, 29:031508 – 31515 doi:10.1116/1.3574350.

76. K.A.Gray (2011). "Five Myths about Nanotechnology in the Current Public Policy Debate: A science and engineering perspective," in **The Nanotechnology Challenge:** ***Creating Legal Institutions for Uncertain Risks*** (David Dana, editor, Cambridge Press), Sept. 2011, Ch 2, 11-60.

75. N.M. Dimitrijevic, B. Vijayan, O.G. Poluektov, T. Rajh, K.A. Gray, H. He; P. Zapol, Peter (2011) "Role of Water and Carbonates in the Photocatalytic Transformation of CO_2 to CH_4 on Titania," *JACS*, 133:3964-3971.

74. P.A. DeSario, R.M. Gelfand, M.E. Graham, K.A. Gray. (2011) "The effect of Nb substitution on synthesis and photo-response of TiO_2 thin films prepared via reactive magnetron sputtering." *Thin Solid Films*, 519:11:3562-356.

73. M. Lindsey, J.L. Schofer, P. Durango-Cohen, K.A. Gray (2011) "The Effect of Residential Location on Vehicle Miles of Travel, Energy Consumption and Greenhouse Gas Emissions: Chicago Case Study," *Transportation Research, Part D*, 16:1–9.

72. C. Ng, K.A. Gray (2011) "Forecasting the effects of global change scenarios on bioaccumulation patterns in Great Lakes Species," *Global Change Biology*, 17, 720–733 (DOI: 10.1111/j.1365-2486.2010.02299.x).

71. B. Vijayan, N.M. Dimitrijevic, J. Wu, K.A. Gray (2010) "The effects of Pt-doping on the structure and visible light photoactivity of titania nanotubes," *Jour. Phys. Chem. C, 114*, 21262–21269.

70. F. Casadio, S. Xie, S. Rukes, B. Myers, K. Gray, R. Warta, L. Fiedler (2010) "Electron Energy Loss Spectroscopy elucidates the elusive darkening of zinc potassium chromate in Georges Seurat's A Sunday on La Grande Jatte – 1884," *Analytical and Bioanalytical Chemistry*, (DOI 10.1007/s00216-010-4264-9).

69. M. Lindsey, J.L. Schofer, P. Durango-Cohen, K.A. Gray (2010) "Relationship between Proximity to Transit and Ridership for Journey-to-Work Trips in Chicago," *Transportation Research, Part A*, 44:697–709 (doi:10.1016/j.tra.2010.07.003).

68. B. Vijayan, N. Dimitrijevic, T. Rajh, K.A. Gray. (2010) "Effect of calcination temperature on photocatalytic reduction and oxidation of hydrothermally synthesized titania nanotube," *Jour. Phys. Chem. C*, 14:30:12994–13002.

67. K. Schulte, P. Desario, K.A. Gray. (2010) "Effect of Crystal Phase Composition on the Reductive and Oxidative Abilities of TiO_2 Nanotubes under UV and Visible Light," *Applied Catalysis B*, 97:3-4:354-360.

66. S. Ciston, R.M. Lueptow, K.A. Gray (2009) "Control of Biofilm Growth on Reactive Ceramic Ultrafiltration Membranes," *Journal of Membrane Science*, 342, 263-268.

65. L. Chen, M.E. Graham, K.A. Gray (2009) "Nitrogen stabilized reactive sputtering of optimized TiO_{2-x} photocatalysts with visible light reactivity," *Journal Vacuum Science & Technology*, 27(4):712-715.

64. C. Ng, K.A. Gray (2009) "Tracking bioaccumulation in aquatic organisms: A dynamic model integrating life history characteristics and environmental change," *Ecological Modeling*, 220, 1266–1273.

63. L. Chen, M.E. Graham, G. Li, D. Gentner, K.A. Gray (2009) "Photoreduction of CO_2 by TiO_2 Nanocomposties Synthesized through Reactive DC Magnetron Sputter Deposition," *Thin Solid Films*, 517:5641–5645.

62. G. Li, N.M. Dimigtrijevic, L. Chen, T. Rajh, K.A. Gray (2008). "Photoactive CuO-TiO_2 Nanocomposites Prepared by a Chemical Method," *Jour. Phys. Chem. C, 112*, 19040–19044.

61. Y. Yao, G. Li, K.A. Gray, R.M. Lueptow (2008) "Single-walled Carbon Nanotube Facilitated Dispersion of Particulate TiO_2 on ZrO_2 Ceramic Membranes," *Langmuir*, 24:7072-7075.

60. F. Casadio, K.A. Gray, R. Warta, I. Fiedler (2008) "Deterioration of Zinc Potassium Chromate: Elucidating the effects of paint composition and environmental conditions on chromatic alteration," ICOM Committee for Conservation, 15th Triennial Meeting, New Delhi, India (James and James Publishers) in press.

59. C.A. Ng, M B. Berg, D.J. Jude, J. Janssen, P.M. Charlebois, L.A.N. Amaral, K.A. Gray. (2008) "Chemical amplification in an invaded food web: Seasonality and ontogeny in a high biomass, low diversity ecosystem." *Environmental Toxicology and Chemistry*, 27:145-154.

58. Y. Yao, G. Li, R.M. Lueptow, K.A. Gray, (2008) "Photoactive TiO_2-Carbon Nanotube Composites: Synthesis and Environmental Application," *Environ. Sci. Techonol.*, 42:4952-4957.

57. G. Li, N.M. Dimitrijevic, L. Chen, J.M. Nichols, T. Rajh, K.A. Gray (2008) "The Important Role of Tetrahedral Ti^{4+} Sites in the Phase Transformation and Photocatalytic Activity of TiO_2 Nanocomposites," *JACS*, 130:5402-5403.

56. S. Ciston, R. Lueptow, K.A. Gray, (2008) "Biofilm Attachment Studies on Reactive Ceramic Ultrafiltration Membranes," *Journal of Membrane Science*, 320:101-107.

55. G. Li, S.M. Ciston, Z.V. Saponjic, Le Chen, N. Dimitrijevic, T. Rajh, K.A. Gray (2008). "Synthesizing mixed-phase TiO_2 using a hydrothermal method for photo-oxidation and photo-reduction applications," *Journal of Catalysis*, 253:105-110.

54. C.K. Ishida, S. Arnon, C. Peterson, J.J. Kelly, K.A. Gray, (2008) "The influence of algal community structure on denitrification rates in periphyton cultivated on artificial substrates," *Microbial Ecology*, 56:140-152.

53. G. Li, K.A. Gray (2007) "Visible Light Photocatalytic Properties of Anion-Doped TiO_2 Materials Prepared from a Molecular Titanium Precursor," *Chemical Physics Letters*, Vol 451/1-3 pp 75-79.

52. S. Arnon, C.G. Peterson, K.A. Gray, A.I. Packman. (2007) "Influence of Flow Conditions and System Geometry on Nitrate Utilization by Benthic Biofilms: Implications for Nutrient Mitigation," *Environmental Science & Technology*, 41:8142-8148.

51. G. Li, K.A. Gray, (2007) "The solid-solid interface: Explaining the high and unique photocatalytic reactivity of TiO_2-based nanocomposite materials," *Chemical Physics*, 339:1-3:173-187 (doi:10.1016/j.chemphys.2007.05.023).

50. G. Li, L. Chen, M. Graham, K.A. Gray, (2007) "A comparison of mixed phase titania photocatalysts prepared by physical and chemical methods: The importance of the solid-solid interface." Journal of Molecular Catalysis A: Chemical, 275:30-35.

49. S. Arnon, K.A. Gray, A.I. Packman, (2007) "Biophysicochemical process coupling controls nitrogen use by benthic biofilms." *Limnol. Oceanogr.* 52: 1665-1671.

48. G. Li, K.A. Gray (2007). "Preparation of Mixed-phase Titanium Dioxide Nanocomposites via Solvothermal Processing." *Chemistry of Materials*, 19:1143-1146.

47. S. Ciston, K.A. Gray (2007). "Photocatalysis for Water Recovery: Importance of nanostructure in reactive membrane filtration," G.I.T. Laboratory Journal, 11:36-37.

46. C. Liu, K. Nakano, E. Obuchi, T. Oike, N. Yukihira, D. Hurum, K.A. Gray (2007). "Photocatalytic decomposition of formaldehyde using titania coated lime tile," *Jour. of Advanced Oxidation Technologies* 10 (1): 11-16.

45. S. Arnon, A.I. Packman, C.G. Peterson, K.A. Gray (2006) "The effects of overlying velocity on periphyton structure and denitrification," *Journal of Geophysical Research*, 112, G01002, doi:10.1029/2006JG000235.

44. L. Chen, M.E. Graham, G. Li, K.A. Gray (2006) "Fabricating Highly Active Mixed Phase TiO_2 Photocatalysts by Reactive DC Magnetron Sputter Deposition," *Thin Solid Films*, 515(3):1176-1181.

43. C.K. Ishida, J.J. Kelly, K.A. Gray, (2006) "Effects of variable hydroperiods and water level fluctuations on the denitrification capacity, nitrate removal, and benthic microbial community structure in constructed wetlands," *Ecological Engineering*, 28:363-373.

42. T. Sirivedhin, K.A. Gray, (2006) "Factors Affecting Denitrification Rates in Experimental Wetlands: Field and Laboratory Studies," *Ecological Engineering*, 26:167-181.

41. D.C. Hurum, A. G. Agrios, S.E. Crist, K.A. Gray, T. Rajh, M.C. Thurnauer, (2006) "Probing reaction mechanisms in mixed phase TiO_2 by EPR," *Journal of Electron Spectroscopy*, 150:2-3:155-163.

40. T. Sirivedhin, K.A. Gray, (2005) "Identifying Anthropogenic Markers in Surface Waters Influenced by Treated Effluents: A Tool in Potable Water Reuse," *Water Research*, 39:1154-1164.

39. T. Sirivedhin, K.A. Gray, (2005) "Comparison of the Disinfection Byproduct Formation Potentials between a Wastewater Effluent and Surface Waters," *Water Research*, 39:1025-1036.

38. D. Hurum, K. Gray, T. Rajh, M. Thurnauer, (2005) "Recombination Pathways in the Degussa P25 Formulation of TiO_2: Surface versus Lattice Mechanisms," *J.Phys.Chem B*, 109:977-980.

37. A. Agrios, K. Gray, E. Weitz, (2004) "Narrow Band Irradiation of Homologous Series of Chlorophenols on TiO_2: Charge Transfer Complex Formation and Reactivity," *Langmuir*, 20, 5911-5917

36. D. Hurum, K. Gray, T. Rajh, M. Thurnauer, (2004) "Photo-initiated Reactions of 2,4,6-TCP on Degussa P25 formulation TiO_2: Wavelength Sensitive Decomposition," *J.Phys.Chem.B*, 108:16483-16487.

35. H.J. Binns, K.A. Gray, T. Chen, M.E. Finster, M. Peneff, P. Schaefer, V. Ovsey, J. Fernandes, M. Brown, B. Dunlop, (2004) "Evaluation of Landscape Interventions to Reduce Potential Exposure to Lead-Contaminated soil in Urban Residential Yards; The Safer Yards Project," *Environmental Research*, 96:127-138.

34. M.E. Finster, K.A. Gray, H. Binns, (2004) "Lead Levels of Vegetables Grown in Contaminated Residential Soils: A Field Survey," *Science of the Total Environment*, 320, 245-257.

33. J.A. Kostel, KA. Gray A. St.Amand, (2003) "The Impact of Metal and Organic Contaminants on the Structure of Periphyton in Lotic Sediments: Observations at Various Scales," *International Journal of Sediment Research*, 18:2:214-222.

32. D.C. Hurum, A.G. Agrios, K.A. Gray, T. Rajh, M.C. Thurnauer, (2003) "Explaining the Enhanced Photocatalytic Activity of Mixed Phase TiO_2 Using EPR," *J.PhysChemB*, vol 107, pp. 4545-4549.

31. A. Agrios, K.A. Gray, E. Weitz, (2003) "Photocatalytic Transformation of 2,4.5-Trichlorophenol on TiO_2 under Sub-bandgap Illumination," *Langmuir*, 19, 1402-1409.

30. M. Bonifacic, K-D. Asmus, K.A. Gray, (2003) "On the Reaction of 2,4,5-Trichlorophenol with hydroxyl Radicals: New Information on Transients and their Properties," *J. Phys. Chem A*, 107, 1307-1312.

29. G.A. Zacheis, K.A. Gray and P.V. Kamat, (2001) "Radiation induced catalytic dechlorination of hexachlorobenzene on oxide surfaces," *Journal of Physical Chemistry B*, 105:4715-4720.

28. G.A. Zacheis, K.A. Gray, P.V. Kamat (2000) "Radiolytic reduction of hexachlorobenzene in surfactant solutions: A steady-state and pulse radiolysis study." *Environ. Sci. Technol.* 34:3401-3407.

27. J.A. Kostel, H. Wang, A. St.Amand, and K.A. Gray, (1999) "1. Use of a Novel Laboratory Stream System to Study the Ecological Impact of PCB Exposure in a Periphytic Biolayer," *Water Research*, 33:18:3735-3748.

26. H. Wang, J.A. Kostel, A. St.Amand, and K.A. Gray, (1999) "2. The Response of a Laboratory Stream System to PCB Exposure: Study of Periphytic and Sediment Accumulation Patterns," *Water Research*, 33:18:3749-3761.

25. G.A. Zacheis, K.A. Gray and P.V. Kamat, (1999) "Radiation-Induced Phenomena on Oxide Surfaces: Catalytic Degradation of Hexachlorobenzene on Alumina Nanoparticles," *Journal of Physical Chemistry B*, 103:2142-2150.

24. D.C. Schmelling, K.A. Gray, and P.V. Kamat, (1998) "Radiolytic Behavior of 2,4,6-Trinitrotoluene in Aqueous Solution." *Environmental Science and Technology*, 32:7:971-974.

23. K.A. Gray and M.R. Cleland, (1998) "Environmental Radiolysis for Soil and Sediment Treatment: Comparison of Gamma and High Energy Electron Beam Systems." *Journal of Advanced Oxidation Technologies*, 3:1:22-36.

22. Ulick Stafford, Kimberly A. Gray and Prashant V. Kamat, (1997) "Photocatalytic Degradation of 4-Chlorophenol. A Model." *Research on Chemical Intermediates*, 23:4:355-388.

21. D. C. Schmelling, K. A. Gray and P. V. Kamat, (1997) "The Impact of Solution Matrix on the Photocatalytic Degradation of TNT," *Water Research*, 31:6:1439-1447.

20. Ulick Stafford, Kimberly A. Gray and Prashant V. Kamat, (1997) "Photocatalytic Degradation of 4-Chlorophenol. The Effects of Varying TiO_2 Concentration and Light Wavelength," *Journal of Catalysis*, 167:25-32.

19. D. L. Widrig, K. A. Gray and K. S. McAuliffe, "Removal of Algal-derived Organic Material by Preozonation and Coagulation: Monitoring Changes in Organic Quality by Pyrolysis-GC-MS," (1996) *Water Research*, 30:11:2621-2632.

18. D. C. Schmelling, K. A. Gray and P. V. Kamat, (1996) "The Role of Reduction in the Photocatalytic Degradation of TNT," *Environmental Science & Technology*, 30:2547-2555.

17. Ulick Stafford, Kimberly A. Gray and Prashant Kamat, "Photocatalytic Degradation of Organic Contaminants: Halophenols and Phenols," (1996) *Heterogeneous Chemistry Reviews*, Vol. 3, 77-104.

16. M.S. Dieckmann and K.A. Gray, (1996) "A Comparison of the Degradation of 4-Nitrophenol via Direct and Sensitized Photocatalysis in TiO_2 Slurries," *Water Research*, 30:5:1169-1183.

15. R.J. Hilarides, K.A. Gray, J. Guzzetta, N. Cortellucci, C. Sommer, (1996) "The Radiolytic Degradation of 2,3,7,8-Tetrachlorodibenzo-p-dioxin on Soil: Feasibility, System Design and Economic Evaluations," *Water Environment Research*, 68:2:178-187.

14. K.A. Gray and R.J. Hilarides, "Radiolytic Treatment of Dioxin Contaminated Soils," (1995) *Radiation Physics and Chemistry*, 46:4-6:1081-1084.

13. D.C. Schmelling and K.A. Gray, "Photocatalytic Transformations and Mineralization of 2,4,6-Trinitrotoluene (TNT) in TiO_2 Slurries," (1995) *Water Research*, 29:12:2651-2662.

12. K.A. Gray, C.R. O'Melia, and C. Yao, (1995) "Inorganic Metal Polymers: A Comparison of Aluminum and Iron(III) Polymers for Water Treatment. I. Preparation and Characterization of Polymers," *Journal of American Water Works Association* 87:4:136-146.

11. R. Baretto, K.A. Gray, and K. Anders, "Photocatalytic Degradation of Methyl-tert-butyl Ether in TiO_2 slurries: A Proposed Reaction Scheme," (1995) *Water Research,* 29:5:1243-1248.

10. R.J. Hilarides, K.A. Gray, J. Guzzetta, N. Cortellucci, and C. Sommer, "Radiolytic Degradation of 2,3,7,8-TCDD in Artificially Contaminated Soils," (1994) *Environmental Science and Technology*, 28:13:2249-2258.

9. K.A. Gray and U. Stafford, "Probing Photocatalytic Reactions in Semiconductor Systems: Study of Chemical Intermediates in 4-Chlorophenol Degradation by a Variety of Methods," (1994) *Research on Chemical Intermediates*, 20:8:835-853.

8. R.J. Hilarides, K.A. Gray, J. Guzzetta, N. Cortellucci, and C. Sommer, (1994) "Radiolytic Degradation of Dioxin on Soil: Optimal Conditions and Economic Considerations," *Environmental Progress*, 13:4:263-268.

7. K. Vinodgopal, U. Stafford, K.A. Gray, and P.V. Kamat, (1994) "Electrochemically Assisted Photolysis. II. The Role of Oxygen and Reaction Intermediates in the Degradation of 4-chlorophenol on Immobilized TiO_2 Particulate Films," *Journal of Physical Chemistry*, 98:6797-6803.

6. Ulick Stafford, K.A. Gray and P.V. Kamat, (1994) "Radiolytic and TiO_2-assisted Photocatalytic Degradation of 4-Chlorophenol. A Comparative Study," *Journal of Physical Chemistry*, 98:6343-6351.

5. M.S. Dieckmann, K.A. Gray, and R.E. Zepp, (1994) "The Sensitized Photocatalysis of Azo Dyes in a Solid System: A Feasibility Study," *Chemosphere*, 28:5:1021-1034.

4. U. Stafford, K.A. Gray, P.V. Kamat, and A. Varma, (1993) "An *in situ* Investigation of Photocatalytic Degradation of 4-Chlorophenol on a TiO_2 Powder Surface By FTIR Spectroscopy," *Chemical Physics Letters*, 205:1:55-61.

3. M. Dieckmann, K.A. Gray, and P. Kamat, (1992) "Photocatalyzed Degradation of Adsorbed Nitrophenolic Compounds on Semiconductor Surfaces," *Water Science and Technology*, Vol. 25, No. 3, 277-279.

2. K.A. Gray, (1991) "Direct Filtration of Model and Natural Waters: The removal of turbidity versus natural organic carbon," *Water Supply*, 9, 521-525.

1. K.A. Gray, F. Bernazeau, C. Hubele, (1989) "Upgrading a slow sand filtration plant for micropollutant

MANUSCRIPTS (in review)

K.A. Gray, D. Farr, A. Hughes, D. Dana, W. Drucker, M. Lindsey, T. K. Kirkby, K. Gong, (2011). "Living Cities: Transforming APEC's Cities into Models of Sustainability by 2030." (under consideration by John Wiley).

B. Sikora, J. Sirk, M. Lestina, K.A. Gray, M. Morowitz (2011). "Estimate of the CO_2 emissions associated with care for pediatric appendicitis in the U.S.," *Journal of Pediatric Surgery*, in review.

Daniel Finkelstein-Shapiro, Sarah J. Hurst, Kimberly A. Gray, Nada Dimitrijevic, Tijana Rajh, Pilarisetty Tarakeshwar, Vladimiro Mujica (2011). "CO_2 pre-activation via the electronic coupling with the charge transfer state of TiO_2-aminosalicylic acid complexes," *JACS,* in review.

K. Bhattacharyya, A. Danon, B. Vijayan, K.A. Gray, P.C. Stair, E. Weitz (2011). "The role of the surface lewis acid and basic sites in the adsorption of CO_2 on titania nanotubes and platinized titania nanotubes: An *in situ* FT-IR study," *Jour. Phys. Chem.,* in review.

T. Tong, C.T.T. Bihn, J.J. Kelly, J-F Gaillar, K.A. Gray (2012). "Cytotoxicity of commercial nano-TiO_2 to *Escherichia coli* using high-throughput analysis: The effects of environmental conditions," *Environ. Sci. Technol.,* in review.

Michael D. Marsolek, Mary Jo Kirisits, Kimberly A. Gray, and Bruce E. Rittmann (2012). "Coupled photocatalytic-biodegradation of 2,4,5-trichlorophenol: effects of photolytic and photocatalytic effluent composition on bioreactor

process performance, community diversity, and resistance and resilience to perturbation," *Water Research*, in review.

Jie Sun, John Janssen, Kimberly A. Gray, and Adilson E. Motter (2012). "Historical Data Reveal Regular Growth Rate Fluctuations Despite Seemingly Erratic Population Abundances," *Nature Communications*, in review.

MONOGRAPHS AND BOOK CHAPTERS (*indicates Peer Review)

A. Agrios, K. Gray, (2005) "Beyond Photocatalytic Environmental Remediation: Novel TiO_2 Materials and Applications," in Environmental Catalysis, V. Grassian, ed. (Marcel Dekker), Ch. 15, 369-390.

M. Starkey, K. Gray, S.I. Chang, M. Parsek, (2004) "A Sticky Business: The EPS Matrix of Bacterial Biofilms", in Microbial Biofilms, M. Ghannoum and G. A. O'Toole, eds. (ASM Press), Chapter 10.

B.A. Ankenman, K.A. Gray, (2001) "The Detached Plume Study: Statistical Analysis of Causative Factors in Portland Cement Manufacturing Plants." (Portland Cement Association, Skokie, Il) 112 pages.

K.A. Gray, (2000) "The Establishment of Stream Standards for Total Organic Carbon: Scientific and Engineering Basis," testimony before Colorado Water Quality Board.

* K.A. Gray, A.H. Simpson and K.S. McAuliffe, "Use of PY-GC-MS to Study the Nature and Behavior of NOM in Water Treatment." In *Water Disinfection and Natural Organic Matter*, Roger Minear and Gary Amy, eds. (ACS Symposium Series 649, Washington, D.C., 1996) 159-181.

*R.J. Hilarides, K.A. Gray, J. Guzzetta, N. Cortellucci, and C. Sommer, "Degradation of Chlorinated Dioxins on Soil using ^{60}Co Gamma Radiation: Considerations and Optimiation," in *Chemical Oxidation: Technology for the 90's*, Vol. 4, J. Roth and A. Bowers, eds. (Technomics, Lancaster, PA, 1996) 205-218.

*D.C. Schmelling and K.A. Gray, "Photocatalytic Transformations of TNT in Titania Slurries: An Analysis of the Role of Interfacial Nitrogen Reduction Utilizing g-Radiolysis," in *Chemical Oxidation: Technology for the 90's*, Vol. 4, J. Roth and A. Bowers, eds. (Technomics, Lancaster, PA, 1996) 173-184.

*U. Stafford, K.A. Gray, and P.V. Kamat, "Photocatalytic Oxidation of 4-Chlorophenol on Titanium Dioxide: A Comparison with g-Radiolysis," in *Chemical Oxidation: Technology for the 90's*, Vol. 4, J. Roth and A. Bowers, eds. (Technomics, Lancaster, PA, 1996) 193-204.

*L. Weitzman, K.A. Gray, R.W. Peters, F.K. Kauahara, and J. Verbicky, (1994), *Innovative Site Remediation Technology, Vol. II: Chemical Treatment*, American Academy of Environmental Engineers, Annapolis, MD, 200 p.

*K.A. Gray, P. Kamat, U. Stafford, and M. Dieckmann, "Mechanistic Studies of Chloro- and Nitrophenolic Degradation on Semiconductor Surfaces," Environmental Aspects of Surface and Aquatic Photochemistry, D. Crosby, R. Zepp, and G. Heltz, eds., (Lewis Publishers/CRC Press, 1994) 399-408.

D.C. Schmelling and K.A. Gray, "Feasibility of Photocatalytic Degradation of TNT as a Single or Integrated Treatment Process," TiO_2 Photocatalytic Purification and Treatment of Water and Air, David Ollis and Hussain Al-Ekabi, eds., (Elsevier Publishers, 1993), 625-632.

K.A. Gray, U. Stafford, M.S. Dieckmann, and P. Kamat, "Mechanistic Studies in TiO_2 Systems: Photocatalytic Degradation of Chloro- and Nitrophenols," TiO_2 Photocatalytic Purification and Treatment of Water and Air, David Ollis and Hussain Al-Ekabi, eds., (Elsevier Publishers, 1993), 455-472.

*C.R. O'Melia, K.A. Gray, C. Yao, *Polymeric Metal Coagulants*, American Water Works Association Research Foundations, Denver, CO, 1989.

T.D. Waite, K.A. Gray, "Oxidation and coagulation of wastewater effluent utilizing the ferrate(VI) ion," in *Chemistry for Protection of the Environment*, L. Pawlowski, A.J. Verdier, and W.J. Lacy, editors (Elsevier Science Publishing Co., 1984) pp. 407-420.

CONFERENCE PROCEEDINGS

D.L. Widrig, K.A. Gray and K.S. McAuliffe, 1996. Removal of Algal-Derived Organic Material by Preozonation and Coagulation: Monitoring Changes in Organic Quality by Pyroysis-GC-MS, in Proceedings of AWWA 1996 Annual Conference.

K.A. Gray, A.H. Simpson and K.S. McAuliffe, 1995. Use of PY-GC-MS to Study the Nature and Behavior of NOM in Water Treatment, in Proceedings of the 210th ACS National Meeting, 35:2:635-638.

U. Stafford, K.A Gray and P.V. Kamat, 1995. Kinetic Modeling of 4-Chlorophenol Degradation in Titania Slurries, in Proceedings of the 210th ACS National Meeting, 35:2:563-566.

D.C. Schmelling, K.A. Gray and P.V. Kamat, 1995. The Role of Nitrogen Reduction in the Photocatalytic Degradation of Nitroaromatic Compounds, in Proceedings of the 210th ACS National Meeting, 35:2:484-486.

K.A. Gray, 1995. Use of Ionizing Radiation to Destroy Pollutants, in Transactions of the American Nuclear Society, 1995 Annual Meeting, Philadelphia, PA, 72:132-133.

K.A. Gray, 1994. Treatment of Soils and Sediments: Radiolytic Destruction of Chlorinated Dioxins Using Cobalt-60, Pages in Proceedings of NSF Workshop on Applications of Ionizing Radiation for Decontamination of Environmental Resources, Miami, FL .

M.S. Dieckmann, K.A. Gray and P.V. Kamat, 1994. The Sensitized Photocatalysis of a Mixed Reactant System of 4-Chlorophenol and 4-Nitrophenol. Pages 726-732 in Proceedings of the 1994 National Conference on Environmental Engineering "Critical Issues in Water and Wastewater Treatment" (J.N. Ryan and M. Edwards, eds.) American Society of Civil Engineers.

K.A. Gray and R.J. Hilarides, 1994. Innovative Treatment of Soil Contamination: Radiolytic Destruction of Dioxin and Co-Contaminants by Cobalt-60. Pages 733-736 in Proceedings of the 1994 National Conference on Environmental Engineering "Critical Issues in Water and Wastewater Treatment" (J.N. Ryan and M. Edwards, eds.) American Society of Civil Engineers.

D.C. Schmelling and K.A. Gray, 1994. Photocatalytic Transformation and Degradation of 2,4,6-trinitrotoluene (TNT) in TiO2 Slurries. Pages 751-755 in Proceedings of the 1994 National Conference on Environmental Engineering "Critical Issues in Water and Wastewater Treatment" (J.N. Ryan and M. Edwards, eds.) American Society of Civil Engineers.

K.A. Gray, A. St. Amand, and H. Wang, 1993. "Role of a Periphytic Biolayer in the Fate of PCBs in Artificial Stream Systems," Proceedings of the First International Specialized Conference on Contaminated Aquatic Sediments: Historical Records, Environmental Impact, and Remediation, (IAWQ), 271-280.

K.A. Gray and K. McAuliffe, 1991. "Use of Pyrolysis-GC-MS to Study the Organic Matrix of Surface Waters," Proceedings of Water Quality Technology Conference, AWWA, Part II, November, 1991, 1219-1231.

PUBLISHED REVIEWS

Book review of Radioactive Waste Management (Y.S. Yang and J.H. Saling) for *Environmental Progress.*

"Report on the First International Conference on TiO_2 Photocatalytic Purification and Treatment of Water and Air," published in European Photochemistry Association Newsletter (47:50-53) and the Inter-American Photochemical Society Newsletter.

RESEARCH REPORTS

K.A. Gray (2008) "Hydrologic and Environmental Effects of Hydraulic Control Structures: Baseline Monitoring," Technical Report, The Wetlands Initiative, Chicago, Il.

C.K. Ishida, K.A. Gray (2005) "Hydraulic Effects on Biological Diversity and Water Quality in Constructed Wetlands," Final Report to U.S. Army Corps of Engineers, February, 2005.

K.A. Gray (2001) "Physical, Chemical, & Biological Characterization of Swam Lake Sediments," Technical Report, The Wetlands Initiative, Chicago, Il.

M.E. Finster, K.A. Gray (1999) "The Urban Heat Island, Photochemical Smog, and Chicago: Local Features of the Problem and Solution." Technical Report, Atmospheric Pollution Prevention Division, U.S.E.P.A.

"Characterization of the Organic Matrix of the Missouri River by Pyrolysis/GC/MS," Burns and McDonnell, February, 1997.

"Removal of DBP Precursors by Optimized Coagulation and Precipitative Softening: Use of PY-GC-MS to Monitor Coagulation Effectiveness ," American Water Works Research Foundation, October, 1996.

"Evaluation of Organic Quality in Prado Wetland and Santa Ana River by Pyrolysis-GC-MS" Orange County Water District, April, 1996.

"Removal of DBP Precursors by Granular Activated Carbon Adsorption: PY-GC-MS Characterization of Organic Quality," American Water Works Research Foundation, Nov. 1995.

"Monthly Monitoring of Prado Wetland Using PY-GC-MS," Orange County Water District, May, 1995.

"Pyrolysis-GC-MS Analysis of Various Contaminated Groundwater Samples," Institut für Wasservorsorge, Universität für Bodenkultur, (Vienna, Austria), February, 1995.

"Metal Ion Concentrations in KDF Treated Ground-Water," KDF Fluid Treatment Inc., March, 1994.

"Safety Kleen Refinery Waste Water Evaluation," Safety Kleen Corp., March, 1992.

"Jar Test Results for Polyferric Sulfate: Comparison of Various Waters and Other Coagulants," submitted to Midland Resources, February, 1992.

"The Role of Water Hardness in Performance of Aqualene for the Coagulation of Clay Turbidity," submitted to Rhone-Poulenc Chemical Company, July, 1991.

"Characterization of Polyferric Sulfate Solutions," submitted to Midland Resources, Inc. and Kemiron Inc., May 1991.

"Radiolytic Destruction of Organics," submitted to Occidental Chemical Company, October 1991.

SIGMA XI DISTINGUISHED LECTURES

Mercer University, Macon GA, Oct. 2,2008
Pennsylvania State University, Erie, PA, Oct. 16, 2008
University of Northern Iowa, Oct. 23, 2008
Michigan State University, Nov. 6, 2008
Syracuse University, Nov. 13, 2008
University of Wisconsin-Fox Valley, Nov. 17, 2008.
Army Research Lab, Adelphi, MD, Dec. 11, 2008
Trinity University, Jan. 26, 2009 (2 talks)
Purdue University, Feb. 3, 2009.

Western Washington University, Feb. 24, 2009 – 2 lectures given.
Western Kentucky University, March 2, 2009
University of Tennessee, March 17, 2009.
Eastern Illinois University, April 2, 2009 – 2 lectures given.
Cornell University, April 7, 2009
Portland State University, April 21, 2009.
Southern Oregon University, May 14, 2009.
Nalco, June 4, 2009
SUNY-Purchase College, Oct. 29, 2009
University of Nebraska, Nov. 19, 2009
Mayo Clinic, Rochester, MN, Jan. 19, 2010
South Dakota State University, February 25, 2010 (2 talks)
Youngstown State University, March 4, 2010
Tarleton State University, March 11, 2010 (2 talks)
University of Northern Michigan, March 18, 2010 (2 talks)
Rollins College, March 25, 2010 (2 talks)
University of Louisville, April 15-16, 2010 (2 talks)
Rockford College, April 20, 2010 (2 talks)

INVITED LECTURES

"Why the energy issue is fundamentally an environmental issue. . .and why this doesn't seem to matter" State of the Nation: Election 2012, Alumnae Continuing Education Lecture Series, 6 Nov. 2012.

"Living Cities: A vision to sustain the exploding megacities of Asia and the shrinking cities of the North America," Vision Seminar, Dept. of Civil Engineering, Purdue University, 25 April 2012.

"Living Cities: The redesign of cities inspired by ecological principles," keynote address at the Mid-west Environmental Leadership Summit, 15 April 2012.

"Living Cities: A vision to sustain the exploding megacities of Asia and the shrinking cities of the Midwest," Environmental Engineering seminar series, Marquette University, 6 March 2012.

"Living Cities: Transforming APEC Cities into Models of Sustainability by 2030," presentation to the Asia Pacific EC Business Advisory Committee, Hong Kong, 24 February 2012.

"Potential Effects of Nanotitania in Benthic Systems," presented at IMI-SEE workshop, "Developing sustainable nanotechnologies: Maximizing Functionality while Minimizing Health Impact," at Sichuan University, Chengdu, China, Sept. 14, 2011.

"Potential Effects of Nanomaterials on Human and Ecological Health," seminar at Geosyntec Consultants, Chicago, IL, 23 June 2011.

"Sustainable Strides in Urban Design: Lessons from Chicago," Sci-Tech Seminar, USEPA Region V Science and Technology Council, 20 April 2011.

"The potential effects of nanotitania in benthic systems," in Reactivity, Transformation and Detection of Natural and Engineered Nanomaterials in the Environment Symposium (Division of Colloid & Surface Science), 241st ACS National Meeting, Anaheim, CA, March 27-31, 2011.

"Sustainable Strides: Lessons from Chicago" plenary presentation at the 2nd Xiamen International Forum of Urban Environment, Xiamen, China, Dec. 11-13, 2010.

"Green Cities/Brown Lakes: The Challenge of Great Lakes Restoration," seminar, Memorial University of Newfoundland, Canada, Oct. 29, 2010.

"Transforming our Cities: Sustainability and the Post Fossil-Fuel Future," Keynote presentation, Dialogue on Advancing Global Sustainability, Memorial University of Newfoundland, Canada, Oct. 28, 2010

"Sustainable Cities and the Many Dimensions of a Post-Fossil Fuel Future," Carbon and Climate: Lessons from the Past, Solutions for the Future, 2nd Annual Climate Change Symposium, NU, Oct. 18, 2010.

"Green Cities/Brown Lakes: The Challenge of Great Lakes Restoration," The Women's Board of Northwestern, Sept. 21, 2010.

"The Debate on the Scientific Evidence of Climate Change" Judicial Symposium on Public Nuisance Litigation sponsored by the Northwestern Law Judicial Education Program, Searle Center on Law, Regulation, and Economic Growth, Northwestern University School of Law, 27 April 2010.

"Chemical and physical synthesis of TiO_2-based nanocomposites for solar energy production and other environmental applications," seminar in Dept. of Chemical Engineering, University of Louisville, 15 April 2010.

"Fabricating Titania-based Nanocomposites for Solar Fuel Production: TiO_{2-x}, $Ti_{1-x}Nb_xO_2$, & Titania Nanotubes," NIMS International Workshop on Photocatalysis and Environmental Remediation, Tsukuba, Japan, 22-24 February 2010.

"Tailoring Nanomaterials for Probing Environmental Systems: React, Identify, and Monitor," Workshop on Nano-Enabled Sensing Microsystems for Geosciences, Organized by the NSF National Nanotechnology Infrastructure Network (NNIN), Ann Arbor, MI, 4 February 2010.

"Chemical and physical synthesis of TiO_2-based nanocomposites for solar energy production and other environmental application," Nebraska Center for Materials and Nanoscience and Physics colloquium, University of Nebraska, Lincoln, NE, 19 November, 2009.

"The Nanotechnology Revolution and its Unintended Environmental Effects," Encouraging appropriate use of the products of scientific research: U.S.-Iran-France Workship, sponsored by NAS, Academie des Sciences, 7-12 November, 2009, Fondation des Treilles, France.

"Progress on Synthesizing Photoactive Nanocomposite Materials to Produce Solar Fuels," Sino-U.S. Workshop on Nanostructured Materials for Global Energy & Environmental Challenges, Changzhou, China, Oct. 15-18, 2009.

"What will finally spark that the Green Revolution?" One Book Science Café, 7 Oct. 2009.

"Five Myths about Nanotechnology in the Current Public Policy Debate," CEE Seminar, 25 Sept., 2009.

"Chemical and physical synthesis of TiO_2-based nanocomposites for solar energy production and other environmental application," Dept. of Civil and Environmental Engineering, Rice University, Houston, TX, 21 September, 2009.

"Ecology and the Green Revolution," 61st Annual Meeting of the Association of American Universities, Chicago Botanical Gardens, 20 September 2009.

"The Feasibility of Achieving Sustainability Goals in the Near-Term," Annual Meeting of North American Management Team, Veolia Energy, 27 Aug. 2009.

"Secrets of the Art World Unlocked: Le Grand Jatte," Chicago Council on Science and Technology, Art and Science, 8 June 2009.

"Sustainable Water Use in Cities and Industry: Future Challenges and Promising Strategies," Metropolitan Water Reclamation District of Greater Chicago, Lue-Hing R&D Laboratory Seminar Series, 29 May 2009.

"Five Myths about Nanotechnology in the Current Public Policy Debate," Searle Center Research Roundtable on *Environmental, Health, and Safety Risks of Emerging Technologies*, Northwestern University School of Law, April 23 - 24, 2009.

"Sustainable Solutions to Energy, Water & Climate Challenges" in Globalization: The Next Stage, Ryan Learning for Life 2008 Lectures, Robert H. Lurie Medical Research Center, NU, Nov. 19, 2008.

"The Effects of Climate Change on Transportation," Transportation Center Business Advisory Committee Meeting, NU, Oct. 22, 2008

"Progress in developing photoactive nanocomposites to improve the efficiency of artificial photosynthesis," seminar in the Department of Geography and Environmental Engineering, Johns Hopkins University, October 21, 2008.

"Energy & the Environment - Election 2008: Inside the Issues", *Classes without Quizzes*, Panel moderated by Les Crystal, NU, Oct. 17, 2008.

"Energy & the Environment: The Central Challenge of Sustainability," NU Club of Milwaukee, Oct. 7, 2008.

"Photoactive Nanocomposite Materials to Produce Solar Fuels," Sino-U.S. Workshop on Nanostructured Materials for Global energy & Environmental Challenges, Sept. 22, 2008.

"Sustainable Water Use in Cities and Industry: Future Challenges and Promising Strategies," 2008 International Open Lecture Series on Business, Technology and Urban Life for a Sustainable Future, Fukuoka University, Japan, July 18, 2008.

"How sustainable does business need to be?" Environmental Sustainability Business Club, Kellogg Business School, Northwestern, 29 May 2008.

"Solar fuel generation: Engineering photocatalytic "hot spots" in TiO_2-based nanocomposites," Physics Colloquium, Northwestern University, 9 May 2008.

"The Sustainability Imperative: The need for interdisciplinary learning, teaching and research," Center for Environmental Studies, Brown University, 15 April 2008.

"Second generation TiO_2-based nanocomposites for solar fuel generation," Division of Engineering, Brown University, 14 April 2008.

"Second generation TiO_2-based nanocomposites for solar fuel generation," Department of Civil Engineering, Duke University, 21 April 2008.

"The Green Wave: Is there really anything to the sustainability buzz?" Science Café, Sigma Xi Scientific Research Society at Northwestern, April 16, 2008.

"The modern American city: Can we ever make it sustainable?" seminar in Civil and Environmental Engineering at Temple University, February 27, 2008.

"What does Sustainability mean for teaching, learning and living at a university?" Keynote address to Residential College Domain Dinner, Northwestern University, February 5, 2008.

"Structuring Highly Active Nanoscale Photocatalytic Films using Reactive Sputtering," presented in an Advanced Surface Engineering Division Session at the 54th AVS Symposium, 14-19 October, 2007, Seattle, WA.

"Progress in synthesizing photo-active titania-based nanocomposites for CO_2 reduction and fuel production," seminar, Honeywell Aerospace & Environmental Quality Group, July 3, 2007.

"Probing the effects of light, humidity and acidity on the deterioration of a zinc potassium chromate pigment," Photochemical Processes in Art and other Standards, Seminar Series on Conservation Science, June 7, 2007.

"Nanotechnology, Energy, and the Environment," inaugural seminar sponsored by the McCormick Graduate Student Leadership Council, Northwestern University, March 8, 2007.

"Progress in synthesizing photo-active titania-based nanocomposites for CO_2 reduction and fuel production," seminar, Dept. of Civil and Environmental Engineering, Duke University, 21 March 2007.

"The feasibility of developing sustainable energy sources for transportation," 2007 SWE Regional conference, Chicago, IL, 27 January 2007.

"Navigating the Choppy Seas of Science: Reflections on Careers in Environmental Science and Engineering," Women in Science & Engineering Symposium, Loyola University, July 27, 2006.

"Energy and The Environment: The Central Challenge of Sustainability," Keynote address at the 2006 Environmental Engineering Spring Symposium, University of Illinois, Urbana-Champaign, March 31, 2006.

"Determining Structure/Function Relationships for Organic Carbon in Surface Waters: Application to Water Reuse," presented to the Department of Hydraulics and Environmental Engineering at Pontificia Univerisidad Catolica de Chile, Oct. 26, 2005.

"Ecological Restoration in Aquatic System: The importance of understanding molecular scale phenomena in the big picture," Seminario Internacional, *"Transporte, Reacción y Destino de Contaminantes en Sistemas Acuáticos Naturales Impactados "* presented to Center for the Environment at the Pontificia Universidad Católica de Chile, Oct. 24, 2005.

"Synthesizing and Characterizing Highly Active TiO_2 Nanocomposite Photocatalysts" presented at TiO_2-10, Chicago, IL, October, 2005.

"Hurricane Katrina: An Ecological Perspective," presented in seminar Hurricane Katrina: Preparation, Response and Rebuilding, Northwestern University, Oct. 17, 2005.

"Energy and Environmental Chemistry," presented at the Midwest Environmental Chemistry Conference, October 16, 2005.

"Nanostructured photoactive materials for environmental applications", presented in Environmental Nanotechnology at the 230th ACS National Meeting, in Washington, DC, Aug 30, 2005.

"Radiation induced catalytic transformation of organohalide contaminants", presented in Strategies and Molecular Mechanisms of Contaminant Degradation Chemistry at the 230th ACS National Meeting, in Washington, DC, Aug 29, 2005.

"Future Cities," plenary lecture at the NSF Summer Institute on Nano Mechanics and Material, Nanotechnology, Biotechnology and Green manufacturing for Creating Sustainable Technologies, Northwestern University, June 22, 2005.

"Nanocatalysis," presented at the NSF Summer Institute on Nano Mechanics and Material, Nanotechnology, Biotechnology and Green manufacturing for Creating Sustainable Technologies, Northwestern University, June 21, 2005.

"New Directions in Environmental Engineering and Chemistry: Catalysis, Analysis, Restoration," presented at Fukuoka University, Kitakyushu, Japan, February 22, 2005.

"New Advances in the Study of Photoactive materials for Environmental Applications," seminar presented at the SPEA, Indiana University, October 13, 2004.

"Impacts of Urban Development on Soil and Water Quality: Characterization and Remediation," seminar presented in the Department of Environmental Science at the University of Illinois-Urbana, March 12, 2004.

"Environmental Engineering and Chemistry: Catalysis, Analysis, Restoration," seminar presented at Gas Technology Institute, Des Plaines, IL, May, 2003.

"Structure and Function of Environmental Biofilms: Three Examples," seminar presented in the Department of Civil Engineering at Case Western University, March, 2003.

Tracking Organic Carbon Quality: Fingerprinting Techniques to Trace the Origins of Organic Material," seminar presented in 2003 Environmental Engineering Seminar Series, "Barriers and Incentives to Wastewater Reuse in Illinois," IIT, March 26, 2003.

"The Impact of Metal and Organic Contaminants on the Structure of Periphyton in Lotic Sediments," presented at the NSF funded US-Chinese Joint Workshop on Sediment Transport and Enviromental Studies, July, 2002.

"Feasibility of Applying Phytoremediation in Urban Residential Communities," presented at the 130th Annual Meeting of the American Public Health Association, Philadelphia, PA, November 13, 2002.

"Radiolytic Dechlorination of Adsorbed Pollutants in Various Matrices," presented in the Symposium on Radiation Chemistry at the 222th Annual Meeting of the American Chemical Society, Chicago, IL, Aug. 2001.

"Monitoring the Impact of Organic Quantity and Quality in Surface Waters: Two Case Studies," presented at IL AWWA Annual Meeting, Springfield, March, 2001.

"The Influence of Organic Quantity and Quality in Aquatic Systems," seminar presented in Dept. of Chemistry, Purdue-Calumet, April, 2001.

"The Combined Effects of Metal and Organic Contaminants on a Periphytic Assemblage in Lotic Sediments" presented in the Symposium on: The Influence of Hydrosphere-Biosphere Interactions on the Speciation and Transport of Metals at the Fall Meeting of the American Geophysical Union, San Francisco, December, 2000.

"Radiation-induced processes in the treatment of contaminated materials. Successes and Challenges.," Gordon Research Conference on Radiation Chemistry, Plymouth, New Hampshire, June 27, 2000.

"Mechanistic Insight into Soil Radiolysis," presented in NSF Workshop, Determination of Optimum Radiolytic Treatment Methodologies for Remediation of PCB Contaminated Sites, University of Maryland, Nov. 15-17, 1999, College Park, MD.

"Molecular Tools to Study Chemical Phenomena inn Environmental Systems," presented at the AEESP Research Needs Conference, Penn State University, Aug. 1, 1999.

"Jumping Through Hoops: The Promotion and Tenure of Women and Minorities," presented at the AEESP Research Needs Conference, Penn State University, July 31, 1999.

"Photobiocatalysis: Optimized Treatment Strategy for Recalcitrant Pollutants," seminar presented to BP-Amoco researchers, June 1, 1999.

"Detached Plumes and Visible Emissions in North American Portland Cement Plants," presented to MTC Semi-annual Meeting, Roanoke, VA, April 12, 1999.

"Photobiocatalysis: Integrating Chemical and Biological Catalysis for the Treatment of Hazardous Chemicals," presented at the 21st Midwest Environmental Chemistry Workshop, University of Michigan, Ann Arbor, MI, Oct. 17, 1998.

"Photobiocatalysis: Integration of Photocatalysis and Biocatalysis," presented at the Center for Catalysis and Surface Scienee Annual Meeting, Evanston, IL. Sept. 9,1998.

"Environmental Applications of Radiolysis," plenary lecture at DOE Workshop Research Needs and Opportunities in Radiation Chemistry, Chesterton, IN, 19-22 April 1998.

"NOM Structure: Pyrolysis/GC/MS versus ^{13}C-NMR," presented in Sunday Seminar, New Developments in Characterizing and Monitoring NOM in Water Treatment, AWWA Water Quality Technology Conference, Denver, CO, Nov. 9, 1997.

"Probing Dissolved Organic Carbon Dynamics in Natural Waters with Pyrolysis/GC/MS," presented to the Department of Geological Sciences, Northwestern University, Nov. 7, 1997.

"Probing Dissolved Organic Carbon Character in Surface Waters," presented to the Department of Environmental Engineering and Science, University of North Carolina, Chapel Hill, May, 28, 1997.

"TiO_2 Photocatalysis: Transformation of Aromatic Pollutants in Particulate Semiconductor Systems." presented to the Catalysis Center, Northwestern University, May 9, 1997.

"Probing the Organic Carbon Cycle in Wetlands using Pyrolysis-GC-MS" presented in Natural Organic Matter in Aquatic Systems Session at American Geophysical Union 1996 Fall Meeting in San Francisco, CA, 15-19 December 1996.

"Photocatalytic Behavior of Nitroaromatic Compounds in TiO_2 Systems," presented to Environmental Engineering at University of Illinois, 25 April 1996.

"Radiolysis at Environmental Surfaces: Radiolytic Transformation of Chlorinated Dioxins and Other Aromatic Compounds in Soils," presented at the 44th Annual Scientific Meeting of the Radiation Research Society, April 17, 1996, Chicago, IL.

"A Comparison of Electron Beam and Gamma Irradiation to Destroy Halogenated Aromatic Contaminants on Soils," to be presented at the Second International Symposium, Environmental application of Advanced Oxidation Technologies, sponsored by EPRI and U.S. DOE, February 28-March 1, 1996, San Francisco, CA.

"Photocatalytic Interactions of Nitroaromatic Pollutants in TiO_2 Systems," presented to Pritzker Department of Environmental Engineering at the Illinois Institute of Technology, 24 January 1996.

"Use of Ionizing Radiation for Reductive Dechlorination: Chemistry, Design and Economics," presented at the 1995 International Chemical Congress of Pacific Basin Societies, December 17-22, 1995, Honolulu, Hawaii.

"Predicting the Course of 4-Chlorophenol Photocatalytic Degradation: Model Development and Design Implications," presented at the World Environmental Congress, Sept. 17-22, 1995, London, Ontario.

"Use of Ionizing Radiation to Destroy Pollutants," presented at American Nuclear Society 1995 Annual Meeting, June 25-29, 1995, Philadelphia, PA.

"Organic Chemical Transformations," presented at the Groundwater Recharge with Reclaimed Water Workshop sponsored by the WateReuse Association of California, 25 May 1995.

"Photocatalysis: Theory, Experiments and Models," presented to the Dept. of Civil Engineering, University of Texas at Austin, April, 1995.

"Inorganic Polymers: Fundamental Aspects Related to their Use for Particle Removal and Dewatering," presented at the Annual Meeting of the Society of Mining Engineers, March 6-9, 1995, Denver, CO.

"Radiolytic Transformation of Soil Contaminants: A Comparison of Gamma and Electron Beam Irradiation," presented to National Institute of Standards and Technology, Ionizing Radiation Division, Gaithersburg, MD, Dec. 1, 1994.

"The Wetland Environment: The Biogeochemistry of Inland and Coastal Systems," presented at the Fall Meeting of the Indiana Academy of Sciences, Nov. 5, 1994.

"Photocatalytic Oxidation of a Model Halogenated Aromatic Compound: A Mechanistic Study," presented to Photocatalysis, Catalysis and Environment Group, Ecole Centrale de Lyon, Lyon, France, Oct. 27, 1994.

"Organic and Inorganic Transformation Products of TNT Photocatalysis," presented at "Emerging Technologies in Hazardous Waste Management VI," ACS, I&EC Division Symposium, Atlanta, GA, Sept. 19-21, 1994.

"Radiolytic Treatment of Dioxin Contaminated Soils," presented at the 9th International Meeting on Radiation Processing, Istanbul, Turkey, Sept. 11-16, 1994.

"Use of PY-GC-MS to Fingerprint the Influences of Algal Material on NOM," presented in the seminar entitled "Natural Organics and Drinking Water-From Ecology to Engineering," at the 1994 Annual Meeting of the American Water Works Assoc., New York, NY, June 1994.

"Gamma Radiolysis of Dioxin on Soils: Theoretical and Practical Considerations," presented at the First International Conference on Advanced Oxidation Technologies for Water and Air Remediation, London, Ontario, June, 1994.

"Treatment of Soils and Sediments: Radiolytic Destruction of 2,3,7,8-TCDD," presented at the NSF Workshop on Applications of Ionizing Radiation for Decontamination of Environmental Resources, Miami, FL, June 2, 1994.

"Free Radicals and Excited States in Environmental Engineering: Photocatalysis and Radiolysis," presented to the Department of Civil Engineering, Northwestern University, April 12, 1994.

"Environmental Applications of Semiconductor Photocatalysis," presented at 3M Corp., St. Paul, MN, March 28, 1994.

"Pyrolysis-GC/MS Analysis of Natural Organic Material in Water," presented to Orange County Water District and National Water Research Institute, Feb. 24, 1994.

"Characterization of Natural Organic Material Using Pyrolysis-GC-MS: Applications in Water Treatment," presented at the U.S. Environmental Protection Agency and University of Cincinnati, Feb. 11, 1994.

"Radiolytic Destruction of Dioxin on Soils Using Cobalt-60: Theoretical and Practical Considerations," presented at Environmental, Ocean and Water Resources Division, Dept. of Civil Engineering, Texas A&M University, Feb. 3, 1994.

"Radiolytic Destruction of Dioxin on Soils: Its Potential as a Pretreatment Method to Enhance Bioremediation," presented at the 1993 Annual Spring Meeting of AIChE in Houston, TX.

"Photocatalysis for Environmental Applications: General Aspects and Mechanistic Insights," presented at Dept. of Environmental Science and Engineering, Rice University, March 29, 1993.

"Advanced Oxidation: Photocatalytic Destruction of Aromatic Compounds," Dept. of Civil Engineering, Northwestern Univ., 3 March, 1993.

Symposium on Environmental Applications of Advanced Oxidation Technologies, sponsored by Electric Power Research Institute and the National Science Foundation," San Francisco, CA, Feb. 22-24, 1993.

"Water Treatment Studies at the University of Notre Dame" presented at the Central Research Laboratories of the Lyonnaise des Eaux-Dumez, Le Pecq, France, December 21, 1992.

"The Role of Oxygen in the Photocatalytic Degradation of 4-Chlorophenol," presented at the First International Conference on TiO_2 Photocatalytic Purification and Treatment of Water and Air, London, Ontario, November, 1992.

"Photocatalysis on Semiconductor Surfaces: Novel Applications for Hazardous Chemical Destruction," presented at the RadTech '92 North America, Boston, MA, April 29, 1992.

"The Raging Dioxin Debate: Scientific and Social Factors," Center for Social Concerns, University of Notre Dame, January 31, 1992.

"Science and Emotion: The Dioxin Debate," Institute for International Peace Studies, November 7, 1991.

"Inorganic and Organic Polymeric Coagulants: Theory and Application," Association of Environmental Engineering Professor Seminar, presented at Annual Meeting of American Water Works Association, Philadelphia, PA, June 24, 1991.

"Alternative Uses of Semiconductor Systems: Photocatalytic Degradation of Halogenated Organic Compounds," presented in a symposium, *Common Problems in Imaging Science and Photocatalysis*, at the 44th Annual Conference of the Society of Photographic Scientists and Engineers, St. Paul, MN, May 12-17, 1991.

"Influences of Natural Organic Material on Water Treatment Processes," J.M. Montgomery Consulting Engineers, November, 1990.

"Direct Filtration and Natural Organic Material," Department of Civil Engineering, Duke University, October 1990.

PRESENTATIONS

Paul A. DeSario, Le Chen, Michael E. Graham, Kimberly A. Gray, "Visible Light Activated TiO_2: Oxygen Vacancies and Cation Substitution," 239th American Chemical Society Meeting , San Francisco, CA, March 21-25, 2010.

Baiju K. Vijayan, Paul Desario, Nada Dimitrijevic, Kimberly Gray, "Photocatalytic reduction of carbon dioxide to fuel using hydrothermally Synthesized Titania Nanotubes", 239th American Chemical Society Meeting, San Francisco, CA, March 21-25, 2010.

S. Ciston, Y. Yao, R.M. Lueptow, K.A. Gray, Fouling Prevention in Rotating Reactive Membrane Filtration, Annual AIChE Meeting, Philadelphia, PA, November, 2008.

L. Chen, M. Graham, K.A. Gray, Photoreduction of CO_2 over reactive DC magnetron sputtered TiO_2 thin films, 234th ACS National Meeting, Boston, MA, August 19-23, 2007.

G. Li, K.A. Gray, Solar Fuel Applications of Titania Nanocomposites: Solid-Solid Interfaces for Photoreduction of Carbon Dioxide, 234th ACS National Meeting, Boston, MA, August 19-23, 2007.

S. Ciston, G. Li, L. Chen, R.M. Lueptow, K.A. Gray, Biofouling Prevention through Reactive Ceramic Ultrafiltration Membranes, North American Membrane Society, May 14, 2007.

Y. Yao, K.A. Gray, R.M. Lueptow, Titanium Dioxide/Carbon Nanotube Composites for Photo-reactive Filtration, North American Membrane Society, May, 2007.

C. Ng, K.A. Gray, Predicting Bioaccumulation in Dynamic Food Webs: *Ontogeny, Seasonality, Invasional Successions*. Session Title: Environmental Fate and Transport Processes II. AIChE Annual Meeting, Thursday

November 16, 2006, San Francisco.

Shannon Ciston, Le Chen, Gonghu Li, Martina Hausner, Richard M. Lueptow, Kimberly A. Gray, "Effects of TiO_2 nanostructure and various ceramic supports in photocatalytic membranes for water Treatment." AIChE Annual Meeting, November 16, 2006. San Francisco, CA.

Le Chen, Michael E. Graham, Gonghu Li, Kimberly A. Gray, "Fabricating Highly Active Mixed Phase TiO_2 Photocatalysts by Low Angle Reactive DC Magnetron Sputter Deposition." 2006 AIChE Annual Meeting, Nov. 15, 2006. San Francisco, CA.

G. Li, L. Chen, S.M. Ciston, T. Rajh and K.A. Gray, "Titania-based Nanocomposite Materials as Highly Active Photocatalysts", *Fundamentals of Environmental Catalysis*, The AIChE 2006 National Meeting, San Francisco, CA; November 14, 2006.

A.I. Packman, S. Arnon, and K.A. Gray, Structure, Transport, Transformation: Hydrodynamic controls on redox conditions and microbial metabolism in surficial sediments, invited presentation at the Geological Society of America Annual Meeting, Philadelphia, Oct. 2006.

G. Li, L. Chen, S.M. Ciston, T. Rajh and K.A. Gray, "TiO_2-based Nanocomposite Materials as Highly Active Photocatalysts: The Role of Adlineation Sites", *Fundamentals of Metal Oxide Catalysis*, The 232nd ACS National Meeting, San Francisco, CA; September 10, 2006.

Shannon Ciston, Le Chen, Gonghu Li, Martina Hausner, Richard M. Lueptow, Kimberly A. Gray, "Effects of TiO2 nanostructure and various ceramic supports." ACS National Meeting, September 10, 2006, San Francisco, CA.

A.I. Packman, J.D. Newbold, S. Arnon, and K.A. Gray, Implications of hyporheic structure and biophysicochemical process coupling for modeling nitrogen dynamics in rivers, presentation at the North American Benthological Society Annual Meeting, Anchorage, Jun. 2006.

S. Arnon, A. I. Packman and K. Gray. "Flow conditions and substrate geometry strongly influence benthic denitrification." North American Benthological Society, Anchorage, AK, USA, June, 2006.

L. Chen, K.A. Gray, M. Graham, "Developing photocatalytically active mixed phase TiO_2 by magnetron sputtering deposition," to be presented in the New Horizons in Coatings and Thin Films Symposium at the International Conference on Metallurgical Coatings and Thin Films, May, 2006.

A.I. Packman, S. Arnon, and K. A. Gray, Structure, Transport, Transformation: A framework for analysis of denitrification and other microbially mediated processes in aquatic systems, presentation at the American Geophysical Union Fall Meeting, San Francisco, Dec. 2005.

S. Arnon, A. I. Packman and K. A. Gray. "The effect of flow on periphyton structure and nitrate removal." 2005 American Geophysical Union, New Orleans, LA, USA.

C. Liu, K. Nakano, E. Obuchi, T. Oike, N. Yukihira, D. Hurum, K. Gray, "Photocatalytic decomposition of formaldehyde using titania coated lime tile," to be presented TiO_2-10, Chicago, IL, October 24, 2005.

C. Ng, M.B. Berg, K.A. Gray, L.A.N. Amaral, "Complex trophic dynamics in an invaded food web," presented at the 90th Annual Meeting of the Ecological Society of America, Montreal, Canada, Aug. 2005.

C. Ng, M.B. Berg, D. Jude, J. Janssen, K.A. Gray, L.A.N. Amaral, "Complex trophic dynamics in a 'simplified' food web: Implications for contaminant transfer," IAGLR 2005, May 25, 2005.

C. Ng, M.B. Berg, K.A. Gray, L.A.N. Amaral, "Network-centered modeling of bioaccumulation in freshwater foodwebs," 228th ACS National Meeting, Philadelphia, PA, Aug., 2004.

C. Ishida, K.A. Gray C. Ng, "Cultivating periphyton to accelerate rates of denitrification in wetlands," 228th ACS National Meeting, Philadelphia, PA, Aug., 2004.

J.A. Kostel, K.A. Gray. "The Impact of Metal and Organic Contaminants on the Structure of Periphyton in Lotic Sediments." 228th ACS National Meeting, Philadelphia, PA, Aug., 2004.

D.C. Hurum, A.G. Agrios, K.A. Gray, T. Rajh, M.C. Thurnauer, "Mixed-Phase titania photocatalysis: EPR studies of catalytic mechanisms," 228th ACS National Meeting, Philadelphia, PA, Aug. 22, 2004.

T. Rajh, M.C. Thurnauer, K.A. Gray, D. Hurum, "Mechanisms of semiconductor photocatalysis revealed via electron paramagnetic resonance," 227th, ACS Annual Meeting, March, 2004.

Hurum, D.C.; Agrios, A.G.; Gray, K.A.; Rajh, T.; Thurnauer, M.C "EPR Studies of Degussa P25 Photochemistry: Insights into Mixed Phase TiO_2 Catalytic Activity" TiO_2-8 Conference, Montreal, Canada, Oct. 27, 2003.

T. Sirivedhin, K.A. Gray. "Assessment of Anthropogenic Influence in Indirect Potable Water Reuse." Water Reuse Annual Symposium XVIII, San Antonio, TX, 2003.

S.J. Chang, K.A. Gray. "Chemical composition and Cu complexationof the extracellular polymeric substances from pseudomonal acruginosa biofilms," 225th ACS National Meeting, New Orleans, LA, March, 2003.

Finster ME, Gray KA, Binns HJ. Lead levels of vegetables grown in contaminated residential soils: a field survey. American Public Health Association Annual Meeting, Philadelphia, PA, November 11, 2002.

Finster ME, Gray KA, Binns HJ. Factors influencing the creation of turf grass barriers on lead-contaminated residential soils. American Public Health Association Annual Meeting, Philadelphia, PA, November 11, 2002.

Binns HJ, Peneff N, Gray KA, Fernandes J, Finster ME; for the Safer Yards Project. Effect of an intervention to reduce soil lead contamination in urban residential yards. American Public Health Association Annual Meeting, Philadelphia, PA, November 13, 2002.

Hurum, D.C.; Agrios, A.G.; Gray, K.A.; Rajh, T.; Thurnauer, M.C "EPR Studies of Degussa P25 Photochemistry: Insights into Mixed Phase TiO_2 Catalytic Activity" 222nd ACS National Meeting, Chicago, IL, Aug. 27, 2001.

Agrios, A.G., K.A. Gray. "Detailing Visible Light Effects of 2,4,5-Trichlorophenol on TiO_2 Surfaces." 222nd ACS National Meeting, Chicago, IL, Aug. 27, 2001.

M. Bonifacic, K-D. Asmus, K.A. Gray. "Time-resolved pulse radiolysis studies on the reaction of free radicals and hydrated electrons with halogenated phenols," 222nd ACS National Meeting, Chicago, IL, Aug. 27, 2001.

T. Sirivedhin, K.A. Gray, "The Influence of Organic Carbon Quality on Denitrification Rates at the Des Plaines River Wetland Demonstration Project," Society of Wetlands Scientists, 22nd Annual Meeting, Chicago, IL May, 2001.

Agrios, A.G., K.A. Gray. "Enhanced Adsorption and Degradation on TiO_2 Due to Visible Light." Second International Conference on the Remediation of Chlorinated and Recalcitrant Compounds, Monterey, CA, May 22-25, 2000.

T. Sirivedhin, K.A. Gray, "Anthropogenically Influenced Wetlands at the Des Plaines River Wetland Demonstration Site," IAGLR Conference, Cornwall, Ontario, May, 2000.

Jill A. Kostel and K.A. Gray, "The Influence of Periphyton on the Bioavailability of Contaminants in Lotic Sediments," IAGLR Conference, Cornwall, Ontario, May, 2000 [IAGLR/Hydrolab 2000 Best Student Presentation Award].

T. Sirivedhin, K.A. Gray, "Identifying Anthropogenic Markers in Dissolved Organic Matter using Py/GC/MS." Natural Organic Matter in Soils and Water, North Central Region Workshop, St. Paul, MN, January, 2000.

T. Sirivedhin, K.A. Gray, "Seasonal Effects on the Enhancement of Low Quality Surface Water by a Restored Riparian Wetland," Annual Conference, American Water Works Association, Chicago, IL, June, 1999.

K.A. Gray and Robert M. Bornick, "Use of PY-GC-MS to Characterize Natural Organic Material in an Artificial Wetland: Issues Related to Drinking Water Quality," presented at the Natural Organic Matter Workshop 18-19 September 1996, Poitiers, France.

D.L. Widrig, K.A. Gray and K.S. McAuliffe, "Removal of Algal-Derived Organic Material by Preozonation and Coagulation: Monitoring Changes in Organic Quality by Pyrolysis-GC-MS," at the AWWA 1996 Annual Conference, Toronto, Canada, June, 1996.

D.C. Schmelling, K.A. Gray and P.V. Kamat, "The Importance of Reductive Transformations in the Photocatalytic Destruction of Nitroaromatic Compounds," presented at the 1996 AIChE Spring National Meeting , Feb. 25-29, 1996, in New Orleans, LA.

K.A. Gray , "Radiolytic Destruction of Hexachlorobenzene on Soils: Comparison of Gamma and High Energy Electron Radiolysis," presented at the 1996 AIChE Spring National Meeting , Feb. 25-29, 1996, in New Orleans, LA.

A.H. Simpson, K.A. Gray and K.S. McAuliffe, "Statistical Analysis of PY-GC-MS Data to Improve Understanding of NOM Chemistry in Water Treatment Processes," presented at AWWA Water Quality Technology Conference, Nov. 11-14, 1995, New Orleans, LA.

Ulick Stafford, Kimberly A. Gray and Prashant V. Kamat, "Kinetic Modeling of 4-Clorophenol Degradation in Titania Slurries," presented in Mechanistic Environmental Photochemistry Symposium at the 210th ACS National Meeting, Chicago, IL, August 24, 1995.

K.A. Gray, A.H. Simpson and K.S. McAuliffe, "Use of PY-GC-MS to Study the Nature and Behavior of NOM in Water Treatment," presented in NOM Isolation and Characterization Symposium at the 210th ACS National Meeting, Chicago, IL, August 23, 1995.

K.A. Gray, K.S. McAuliffe and A.H. Simpson, "Monitoring Organic Removal for a Variety of Enhanced Coagulation Processes Using Pyrolysis-GC-MS," presented at AWWA Enhanced Coagulation Workshop in Charleston, SC, Dec. 6, 1994.

R.J. Hilarides and K.A. Gray, "Destruction of Dioxin on Soils: Radiolysis of Model and Real Soils," presented at the 1994 AIChE Summer Meeting, August 14-17, Denver, CO.

J.M. Noris, K.A. Gray and J-F. Gaillard, "Treatment of High Selenium Wastewaters," presented at the 1994 AIChE Summer Meeting, August 14-17, Denver, CO.

M.S. Dieckmann, K.A. Gray and P.V. Kamat, "The Sensitized Photocatalysis of a Mixed Reactant System of 4-Chlorophenol and 4-Nitrophenol," presented at the 1994 National Conference on Environmental Engineering, July 11-13, Boulder, CO.

K.A. Gray and R.J. Hilarides, "Innovative Treatment of Soil Contamination: Radiolytic Destruction of Dioxin and Co-Contaminants by Cobalt-60," presented at the 1994 National Conference on Environmental Engineering, July 11-13, Boulder, CO.

D.C. Schmelling and K.A. Gray, "Photocatalytic Transformation and Mineralization of TNT in TiO_2 Slurries," presented at the 1994 National Conference on Environmental Engineering, July 11-13, Boulder, CO.

P.V. Kamat, K. Vinodgopal, U. Stafford and K.A. Gray, "Semiconductor Particulate Films for the Photocatalytic Degradation of Organic Contaminants," presented at the 185th Electrochemical Society Meeting, San Francisco, May 25, 1994.

U. Stafford, K.A. Gray, and P.V. Kamat, "Photocatalytic Oxidation of 4-Chlorophenol on Titanium Dioxide: A Comparison with g-Radiolysis," presented at the 4th Annual Symposium on Chemical Oxidation, Nashville, TN, Feb. 1994.

R.J. Hilarides and K.A. Gray, "Gamma Irradiation of Soils Contaminated with 2,3,7,8-Tetrachlorodizenzo-p-dioxin using ^{60}Co," presented at the 4th Annual Symposium on Chemical Oxidation, Nashville, TN, Feb. 1994.

D.C. Schmelling and K.A. Gray, "Photocatalytic Destruction of TNT Contaminated Waters," presented at the 4th Annual Symposium on Chemical Oxidation, Nashville, TN, Feb. 1994.

K.A. Gray and K.S. McAuliffe, "Pyrolysis-GC-MS Characterization of the Natural Organic Matrix of Waters and Soils: New Insights into Organic Influences on Treatment Performance," presented at the 20th Annual Water Quality Technology Conference, Miami, Florida, November 14-18, 1993.

D.C. Schmelling and K.A. Gray, "Photocatalytic Degradation of TNT," presented at the 24th Annual Meeting of the Fine Particle Society, Chicago, IL, August 1993.

R.J. Hilarides and K.A. Gray, "Radiolytic Destruction of Dioxin on Soils: Optimal Conditions and Economic Consideration," presented at the Summer Meeting of the American Institute of Chemical Engineers, Seattle, WA, August 1993.

K.A. Gray, A. St. Amand and Hong Wang, "Role of a Periphytic Biolayer in the Fate of PCBs in Artificial Stream Systems," presented at the First International Specialized Conference on Contaminated Aquatic Sediments: Historical Records, Environmental Impact, and Remediation, sponsored by the International Association on Water Quality, Milwaukee, WI, June 14-16, 1993.

K.S. McAuliffe and K.A. Gray, "Characterization of Natural Organic Matrix Using Pyrolysis-GC-MS," presented at the 26th Great Lakes Regional Meeting of the American Chemical Society, May 27, 1993.

K.A. Gray, R. Barreto, P. Yocum, and K. Anders, "The Influence of Photocatalytic Pretreatment on the Biodegradation of MTBE," presented at the Summer Meeting of AIChE, Minneapolis, MN, August, 1992.

K.A. Gray, "Mechanistic Studies of Photocatalysis on Semiconductor Surfaces," poster presentation at the Gordon Conference on Environmental Sciences: Water, June, 1992.

K.A. Gray, P. Kamat, U. Stafford and M. Dieckmann, "Mechanistic Studies of Chloro- and Nitro-phenolic Degradation on Semiconductor Surfaces," presented at The Annual Meeting of the American Chemical Society, San Francisco, April, 1992.

K.A. Gray and K.S. McAuliffe, "Application of Pyrolysis-GC-MS to Characterize a Variety of Surface Waters: Influence of Algal Dynamics," presented at the Annual Meeting of the American Chemical Society, San Francisco, April, 1992.

K.A. Gray, "Use of Pyrolysis-GC-MS to Study the Organic Matrix of Surface Waters," presented at the 1991 Water Quality Technology Conference, American Water Works Association, Orlando, Florida, November, 1991.

U. Stafford, K. Gray, P. Kamat, A. Varma, "The Effects of Semiconductor Properties Upon Photocatalytic Rates for Organic Contaminant Degradation," presented at the 1991 Annual Meeting of the American Institute of Chemical Engineers, Los Angeles, CA, November, 1991.

J. Earley, K. Gray, P. Garrity, "Radiolytic Destruction of Dioxin," presented at the 1991 Annual Meeting of the American Institute of Chemical Engineers, Los Angeles, CA, November, 1991.

K. Anders and K. Gray, "Photocatalytic Degradation of Methyl-tert-Butyl Ether on Semiconductor Surfaces," presented at 2nd Annual Argonne Symposium for Undergraduates, Argonne National Laboratory, November 8-9, 1991.

M.S. Dieckmann, K.A. Gray, and P.V. Kamat, "Photocatalyzed Degradation of Adsorbed Nitrophenolic Compounds on Semiconductor Surfaces," presented at Waste Management in The Chemical and Petrochemical Industries, IAWPRC & Tulane University, New Orleans, June, 1991.

K.A. Gray, "Specific Chemical Effects of The Calcium and Bicarbonate Ions on Colloidal Destabilization by an Inorganic Aluminum Polymer," presented at the Mid-West Environmental Chemistry Workshop, October, 1990.

M.S. Dieckmann, P.V. Kamat, and K.A. Gray, "The Effect of Semiconducting Materials as Photocatalysts in the Degradation of Nitrophenols," presented at the Mid-West Environmental Chemistry Workshop, October, 1990.

K.A. Gray, "Direct Filtration of Model and Natural Waters: The Removal of Turbidity versus Dissolved Organic Matter," presented at the IAWPRC/IWSA Joint Specialist Conference on Coagulation, Flocculation, Filtration, Sedimentation, Flotation, Jonkoping, Sweden, 24-26 April, 1990.

K.A. Gray, "Direct Filtration on the Seine River: The Importance of Chemistry," presented at the 1st Macao Workshop on Water Treatment, 3-4 November, 1989, sponsored by the Macao Water Supply Co., Ltd. and the Lyonnaise des Eaux.

K.A. Gray, F. Bernazeau, C. Hubele, "Reduction of Total Organic Carbon by Direct Filtration: A Pilot Study on the Seine River," presented at the 7th Regional Conference of the Asian-Pacific Group of the International Water Supply Association (IWSA), 29 Oct.-2 Nov., 1989, Nagoya, Japan.

K.A. Gray, F. Bernazeau, C. Hubele, "Upgrading a Slow Sand Filtration Plant for Micropollutant Removal: Use of Direct Filtration Prior to Granular Activated Carbon for Reduction of Total Organic Carbon," presented at the IWSA/AIDE Specialized Conference "Organic Micropollutants," 19-21 Sept. 1989, Barcelona, Spain.

K.A. Gray, F. Bernazeau, C. Hubele, "Direct Filtration on the Seine River: A Pilot Study," presented at the Annual Conference of the American Water Works Association, Los Angeles, June, 1989.

K.A. Gray, C.H. Yao, C.R. O'Melia, "Polymeric Metal Coagulants," presented at the Annual Conference of the American Water Works Association in Kansas City, MO, June, 1987.

K.A. Gray, C.R. O'Melia, "Use of Inorganic Iron(III) Polymers for Coagulation in Industrial Water Treatment," presented at the 18th Mid-Atlantic Industrial Waste Conference, Virginia Polytechnic Institute, Blacksburg, VA, June, 1986.

K.A. Gray, C.R. O'Melia, "The Formation, Characterization and Use of Inorganic Iron(III) Polymers for Coagulation in Water Treatment," presented at the Annual Conference of the American Water Works Association in Denver, CO, June, 1986.

K.A. Gray, C.R. O'Melia, "The Use of Inorganic Iron(III) Polymers for Coagulation in Water Treatment," presented at the 37th Annual Meeting of the Chesapeake Section of the American Water Works Association, Ocean City, MD, Sept., 1985.

K.A. Gray, T.D. Waite, "Coagulation and Precipitation Studies of the Ferrate(VI) Ion," presented at the 186th National Meeting of the American Chemical Society, Environmental Chemistry Division, Washington, D.C., Aug., 1983.

T.D. Waite, K.A. Gray, "Oxidation and Coagulation of Wastewater Effluent Utilizing the Ferrate(VI) Ion," presented at the Fourth International Conference on Chemistry for Environmental Protection, Toulouse, France, Sept., 1983.

UNIVERSITY COMMITTEES AND RESPONSIBILITIES

Department:

Northwestern University:

Environmental Group Coordinator, 2002-2010.
Graduate Recruiting and Admissions, Environmental Program, 2002-present
Redesigned Website – 2001-2002
Environmental Faculty Search Committees (1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010)
Service Learning Pilot and Program Director, 1996-present
Strategic Planning – 2000, 2004-05
Undergraduate Curriculum Development, 1995-present

University of Notre Dame:

Departmental Seminar Coordinator, 1992-1995
Undergraduate Curriculum Committee, Chair, 1989-1993
ASCE Faculty Advisor, 1990-1993
Graduate Recruiting, 1990

College:

Northwestern University:

Promotion & Tenure Committee – 2007-2009.
Search Committee – Associate Director, Industrial Relations, 2005
Dean Search Committee, Spring, Fall 2004
Freshman Advisor - 1996-2001
McCormick Identity Committee, 2001-2002
MEOP – Summer EXCEL Program, Designed and Supervised Community Engineering course and integration into Leadership Program, 1998,1999.
Planning Committee for the Institute for Manufacturing and Design Technology, *1998*
Speaker/Facilitator - McCormick Career Night, 1995

University of Notre Dame:

Grievance Committee, Alternate, 1994-1995
Committee on Undergraduate Studies, 1989-1993
Minority Mentor Program, Advisory Board (member, 1993-1995) and mentor, 1989-1995
Summer Program in Engineering for High School Women and Minorities; Seminar Speaker, 1990-1995

University:

Northwestern University:

Environmental Policy & Culture Faculty Advising Committee, Weinberg CAS, 2008-present.
School of Continuing Studies' Graduate Faculty Advisory Board, 2007-present
Program Review Committee (2002-2005); Member Geological Sciences Internal Review Subcommittee, 2001; Chair, University Services Internal Review Subcommittee, 2003; Chair, Department of Family Medicine, Internal Review Subcommittee, 2004; Chair, Department of French and Italian Internal Review Subcommittee, 2005
University Re-accreditation; Faculty Self-Study on Interdisciplinarity in Undergraduate Programs, 2003-2004.
Faculty Search Committees; Chemistry (2003-04), Mathematics (2004-05)
Director, Environmental Science, Engineering and Policy Program (formerly, Environmental Science Program, WCAS), 2003-present

Plant Biology and Conservation Graduate Program in WCAS, member of Oversight Committee
Environmental Science Task Force, 2001-02
Committee on Women in the Academic Community, 2001-2003
University Faculty Reappointment, Promotion and Tenure Denial Appeal Panel, 1999-2002
Master (1998-2002), Associate Master (1997-98) and Faculty Associate of Public Affairs Residential College, 1996-present.

University of Notre Dame:

Committee to Select Proposal to Henry R. Luce Professorship Program, 1994
Graduate Council, Appointed Member, 1991-1994
Planning Committee of Graduate Council, 1992, 1993
Freshman Year of Studies, Discussion Group Leader Freshman Orientation, 1991-1994
Notre Dame Science and Engineering Talent Search, Seminar Speaker, 1991
Program to Promote Minority Enrollment in Graduate School, Seminar Speaker, 1991
Center for Social Concerns, Pilot Workshop to consider Ethical Dimensions of Undergraduate Education, Discussion Leader, January 12-13, 1992
Reilly Center, Scholarship Review Committee, 1992, 1994, 1995
Conference on Business Leadership in the Environmental Crisis, Panelist, Sept., 1992
Institutional Animal Care and Use Committee, Member, 1991-1995
Selection Committee for Graduate Teaching Award, 1993
Speaker-Placement Office Graduate School Information Session, 1993, 1994
Environmental Issues Group, Kroc Institute of Peace Studies
Faculty Fellow and member of Undergrad Advisory Committee, Joan B. Kroc Institute for International Peace Studies 1993-1995
Panel Member: Women in a Catholic University: The Challenge and Promise, 1993
Participant, Information Session for Women in Science and Engineering; Freshman Year, 1993.

EDUCATIONAL and COMMUNITY OUTREACH

K-12 Educational Outreach:

- Designed, organized, and taught in Middle- and High-School Teachers Workshop, Unlocking Nature's Secrets: Catalysis in the Environment and Industry; at Argonne National Laboratory, 2000, 2001 & 2002. Total number of teachers was 91.
- Primary author of educational laboratory module, Environmental Catalysis,; 10th in a series of Material Worldwide Modules; designed, tested, wrote series of activities for students to learn about various principles of catalysis and the importance of catalysis for environmental protection. Field-tested activities in various high schools (ETHS, New Trier, Schaumburg, etc.) in Chicago area and nationally.
- Mentored 7 High School Teachers participating in the NSF REST program (Research Experience for Science Teachers) since 1999, as well as over 26 REU or high school students working on summer research over the last 10 years.

Community Outreach

- Chicago Cross-Pollinator Project, panel member, 11 June 2012.
- The Green City: A Field Study in Chicago; organized and lectured in Summer Institute of School of Continuing Studies, Aug. 9-11, 2006, Aug 1-3, 2007, July 28-30, 2008.
- Technical Advisory Committee, Friends of the Chicago River, 2004-present.
- Advisory Board, Healthy Schools Campaign, 2004-present.

NU Alumni, Development, Student Group, and General University Talks

- "Living Cities: An urban model of sustainability," Fireside at Slivka Residential College, 10 May 2012.
- Undergraduate Research and Arts Exposition, Session Moderator, May 21, 2012.
- Guest lecture, Science of Climate Change, NU Law School, Seminar on Climate and Energy, Jan. 10, 2012.
- Panel member, Sustainability and Renewable Energy Panel, The Graduate School Centennial Celebration, Nov. 4, 2011.

- "Fabricating Titania-based Nanocomposites for Solar Fuel Production: TiO_{2-x} & $Ti_{1-x}Nb_xO_2$ Thin Films & TiO_2 Nanotubes," Northwestern Undergraduate Chemistry Council, March 8, 2011
- "Sustainable Strides in Urban Design: Lessons from Chicago," SEED Green Cup Kick-off, 31 January, 2011.
- Panel: Environmental Justice and Hurricane Katina for Undergraduate Lecture Series on Race, Poverty, and Inequality at Northwestern University & NU Conference on Human Rights – November 22, 2010.
- "The Modern American City: Can we ever make it Sustainable?" McCormick Engineering Week, McCormick Student Advisory Board, NU, May 20, 2010.
- Panel: Working with the Community, Community Research Workshop, NU, May 14, 2010.
- Panel: Environmental Racism: Poverty and Pollution in Minority Communities, in the Martin Luther King, Jr. Lecture Series, NU Medical and Law School, January 12, 2010.
- Panel: Infrastructure Now and Then: Seeing the Future At Another Level, in The Infrastructure Universe: From Highways to Molecules, Alumnae Continuing Education Course, Dec. 3, 2009.
- Domain Dinner on Sustainability, "The Elusive Concept of Sustainability," 16 Nov. 2009.
- "Can you have a Green City on a Brown Lake," Junior Science Café, Arlington Heights, 4 Nov., 2009
- "Making Chicago Sustainable: The Water-Energy Connection" in The Infrastructure Universe: From Highways to Molecules, Alumnae Continuing Education Course, Oct. 1, 2009.
- "Can you have a Green City on a Brown Lake," Sigma Xi Junior Science Café, 21 March, 2009
- "Why this isn't your father's energy crisis," Science Café, Wilmette Public Library, Nov 5, 2008.
- Women in Science and Technology Panel, POWER Dinner, Chicago, IL, May 22, 2008.
- "Sustainability: Fad or Necessity?" Fireside at CCS, May 12, 2008.
- "Who wants to be a billionaire? The mad dash to find sustainable alternatives to fossil fuels?" Northwestern University Circle, March 13, 2008.
- Survival Skills for Graduate Students and Junior Faculty, Women's Center, NU, Feb. 20, 2008
- "Who wants to be a billionaire? Some thoughts on energy, geopolitics, economics, & technology." Fireside at Slivka Residential College, Nov., 2007.
- "Are we ever going to be able to make modern American cities sustainable?" Twin Cities NU Club, May 23, 2007.
- "Opportunities in Environmental Science and Engineerng," SEED, May 1, 2007.
- "Design for the Environment – what that means" guest lecture, IDEA 398, Feb. 1, 2007
- "Environmental Engineering: Biology, Chemistry and Physics for Ecological and Public Health Protection," Society of Hispanic Professional Engineers, Midwestern Expo, Nov. 1, 2006.
- "Energy and Sustainability: Business Opportunities," Energy Club in Kellogg School of Management, Oct. 3, 2006.
- Domain Dinner on Energy and Environmental Issues, April 11, 2006, organizer, speaker.
- "Designing the Ecologically Sound City: New Orleans as a Case Study" Alumnae Continuing Education Lecture Series, Dreams, Designs, and Development, April 20, 2006.
- "Hurricane Katrina: Preparation, Response and Rebuilding," Panel member, sponsored by MEAS, Oct. 17, 2005.
- "The Sustainable City: If we know what to do, why aren't we doing it?" NU Club of Virginia, Richmond, VA, March 18, 2005.
- "The Sustainable City: Ecology, Efficiency, Equity," NU Engineers for a Sustainable World, May, 2004.
- "Urban Ecology and Technology: Opportunities for Sustainable Societies," ARCS lunch, Norris Center, April, 2004.
- "Sustainability: Engineering the City of the Future," Public Interest Alumni Assoc., John Evans Center, Evanston, IL, Oct., 2003.
- "Undergraduate Research and Project Based Learning," New Student Visits, Norris Center, April, 2003.
- "Engineering the City of the Future: An Environmental Perspective," NU Alumni Association, March, 2003.
- "Do Environmental Issues Really Matter," NU Alumni Association, Classes without Quizzes, Nov. 12, 2001.
- "Do Environmental Issues Really Matter," Provost's Reception for Residential College Faculty Fellows, Hardin Hall, Sept. 25, 2001.
- "Environmental Issues of Urban Areas," NU Alumni College Program, *The City: Past, Present,*

and Prospects. July 28, 1999.
- "PCB Contamination and Other Threats to the Ecological and Human Health of the Great Lakes Region," Seminar Day, Northwestern Alumni Assoc., April 17, 1999.
- "Environmental Catalysis," presented at Tech Review, March 23, 1999.
- "Community Service in Chicago Neighborhood," Lunchtime Seminar, PARC, Sept. 15, 1998.
- "Local Pollution," Earthday, SEED, NU, 23 April 1998.
- Member, Panel Discussions to Undergraduate and Graduate students on issues related to gender, environmental quality and justice, sustainability issues.

SERVICE LEARNING AND COMMUNITY BASED PROJECTS (students supervised in parentheses)

- Cook County Climate Change and Public Health Action Plan (Beau Garrett & Natalie Lake) 2012.
- Confined Animal Feed Operations (CAFO) Best Management Practices (Regan Radcliffe & Kaleb Tsang) 2012.
- Midwest Generation Trona Injection (Anusha Vadlamanu & Bingshu Li) 2012.
- Oxbow Corp. Calcined Petroleum Coke Facility –SO2 Non-compliance (Lauren Lopez & Yufei Zhou) 2012.
- Hegewisch March (William Boulay & Xingcheng Lu) 2012.
- Air Quality Evaluation for Southeast Chicago with Respect to the Proposed Universal Cement Facility (Jeff Goto & Nopparat Chiangwong) 2012.
- Chicago Area Confined Disposal Facility (Adrienne Masterton, Yan Zou) 2012.
- Preliminary Phase II Remedial Investigation Report; OU3 Onsite Soils & Groundwater Assessment (Lauren Miller & Paige Humecki) 2012.
- Closure, Remediation, and Future Land Use at State Line Power Plant (Lauren Fleer & Taylor Sweet) 2012.
- Clean Construction or Demolition Debris; Rule Making (Tina Wang & Sarist Macksasitorn), 2011.
- 2727 South Troy Street, Little Village: Site Remediation (Dustin Grossheim & Sasha Letuchy), 2011.
- State Line Energy Power Plant: New Source Review (Roshni Barot & Brian Kennedy), 2011.
- South Suburban Citizens Opposed to Polluting the Environment: Storm-water Management & Flooding in Longwood Farms (Michael Giannetto & Ke Gong), 2011.
- Understanding the EPA's Greenhouse Gas Reporting Program (Ben Shorofsky & Boping Liu), 2011.
- Calumet CID Landfill: Future Use Recommendations (Walter Furness & Andrea Morgan), 2011.
- Methods for Attaining Aquatic Life Use A Standards in the Calumet Area Waterways (Sara Thomas & Susan Vescovi), 2011.
- Lake Depue Sediment Contamination: Evaluation of OU5 Ecological and Human Health Risk Assessments (Chelsea Baldino & Anjulie Cheema), 2011.
- Restoration of Miller Meadow (S. Katragadda, M. Roehuck, J. Young), 2010.
- Brownfield Redevelopment in Little Village: Assessing the extent of contamination, remediation strategies, and future use (E. Och, S. Pavlik), 2010.
- Zero Energy Buildings (for Doug Farr & Assoc. by M. James and E. McCarthy), 2010.
- HVAC & Boiler Systems: Proposal for the Robert H. Lurie Medical Center (for Earthwise Environmental, Inc. by B. Sikora, J. Sirk, R. Gophal), 2010.
- Sustainable Urban Infrastructure Systems: Lathrop Homes (for Doug Farr & Assoc. by E. Ulion, S. Bernard, P. Slevin, S. Chaturvedi), 2010.
- Installing an Inflatable Dam at Busse Woods - Assessing Environmental Impacts and Identifying Reasonable Alternatives (Robert Pickering, Mark Woodsum), 2009.
- Transforming the Former Celotex Industrial Site in Little Village to a Community Park - Design Features That Protect the Public and Create a Community Recreational Resource (Virginia Palmer, Nancy Shan), 2009.
- BP Whiting Refinery Permit Review (Christopher Trigg, Shuchi Talati), 2008.
- Robbins Community Power Plant (Maggie Fry, Erica Schleimer), 2008.
- Redesignation of the Calumet River System (Teri McClerklin, Carmen Shank), 2008.
- Revegetation of the Calumet Cluster Site (Ahmad Harake), 2007.
- The City of the Future Competition, sponsored by ASCE, IBM, The History Channel, selected for Chicago competition (Julia Hand, Caitlin Freehan, Jennifer Raber, Siti Abidin), 2007.
- Analysis of the Proposed Ford Heights Ethanol Plant (Siti Abidin, Jonathan Adams, Nur Atiah Ashar, Maya Jensen), 2006.
- USX Bike Path/Public Access (Duane Ambroz, Rosemary Bush, Eva Dubey, Kevin Lee), 2006.
- Lake Calumet Cluster Site: Future Land Use Proposal (Margaret Adsit, Allan Castillo, Douglas Groux, Megan Mann), 2006.

- Probing the photochemical aging of the Seurat's zinc yellow pigments in Sunday at La Grand Jatte with Francesca Casadio at the Art Institute of Chicago (Nirav Shah), 2004-2006.
- Natural Resource Damages for Indian Ridge Marsh (Sara Patrawala and Sohier Dane), 2006.
- Contamination of the Celotex Site at La Villita (Chris Lee and Melissa Mendez), 2006.
- Lucak-Berg Pit Project (Calista Fisher and Marshall Lindsey), 2006.
- Proposal for Quarry Shopping Center's Storm Water Runoff (Debra Weissman and Ori Sivan), 2004- 2005.
- Assessment of Opacity Issues at Five Midwest Generation Coal-fired Power Plants in the Chicago Area (Jonathan Flowers, Nyak Shidawati, Sharon Waller), 2004-2005.
- Methane Production and Energy Cogeneration Potential in the Sediments of the Chicago Sanitary Canal (Colin Barett), 2003-2004.
- LEEDing the Redevelopment of Brownfields with Green Design (Betty Jurkowski), 2003-2004.
- Remediation of Thorium Contaminated Soils and Sediments: Kerr-McGee Kress Creek and Warrenville Retreat Center (Clare Frederick and Allison Walk), 2003-2004.
- Healthy and High Performing Schools: Economic Analysis of LEED Rated School Construction (Robert Kutter and Megan Johnson), 2003-2004.
- Urban Honey Production: Risk Assessment of Metal and Organic Contamination (Erin Jordan), 2003-2004.
- PM_{10} Compliance in Southeast Chicago (Michael Goldrich and Ben Jewel), 2003-2004.
- Going Green: A Comprehensive Review of Green Roofs (Aarti Ramachandran) 2003-2004.
- Indiana Harbor/East Chicago CDF (Todd Waldrop), 2002-2003.
- Fort Sheridan Closure (Polina Liberman and Don Walsh), 2002-2003.
- PAH Contamination at Bridgeport Homes (Hilary Holmes), 2002-2003.
- Healthy and High Performance Schools (Se Jong Cho and Francis Wambi-Buesso), 2002-2003.
- Wastewater Disinfection Methods and Their Feasibility at the Metropolitan Water Reclamation Plants in the Greater Chicago Area (Kirsten Dickson), 2002-2003.
- An Investigation of Remediation Alternatives for Contaminated Sediments in the Vessel Slips of Wisconsin Steel Works and United States Steel South Works (Andrew Burnham and Travis Cobb), 2001-2002.
- The Suitability of Shallow Wells to Solve Lockport's Radium Problems (Cari Ishida, Todd Waldrop, Nathan Turner, Cody Prentice, Andrew Marcus), 2001-2002.
- Solar and Wind Renewable Energy Systems at the Southeast Chicago Cluster Site (Todd Waldrop), 2001-2002.
- The CTA's Forest Glen Bus Garage: The Air Pollution and Some Solutions (Jennifer Wilson), 2000-2001.
- Hazardous Air Pollutant Emissions from Natural Gas-Fired Peaking Power Plants in Northeast Illinois (Lynette Cheah), 2000-2001.
- Health Risks from Radioactive Emissions from Coal Burning Power Plants (Ben Porter), 2000-2001.
- Evaluation and Design of Enhanced Wetlands for the Lake Calumet Cluster Site (Jennifer Wendrowski), 1999-2000.
- A Guide to Identifying Communities with Health Hazards: Using the Tools of CCRI (Emily C. Anderson and Marlena M. Lacey), 1999-2000.
- A Characterization and Assessment of Vessel Slip Contamination: United States Steel South Works Site and Wisconsin Steel Works Site (Nuria Bertran-Ortiz and Christina Hemphill), 1999-2000.
- Resource Guide: The Phytoremediation of Lead in Urban, Residential Soils (Joseph Fiegl and Bryan McDonnell), 1999-2000.
- Pollution Prevention in the Metal Finishing Industry (Allison McCormick and Tracey Rissman), 1998-1999.
- The Chicago Cumulative Risk Initiative–Mercury Rising (Saba Fatima and Katie Sovik), 1998-1999.
- Lake Calumet Cluster Site: Site Characterization and Use of Experimental Wetlands for Reclamation (Michael Butler and Kim Sopocy), 1998-1999.
- Chicago Cumulative Risk Initiative – Hazard Mapping (Kelly Hirsch and Junaluska Williams), 1998-1999.
- Planting the Seed for Recovery: Altgeld Gardens (Angela Change and Mausami Desai), 1998-1999.
- Regional Air Quality and Chicago's Ground Level Ozone Problem (Terah Luchey and Shanthi Nataraj), 1998-1999.
- Wetland Remediation: Cleaning up the Lake Calumet Cluster Site (Beverly Ahoni), 1998-1999.
- Lake Calumet Cluster Site: An Analysis of Future Remedial Action (Sarah Bender and Ted Ekkers), 1997-1998.
- Risk Assessment and Site Characterization of the Wisconsin Steel Works Site (Emily Fahsl and Matthew Lamb), 1997-1998.

- PAH Contamination at Altgeld Garden's (Kimberly Mertz and Neal Steffan), 1997-1998.
- An Analysis of Natural Attenuation at the United States Steel South Works Site (Lisa Bongiovanni, Sanne Knudsen, Todd Wildermuth), 1996-1997.
- Assessing Wetlands Creation and Landfill Gas Reuse Projects at Site Adjacent to Indian Ridge and Big Marshes (Bob Cummings and Nikki Kryda), 1996-1997.
- Celotex Corporation Superfund Site (Pam Kearfott and Claire Hilger), 1996-1997.
- The Little Village Air Quality Analysis (Jaime Hardt and Kary Hisrich), 1996-1997.

CONSULTING

- Crowell & Moring, LLP (Intellectual property, photocatalysis patent analysis)
- Industrial Facilities Engineering (Disinfection of public drinking water supplies at a naval base)
- Cochran, Cherry, Givens, Smith & Montgomery, L.L.C. (environmental justice, investigated property and groundwater contamination from landfill in Michigan)
- Munday and Nathan (investigated suspected contamination of groundwater)
- Edward Scanlan Law Office (aquifer and soil contamination by TCE at Lockformer site in Lisle, IL)
- Levy and Leopold Law Office (PAH contamination at CHA facility, Altgeld Gardens)
- Sugar Law Center for Economic and Social Justice (Soil contamination and inadequate brownfield cleanup on Detroit public school site)
- City of Thornton, CO ((Organic Characterization & Surface Water Quality for Indirect Potable Reuse, testified before Colorado Water Board on the development of organic carbon control and in Water Court)
- The Wetlands Initiative (Various Restoration Projects along the Illinois and Chicago Rivers; wetland restoration, nutrient dynamics)
- Burlington, WI Giardia outbreak (Expert for Plaintiffs on Water Quality and Drinking Water Treatment)
- Cascino Vaughan, Chicago, IL (Milwaukee Cryptosporidium Outbreak, Expert for Plaintiffs on Coagulation Process and Use of Polymeric Coagulants)
- Employment Research and Development, Inc. Wilmette, IL (accreditation testing)
- Burns and McDonnell Consulting Engineers, Kansas City, MO (Organic Characterization and Surface Water Quality for Drinking Water Treatment)
- Orange County Water District (Organic Characterization and Surface Water Quality for Indirect Water Reuse)
- Safety Kleen (Waste Characterization & Treatment)
- KDF Fluid Treatment, Inc., MI (Pilot Testing Iron Removal Catalyst)
- Midland Resources, Inc., Lawrence, KS (Characterization and Use of Polymeric Iron Coagulant)

EXHIBIT 4

Citizens Utility Board, ***Ameren Corporation's Performance Under the Illinois Electric Service Customer Choice and Rate Relief Law of 1997*** **(February 2006)**

Ameren Corporation's Performance Under the Illinois Electric Service Customer Choice and Rate Relief Law of 1997

Produced for the Citizens Utility Board
By Edward Bodmer
February, 2006

Executive Summary

This report summarizes an independent study of Ameren Corporation's performance under the Illinois Electricity Restructuring Act ("the Act").[1] Primary findings of this study include:

(1) Investors in companies that owned Illinois assets purchased by Ameren have realized $2.6 billion in value from passage of the Act. Predecessor companies included utility companies – Illinova, CILCORP and CIPS – as well as Merchant Companies that purchased generation assets – AES and Dynegy.

(2) Even excluding profits realized by Illinova, CILCORP, CIPSCO, Dynegy and AES, Ameren's investors have realized returns far above both the S&P 500 and other utility companies. In dollar terms, Ameren investors have gained $2.1 billion more than they would have generated from investing in other utility companies.

(3) Ameren is well positioned to increase its earnings in the future even if Illinois rates stay at current levels as its return on equity from its generation business - currently 28% - is increasing due to high natural gas and oil prices.

(4) The aggregate amount earned by investors exceeds the value of the rate reductions to consumers of Illinois Power, CIPS, CILCO and Union Electric. The value of rate reductions has been about $800 million, far less than the investor benefits.

Introduction

Ameren's Illinois operations are currently made up primarily of assets that have been acquired since the passage of the Act. When Ameren purchased these assets, it paid high premiums to investors of the acquired companies. Ameren's current utility holdings in Illinois include the regulated AmerenCIPS, AmerenCILCO, and AmerenIP, and unregulated AmerenEnergy affiliates. At the time the Act was passed in 1997, Illinois Power (now AmerenIP) and CILCO (now AmerenCILCO) were independent companies. As the Act was being debated, CIPS (now AmerenCIPS) was in the process of merging with Union Electric to form Ameren. Because of the timing of these acquisitions as well as the separation of the generating assets into a subsidiary company, the performance of assets currently owned by Ameren cannot be gauged solely by analyzing the performance of Ameren's stock price.

Investors in companies other than Ameren have benefited by about $2.6 billion from realizing the proceeds of acquisition payments and from retaining generation assets. The primary investor groups who have benefited include:

[1] The Electric Service Customer Choice and Rate Relief Law of 1997. (220 ILCS 5/16-101 et seq.)

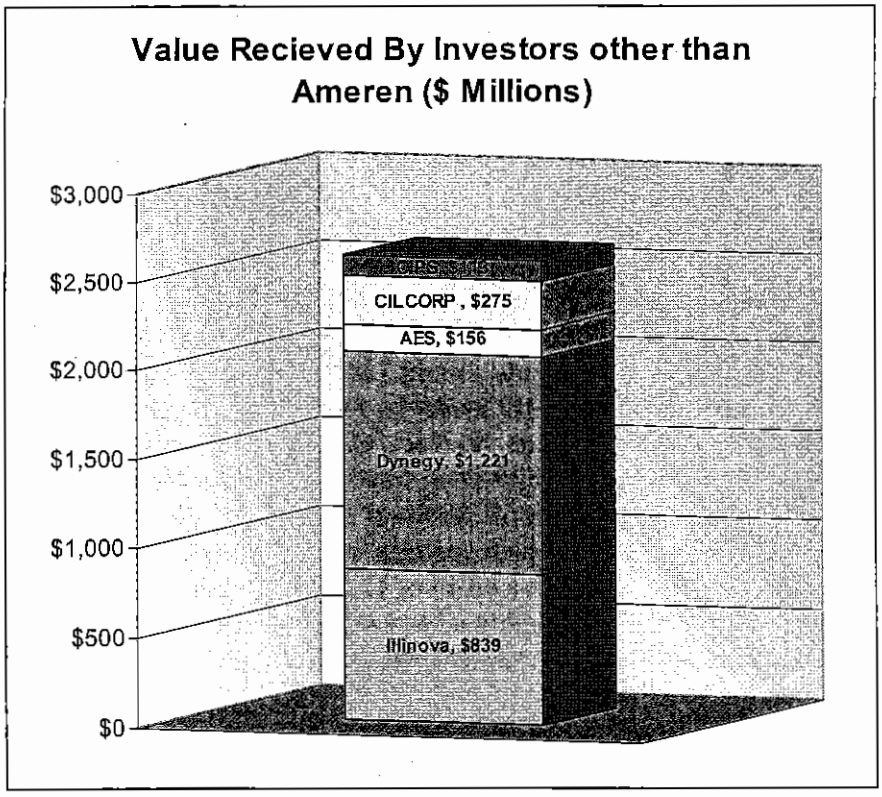
- Investors in Illinova who realized $838 million or a 49% return in a two-year period following the signing of the Act when they sold their shares to Dynegy[2];

- Investors in Dynegy who were effectively able to secure Illinois Power generation assets at a discount to their market value through selling Illinois Power distribution operations to Ameren at a premium. The approximate value to Dynegy of keeping the Illinois Power generation assets is $1.2 billion;

- Investors in CILCORP who realized $275 million or a 52% return over the one an a half year time frame after passage of the Act from selling their shares to AES;

- Investors in AES who realized a profit of $156 million from reselling CILCO to Ameren in 2003 after purchasing the company in 1998.

- Investors in CIPSCO who realized a premium on their shares of $113 million when Ameren completed the merger at the end of 1997. This premium is over and above the amount CIPSCO shareholders would have received had the companies not merged.



Despite all of these transactions and realization of profits by many different investor groups, Ameren still was able to realize a rate of return four times as high as the S&P 500

[2] The source of the returns and financial data are reports filed by Ameren, Illinois Power, Dynegy, and CILCORP to the SEC.

and double the return of the utility company stock index. Ameren's stock value increased 346 percent more than the increase in value of the S&P 500. The manner in which these investor groups profited from the Act is described in the next section.

Summary of Merger Activities

As mentioned before, Ameren's current Illinois operations are the result of various mergers and acquisitions. These mergers and acquisitions include:

- Ameren purchased CILCORP assets from AES (an Enron type merchant company) in early 2003 for $1.4 billion. AES had earlier purchased CILCORP for $1.244 billion implying that AES profited by $156 from holding CILCORP for a few years.[3] The financial benefits that accrued to AES investors are not included in an analysis of Ameren's stock price.

- Prior to the Ameren purchase of CILCORP from AES, AES made a bid to purchase CILCORP for $65 per share in late 1998. CILCORP's shareholders did very well from the AES purchase because CICLORP's share price was $44.75 at the end of 1997 when the Act was passed. CILCORP shareholders also received a dividend of $3.08 per share between passage of the Act and the AES acquisition. The stock price together with the dividend yielded a return of 52% over less than two years to investors who would have purchased CILCORP shares at the date the Act was passed. On a dollar basis, the AES acquisition value including debt and equity was $1.244 billion.[4] The value of the $65 share plus the $3 dividend less the 1997 stock price of $44.75 on an aggregate basis was $275 million. The financial benefits realized by CILCORP shareholders are not included in an analysis of Ameren's stock price alone.

- Ameren purchased Illinois Power's transmission and distribution assets from Dynegy in 2004 for $2.3 billion. Dynegy kept IP's generating assets in its generation portfolio which include about 4,000 MW of coal capacity. Since Dynegy earlier purchased all of IP assets for $4.6 billion and then sold the distribution assets for $2.3 billion, it effectively paid $2.4 billion for the generation. Dividing the $2.4 billion by 4,000 MW of capacity implies that Dynegy paid a net cost of $595/kW for the IP generation. Assuming (very conservatively) that the coal capacity is now worth $800/kW in the market[5], Dynegy has been able to realize a profit of $1.221 billion from the merger transaction. The financial benefit that has accrued to Dynegy shareholders also is not included in an analysis of Ameren's stock price below.

- Dynegy originally purchased IP from Illinova Corporation for $33 per share or $4.6 billion in mid 1999.[6] Illinova's share price was $23.785 when the Act was passed. Including 2 years of dividends at $0.31 per quarter, Illinova's

[3] The source of numbers in this section is from financial reports and merger documents presented by Ameren, CILCO, and Illinova to the SEC.
[4] The value consists of $884 million in equity plus $360 million in debt.
[5] The value of a new coal plant is almost $2,000/kW and valuations using current power prices would probably imply values above $1,000/kW.
[6] The Illinova/Dynegy transaction was a complex share exchange transaction involving the spin-off by Dynegy of Chevron. The effect of the transaction was payment of a premium to Illinova shareholders.

shareholders realized a return of 49% over the two-year between passage of the Act and the Dynegy purchase. Since there were 71.7 million shares outstanding in 1997, the profit realized by Illinova investors was $838 million. The financial benefit that has accrued to Illinova's shareholders also is not included in any analysis of Ameren's stock price.

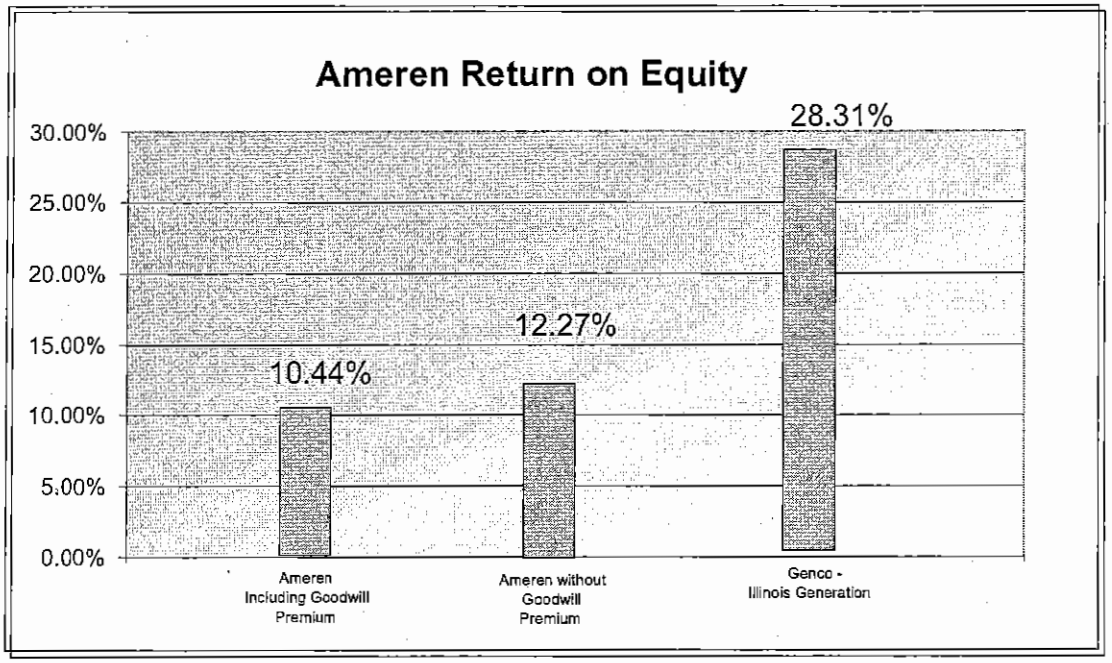
- Union Electric and CIPS were in the process of merging when the Act was passed. At the end of 1997, the merger was completed through a share exchange transaction where CIPSCO shareholders received 1.03 shares of Ameren for each of their original shares. Since prior to announcement of the merger in 1996, CIPSCO shares were trading at about a 6% discount to Union Electric shares, the transaction provided CIPSCO with a 9% premium. Applying the 9% premium to CIPSCO market value implies that CIPSCO shareholders earned a premium of $131 million above their market value before the merger was announced. The premium paid to CIPSCO means that its shareholders profited on a relative basis by more than Ameren shareholders from passage of the Act. These investors effectively retained the assets of Ameren and also received the premium.

Analysis of Ameren's Financial Performance

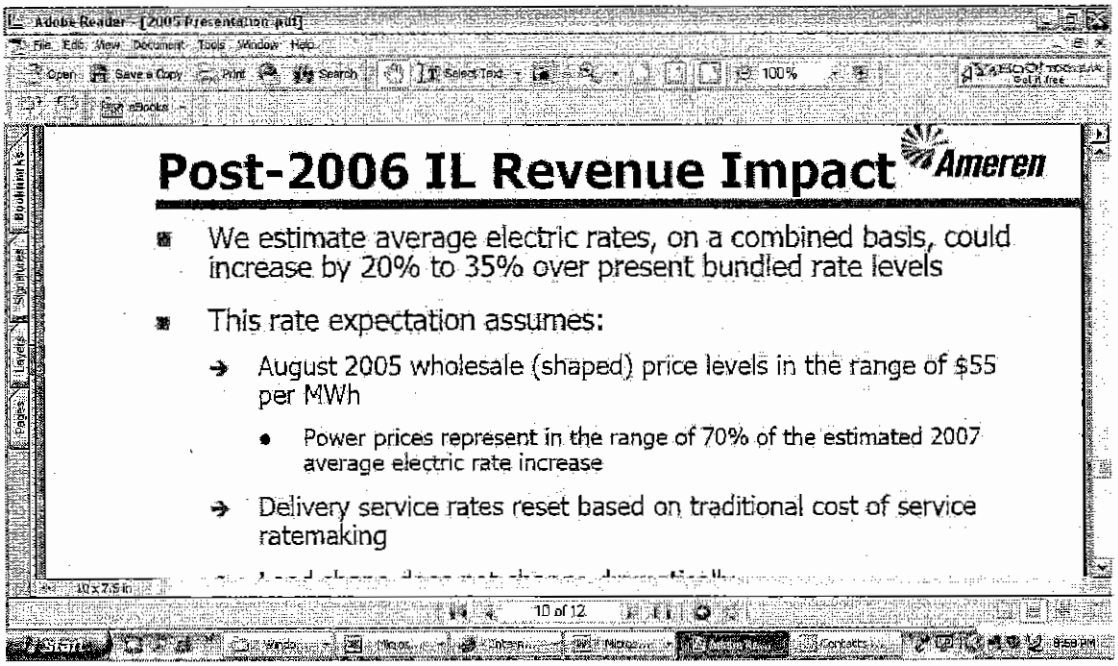
Unlike other beneficiaries of the 1997 Act[7], Ameren's return on equity has not shown a dramatic increase since passage of the Act. This is because Ameren's equity base (the denominator of the return on equity calculation) includes the premiums the company paid to the investors of Illinova, CILCORP, CIPSCO, AES and Dynegy. The returns of Ameren are also affected by regulatory events in Missouri and profits from the natural gas business.

The return on equity graph below shows that Ameren realized a return in 2004 (the latest year for which a full year of data is available from Ameren's annual report) of just above 10%. Without the premiums paid to non-Ameren investors in merger transactions recorded as goodwill, the return would have been 12.27% -- which is higher than the returns being allowed to utility companies elsewhere in the nation. The subsidiary company that now owns Illinois generation assets has a very high return of above 28%. This return has been consistently above 20% ever since the generating company was formed in 2000. In the future, the generating company should earn even higher returns as the market prices increase with the sustained high price of oil and natural gas.

[7] An analysis of the performance of investors and ratepayers is made in the report "ComEd/Exelon's Performance Under The Illinois Electric Service Customer Choice And Rate Relief Law of 1997 And Beyond."

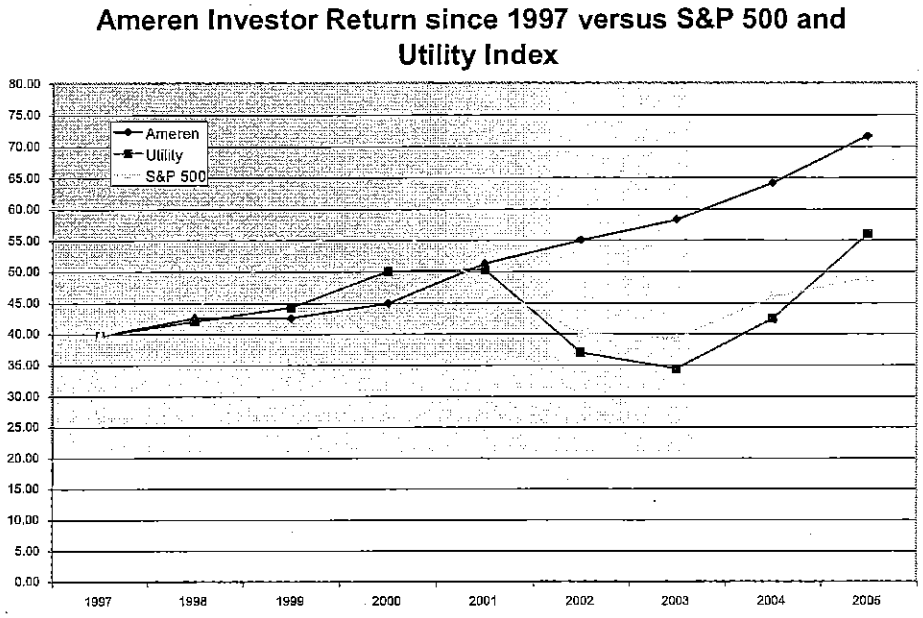


The most important implication from the return on equity graph above is projection of what will happen to Ameren's returns in the future once the rate freeze ends. Ameren itself projects rate increases of 20-35%, as shown below in an excerpt from a presentation made to investors.

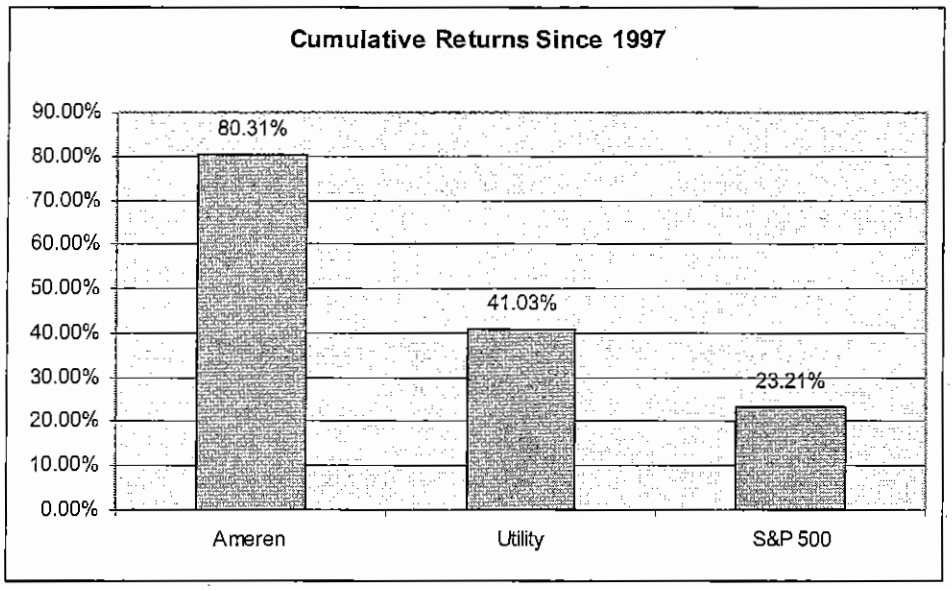


Given that Ameren's profits have been depressed because it paid merger premiums to the investors of CIPS, Illinova, CILCORP, AES and Dynegy, who reaped substantial benefits from the Act, one would not expect Ameren's shareholders to have realized much benefit. However, despite these premiums, the stock performance of Ameren has been better than the utility and the S&P 500 index. Consider an investor who owned one share of Ameren at the end of 1997. At the end of 1997, the stock value was about $39/share.

This investor holding this share from 1997 through today would have realized dividends and capital gains yielding $72/share as shown on the time line graph below. As the investor in 1997 realized his or her dividends and share price increases, he or she would also now have a company that owns the assets of CIPS, CILCO, and Illinois Power. By comparison, if the investor put his or her $39 in a mutual fund consisting of S&P 500 stocks or a mutual fund that includes a mix of utility shares, he or she would have ended up today with $49 and $56 respectively.



The returns realized by an investor who put money in Ameren shares or the S&P 500 or the utility fund are demonstrated by computing the overall percent return and the dollar amount that has been realized. The graph below illustrates that Ameren investors have realized an 80% increase while the same investment in the S&P 500 fund would have generated only 23%. The Ameren return is almost four times as much as the S&P 500. Similarly, the investor return of 41% on utility shares is half the return realized by the Ameren investment.



The table below shows how Ameren investors have fared on an aggregate basis. There were 137 million Ameren shares outstanding at the end of 1997. Multiplying these shares by increase in share value ($72-$39) produces an aggregate value of $4.4 billion. By contrast, the S&P fund on an aggregate basis would have only yielded $1.2 billion, implying the Ameren shareholders earned $3.1 billion more than the S&P 500. Similar numbers for the overall utilities fund reveals that Ameren investors realized $2.1 billion more than other utility companies.

	Value per Share	Shares in 1997	Value in ($ Millions)	Value Versus Ameren
Ameren				
Initial Value	$39.69	137.215	$5,445.72	
2006 Value	71.56	137.215	9,819.11	
Increase			4,373.39	0.00
S&P				
Initial Value	39.69	137.215	5,445.72	
2006 Value	48.90	137.215	6,709.49	
Increase			1,263.77	3,109.62
Utilities				
Initial Value	39.69	137.215	5,445.72	
2006 Value	55.97	137.215	7,680.17	
Increase			2,234.45	2,138.94

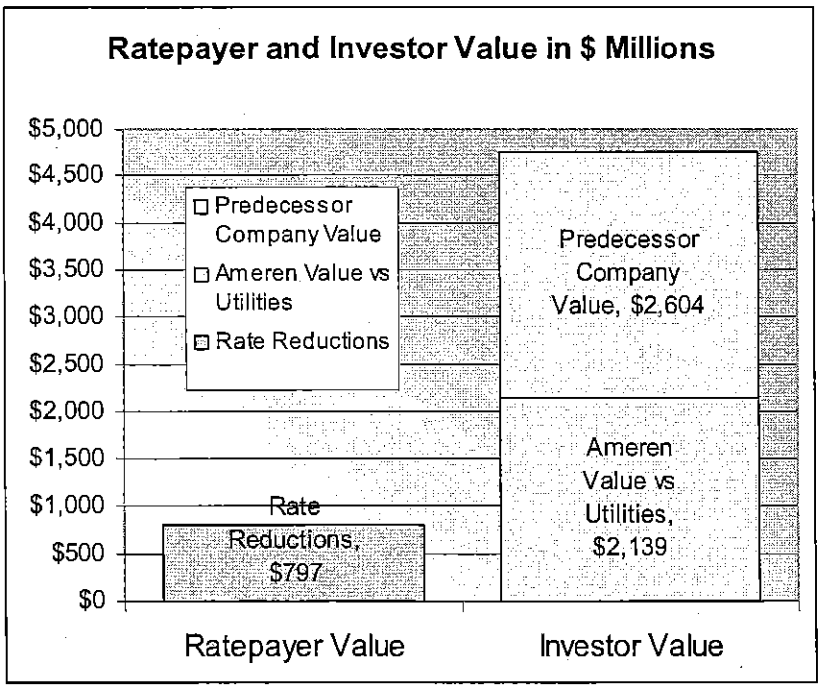
Investor Value as Compared to Ratepayer Value

The Act provided benefits to residential ratepayers in the form of rate reductions. These rate reductions were higher for Illinois Power than for Union Electric, CIPS and CILCO.

The rate decreases for Illinois Power (15% in 1998 and another 5% in 2002) were more than the reductions for the other companies. The aggregate value of the rate decreases has been approximately $800 million as shown on the table below.[8]

Value of Rate Reductions in $ Millions					
	IP	CIPS	UE	CILCO	Total
1998	$35.00	$5.75	$1.46	$3.13	$45.33
1999	$70.00	$11.49	$2.92	$6.25	$90.67
2000	$70.00	$11.51	$2.98	$6.29	$90.79
2001	$70.00	$11.54	$3.03	$6.34	$90.91
2002	$90.00	$11.56	$3.09	$6.38	$111.03
2003	$100.00	$11.58	$3.15	$6.42	$121.15
2004	$101.53	$11.61	$3.21	$6.46	$122.80
2005	$103.06	$11.63	$3.26	$6.50	$124.45
Total	$639.59	$86.67	$23.10	$47.76	$797.12

The aggregate value of these rate increases pales in comparison to the $2.6 billion realized by investors in predecessor companies, without even considering the financial performance of Ameren. However, to accurately compare the rate reductions with investor benefits, we included the value of Ameren investors relative to other utility companies. This is necessary because Ameren generates returns from Missouri as well as Illinois operations. (We assume that as a regulated Missouri utility, the investors would have received about the same value as the utility index.). On this basis, the graph below demonstrates investors have received almost six times the value that has been received by ratepayers.



[8] The source of the Illinois Power figures are numbers provided in SEC documents. The source of the other figures are residential revenue figures from the FERC Form 1 reports.

Summary

Ameren has been able to generate substantial returns to shareholders despite the premiums the company has paid to the investors of CIPS, Illinova, CILCORP, AES and Dynegy. The assets that Ameren now controls have been very profitable and, if Ameren's management's projections are accurate, the company is poised to become one of the most profitable utilities in the country.

EXHIBIT 5

Comments of Illinois Health Professionals (August 10, 2012)

August 10, 2012

Illinois Pollution Control Board
c/o John Therriault
Assistant Clerk of the Board
James R. Thompson Center
100 W. Randolph
Suite 11-500
Chicago, Illinois 60601

Re: Docket No. PCB 2012-126

Dear Members of the Illinois Pollution Control Board:

As health professionals living and working in Illinois, we support the Multi-Pollutant Standard (MPS) adopted by the Illinois Pollution Control Board in 2006. By controlling power plant emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_x), and mercury, the MPS helps protect the air we breathe, the local fish we eat, and the wildlife and natural spaces we love from harmful pollution. We are concerned by the present effort to weaken the MPS before the Illinois Pollution Control Board. We urge you to vote against any action eroding MPS standards.

Nationally, coal-fired power plants are the largest sources of SO_2 and mercury emissions, and are among the largest single source emitters of NO_x. Emissions of these air pollutants impact human and ecosystem health in a number of ways. Exposure to mercury, a potent neurotoxin, can result in developmental delays (e.g. speech, motor, and memory skills) in children, and cause nervous system damage in adults. High levels of SO_2 and NO_x can exacerbate respiratory symptoms in at-risk individuals (including children and the elderly), including asthma and COPD attacks. Wildlife and plant species are also impacted by the toxic effects of these pollutants, (e.g. reproductive impacts of mercury to wildlife, SO_2-derived acid rain damage to foliage).

In addition to the health impacts of directly regulated chemicals, SO_2 and NO_x are also precursors to other harmful pollutants such as fine particulate matter and ground-level ozone. Fine particulate matter ($PM_{2.5}$) is a complex mixture of solid and liquid particles, and a very large proportion of measured $PM_{2.5}$ results from the chemical transformation of SO_2 and various NO_x molecules in the atmosphere. Numerous scientific studies and authoritative panels have identified $PM_{2.5}$ as harmful to human health, with causal linkages found between short- and long-term exposures and premature mortality and cardiovascular effects. According to a 2010 report by the National Research Council, in 2005 alone, the annual health and related damages from particulate, NO_x, and SO_2 cost the public $62 billion (2007 USD). The vast majority ($53 billion) of these costs were due to health damages associated with the transformation of SO_2 into $PM_{2.5}$.

As it stands, the MPS is designed to require substantial reductions in the emission rates of SO_2, NO_x, and mercury. These reductions will allow for substantial gains in the public health of our state and surrounding regions, particularly for vulnerable populations. By maintaining the present MPS emission rate requirements for each of the pollutants, you will ensure that the health improvements behind the spirit of the law remain intact, and that the public does not bear the costs of polluter non-compliance. We applaud you for your decision to put the MPS in place six years ago, and we ask that you continue to show your support for this standard by voting against any effort to weaken its protective power.

Sincerely*,

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Lisa Henry-Reid, MD
Simon Piller, MD
(*representing 500 health professionals throughout Cook County*)

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*Affiliation for information only. Not to imply institutional endorsement.

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EXHIBIT 6

National Research Council, *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use* (2010), Public Access File 34, Estimates of damages associated with specific coal-fired electricity-generating facilities and natural-gas-fired electricity generating facilities

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July 6, 2012

Dear Mr. Armstrong:

Please find below the invoice for the requested Public Access Files Materials.

PROJECT: Health, Environmental, and Other External Costs and Benefits of Energy Production and Consumption
PIN# BEST-K-08-02-A

File(s): #34. Supplemental results of the committee, April 22, 2010
Estimates of damages associated with specific coal-fired electricity-generating facilities and natural-gas-fired electricity-generating facilities. Two Excel spreadsheets.

Cost of Materials/Shipping: $12.00

Thank you for your interest in The National Academies. Please let me know if we can help you with anything else.

Regards,
Suzanne Thilenius

Suzanne Thilenius
Public Access Records Office (PARO)
The National Academies
PARO@nas.edu

Note: All figures are in 2007 USD and use a VSL of $6 million (2000 USD)

ORISPL	OPRNAME	FACILITY NAM	FIPS	LAT	LON	2005 Net Generation (kWh)	SO2 Damages	Nox Damages	PM 2.5 Damages	PM 10 Damages	Total Damages	Damages per Ton of SO2	Damages per Ton of NOx	Damages per Ton of PM 2.5	Damages per Ton of PM 10
3	Alabama Pow	Barry	01097	31.0069	-88.0109	1.16E+10	1.81E+09	1.49E+07	6.25E+06	9.29E+05	1.91E+09	2.43E+03	7.84E+02	2.54E+09	3.19E+02
7	Alabama Pow	Gadsden	01055	34.0196	-85.9709	4.30E+08	4.85E+07	1.81E+06	2.56E+06	1.81E+05	4.80E+07	4.66E+03	8.84E+02	8.74E+09	2.65E+02
8	Alabama Pow	Gorgas	01127	33.6466	-87.0069	7.90E+09	3.64E+08	1.06E+07	1.89E+07	5.45E+05	3.89E+08	4.94E+03	8.15E+02	6.71E+09	2.82E+02
10	Alabama Pow	Greene County	01063	33.0017	-87.7811	1.58E+09	5.06E+06	8.79E+06	4.18E+05	1.73E+08	3.48E+03	5.63E+02	9.48E+09	1.99E+02
26	Alabama Pow	E C Gaston	01117	33.2442	-86.4567	1.18E+10	5.01E+08	2.07E+07	2.65E+07	1.42E+06	5.50E+08	3.93E+03	8.17E+02	4.23E+09	1.88E+02
47	Tennessee Val	Colbert	01033	34.7439	-87.8486	7.74E+09	1.98E+08	1.52E+07	1.75E+07	9.17E+05	2.26E+08	4.94E+03	9.36E+02	4.80E+09	2.29E+02
50	Tennessee Val	Widows Creek	01071	34.8925	-85.7547	9.84E+09	1.84E+08	1.56E+07	1.97E+07	9.86E+05	2.13E+08	5.39E+03	8.24E+02	5.47E+09	2.59E+02
51	CLECO Power I	Dolet Hills	22031	32.0806	-93.5692	4.84E+09	6.05E+07	2.26E+07	2.70E+06	1.54E+05	8.60E+07	2.55E+03	1.73E+03	4.46E+09	2.11E+02
56	Alabama Elect	Charles R Lowm	01129	31.4838	-87.9125	8.65E+08	5.26E+07	8.50E+06	4.98E+06	2.24E+05	6.37E+07	9.87E+03	6.11E+02	3.85E+09	1.69E+02
87	TH-State G & T	Escalante	35091	35.4159	-108.0820	1.91E+09	8.55E+06	4.58E+06	5.86E+05	3.75E+04	8.76E+06	2.75E+03	1.21E+03	2.78E+09	1.69E+02
108	Sunflower Elec	McAlcomb	20055	37.9306	-100.9725	2.68E+09	6.45E+06	8.21E+06	3.74E+05	5.27E+04	1.26E+07	9.66E+03	1.15E+03	3.79E+09	1.47E+02
113	Arizona Public	Cholla	04017	34.9333	-110.3000	7.57E+09	6.35E+07	1.64E+07	6.16E+06	4.49E+05	6.69E+07	2.90E+03	1.11E+03	9.00E+09	1.72E+02
126	Tucson Electric	Wilson Sundt	04019	32.1600	-110.9047	7.79E+08	2.29E+06	3.52E+06	2.91E+04	1.12E+07	2.82E+03	1.22E+03	3.97E+09	1.91E+02
127	Public Service	Oklaunion	48487	34.0828	-99.1759	4.34E+09	1.39E+07	2.57E+06	1.73E+05	2.98E+03	1.66E+07	1.61E+03	3.99E+09	1.99E+02
130	South Carolina	Cross	45015	33.3692	-80.1119	7.85E+09	4.11E+07	1.39E+06	5.13E+06	2.80E+05	4.84E+07	5.03E+03	5.27E+09	2.40E+02
136	Seminole Elect	Seminole	12107	29.7833	-81.5339	7.16E+09	7.79E+07	9.87E+06	2.92E+06	1.56E+05	9.02E+07	2.75E+03	4.69E+09	1.35E+02
160	Arizona Electri	Apache Station	04003	32.0619	-109.8991	2.76E+09	6.17E+06	7.67E+06	8.29E+05	5.16E+04	1.47E+07	2.92E+09	1.00E+09	2.64E+09	1.66E+02
165	Grand River Dn	GRDA	40097	36.1906	-95.7889	5.72E+09	8.41E+07	2.89E+07	8.25E+05	6.86E+04	1.22E+08	5.05E+03	1.85E+09	4.77E+09	2.27E+02
207	JEA	St Johns River	12031	30.4311	-81.5508	6.65E+09	3.41E+07	1.21E+07	2.60E+06	1.24E+05	4.90E+07	2.89E+09	7.77E+02	2.96E+09	1.93E+02
298	NRG Energy	Limestone	48293	31.4108	-96.2617	1.26E+10	4.82E+07	2.48E+07	9.15E+06	4.11E+05	8.16E+07	2.71E+03	2.04E+09	5.03E+09	2.53E+02
465	Public Service	Arapahoe	08031	39.6700	-105.0028	8.92E+08	6.37E+06	5.96E+06	7.71E+06	5.70E+05	2.26E+07	9.47E+03	3.55E+09	5.35E+09	2.51E+03
468	Public Service	Cameo	08077	39.1486	-108.3109	4.87E+08	8.62E+06	1.70E+06	9.05E+05	3.05E+04	1.06E+07	2.90E+03	1.22E+03	3.80E+09	2.49E+02
469	Public Service	Cherokee	08001	39.8093	-104.9603	4.98E+09	2.02E+07	2.95E+07	5.99E+06	4.55E+05	5.01E+07	2.87E+03	2.17E+09	9.00E+09	5.54E+02
470	Public Service	Comanche	08101	38.2091	-104.5747	4.26E+09	3.38E+07	1.13E+07	8.18E+05	5.54E+04	4.54E+07	2.47E+03	1.41E+09	8.02E+09	1.82E+02
477	Public Service	Valmont	08013	40.0195	-105.2820	2.17E+09	4.21E+06	7.57E+05	6.77E+04	7.20E+06	2.47E+03	1.67E+09	4.24E+09	5.23E+09	5.23E+02
492	Colorado Sprin	Martin Drake	08041	38.8244	-104.8331	2.09E+09	2.44E+07	6.39E+06	1.06E+06	6.41E+04	3.40E+07	2.67E+03	1.70E+09	5.23E+09	4.06E+02
525	Public Service	Hayden	08107	40.4856	-107.1850	5.65E+09	8.15E+06	1.09E+07	1.51E+06	1.31E+05	2.06E+07	2.82E+03	1.25E+09	2.51E+09	1.90E+02
527	TH-State G & T	Nucla	08085	38.2887	-108.5089	7.94E+08	8.72E+06	2.18E+06	1.60E+05	1.78E+04	6.07E+06	2.65E+09	1.19E+09	3.81E+09	2.03E+02
564	Orlando Utilities	Stanton Energy	12095	28.4836	-81.1696	6.15E+09	2.78E+07	5.78E+06	3.95E+06	1.44E+05	3.71E+07	9.35E+03	5.86E+02	4.62E+09	1.83E+02
568	PSEG Fossil	Bridgeport Sta	09001	41.1684	-73.1845	2.70E+09	1.14E+07	3.71E+06	2.95E+06	1.56E+05	1.76E+07	4.18E+03	1.89E+09	8.88E+09	4.48E+02
593	Cinergy Energy	Edge Moor	10003	39.7372	-75.5033	1.12E+09	7.44E+07	2.89E+06	8.95E+06	5.21E+05	6.89E+07	1.68E+04	1.51E+09	2.57E+04	1.32E+09
594	NRG Energy	Indian River Op	10005	38.5833	-75.2333	3.49E+09	1.99E+08	1.14E+07	2.02E+07	1.07E+06	2.31E+08	9.58E+03	1.62E+03	1.92E+04	6.12E+02
602	Constellation E	Brandon Shore	24003	39.1792	-76.5383	8.99E+09	3.01E+08	1.61E+07	1.56E+07	1.09E+06	3.37E+08	7.29E+03	1.37E+03	1.11E+04	5.26E+02
628	Progress Energy	Crystal River	12017	28.9594	-82.7003	1.56E+10	9.28E+09	2.10E+07	1.92E+07	6.16E+08	9.69E+09	9.21E+03	5.48E+02	4.20E+09	1.65E+02
641	Gulf Power Co	Crist	12033	30.6061	-87.2269	4.95E+09	5.88E+06	8.09E+07	9.97E+06	6.38E+05	1.04E+08	3.08E+03	7.18E+02	4.26E+09	1.90E+02
642	Gulf Power Co	Scholz	12063	30.6683	-84.8839	3.65E+08	1.71E+07	9.07E+05	6.41E+05	3.33E+04	1.87E+07	9.82E+03	6.05E+02	4.36E+09	1.96E+02
643	Gulf Power Co	Lansing Smith	12005	30.3089	-85.7003	2.86E+09	5.57E+07	3.62E+06	2.40E+06	1.27E+05	6.35E+07	3.27E+03	6.47E+03	3.93E+03	1.73E+02
645	Tampa Electric	Big Bend	12057	27.7944	-82.4036	8.19E+09	5.83E+07	2.06E+07	2.68E+07	1.39E+06	1.18E+08	5.99E+03	9.64E+02	5.29E+09	2.51E+02
663	Gainesville Rg	Deerhaven Ge	12001	29.7888	-82.3889	1.45E+09	2.84E+07	2.62E+06	1.77E+06	9.80E+04	3.29E+07	8.54E+03	6.78E+02	5.20E+09	2.41E+02
676	Lakeland City of	C D McIntosh J	12105	28.0809	-81.9256	2.40E+09	8.07E+07	5.86E+06	3.40E+06	1.77E+05	4.03E+07	4.58E+03	1.20E+03	9.03E+03	9.29E+02
703	Georgia Power	Bowen	13015	34.1256	-84.9192	2.23E+10	9.06E+08	2.86E+07	5.04E+07	3.22E+06	9.84E+08	4.86E+03	9.00E+02	5.53E+03	2.66E+02
708	Georgia Power	Hammond	13115	34.2533	-85.2456	4.85E+09	1.94E+08	5.92E+06	8.89E+06	5.21E+05	2.10E+08	4.52E+03	8.77E+02	5.78E+03	2.79E+02
709	Georgia Power	Harllee Branch	13237	33.1942	-83.2994	9.78E+09	3.99E+08	1.45E+07	2.08E+07	1.29E+06	4.35E+08	4.40E+03	7.23E+02	4.66E+03	2.29E+02
710	Georgia Power	Jack McDonou	13067	33.8234	-84.4750	9.64E+09	1.25E+08	5.17E+06	8.44E+06	4.65E+05	1.44E+08	4.71E+03	1.15E+03	5.57E+03	2.69E+02
727	Georgia Power	Mitchell	13095	31.4444	-84.1972	6.95E+08	3.99E+07	1.95E+06	1.95E+06	7.60E+04	9.77E+07	4.34E+03	8.77E+02	5.17E+03	2.58E+02
728	Georgia Power	Yates	13077	33.4622	-84.8986	6.58E+09	3.21E+08	1.17E+07	1.65E+07	1.06E+06	3.52E+08	4.87E+03	9.57E+02	5.16E+03	2.64E+02
733	Georgia Power	Kraft	13051	32.1468	-81.1450	1.11E+09	2.79E+07	2.09E+06	1.87E+06	1.32E+05	3.20E+07	4.49E+03	6.13E+02	5.15E+03	2.59E+02
856	AmerenEnergy	E D Edwards	17143	40.5958	-89.6651	4.85E+09	2.29E+08	1.70E+07	2.00E+07	1.08E+06	2.67E+08	6.58E+03	2.65E+03	9.95E+03	4.58E+02
861	AmerenEnergy	Coffeen	17135	39.0586	-89.4081	4.44E+09	2.46E+08	1.71E+07	3.66E+08	4.72E+05	2.98E+08	6.01E+03	1.08E+03	6.71E+03	3.29E+02
863	AmerenEnergy	Hutsonville	17099	39.1833	-87.6597	5.89E+09	9.92E+06	9.47E+06	4.57E+05	7.20E+07	5.99E+09	2.01E+03	8.48E+03	4.05E+02
864	AmerenEnergy	Meredosia	17137	39.8194	-90.5647	1.26E+09	8.05E+07	6.30E+06	9.61E+06	4.59E+05	9.69E+07	6.00E+03	2.63E+03	8.76E+03	4.18E+02
867	Edison Mission	Crawford	17031	41.8278	-87.7126	2.96E+09	5.91E+07	9.40E+06	7.98E+06	6.90E+05	7.15E+07	6.40E+03	1.70E+03	1.75E+04	8.21E+02
876	Dominion Energ	Kincaid Generat	17021	39.5942	-89.4583	6.14E+09	1.10E+08	2.98E+07	3.66E+08	1.95E+05	1.44E+08	6.29E+03	2.05E+03	8.20E+03	3.93E+02
879	Edison Mission	Powerton	17179	40.5408	-89.6705	9.47E+09	1.97E+08	5.69E+07	7.06E+06	4.75E+05	2.00E+08	5.89E+03	1.08E+03	7.38E+03	3.56E+02
880	Edison Mission	Waukegan	17097	42.3833	-87.8133	4.72E+09	7.80E+07	7.22E+06	8.16E+06	6.65E+05	9.99E+07	6.40E+03	1.52E+03	1.67E+04	8.45E+02
884	Edison Mission	Will County	17197	41.6044	-88.0592	5.24E+09	1.51E+08	1.40E+07	2.07E+07	1.45E+06	1.87E+08	9.95E+03	1.88E+03	4.71E+04	2.38E+03
886	Edison Mission	Fisk Street	17031	41.8508	-87.6533	1.44E+09	3.86E+07	2.06E+06	7.89E+06	6.79E+05	4.92E+07	6.39E+03	1.84E+03	3.65E+04	1.89E+03
887	Electric Energy	Joppa Steam	17127	37.2103	-88.8686	7.86E+09	1.29E+08	8.49E+06	3.92E+06	1.81E+05	1.41E+08	4.39E+03	1.58E+03	5.02E+03	2.39E+02
889	Dynegy Inc	Baldwin Energ	17157	38.2050	-89.8550	1.26E+10	1.15E+08	6.89E+06	8.04E+06	7.05E+05	1.97E+08	4.97E+03	1.40E+03	5.33E+03	2.51E+02
891	Dynegy Inc	Havana	17125	40.2797	-90.0775	2.08E+09	4.15E+07	1.01E+06	3.99E+06	2.22E+05	4.71E+07	5.65E+03	1.79E+03	7.19E+03	3.46E+02
892	Dynegy Inc	Hennepin Pow	17155	41.3017	-89.3136	1.58E+09	2.88E+07	2.87E+06	2.09E+06	1.65E+05	3.89E+07	6.24E+03	2.17E+03	9.52E+03	4.58E+02
897	Dynegy Inc	Vermillion	17183	40.1781	-87.7433	6.28E+08	7.01E+07	3.01E+06	5.41E+06	3.12E+05	8.79E+07	6.85E+03	2.41E+03	9.66E+03	4.62E+02
898	Dynegy Inc	Wood River	17119	38.8639	-90.1325	2.93E+09	4.88E+07	5.59E+06	4.99E+06	2.98E+05	9.55E+07	6.73E+03	2.43E+03	1.35E+04	6.25E+02
976	Southern Illino	Marion	17199	37.7206	-88.9550	1.79E+09	4.09E+07	6.48E+06	1.16E+07	5.67E+05	6.13E+07	5.61E+03	1.90E+03	7.11E+03	3.33E+02
981	Dominion Energ	State Line Ene	18089	41.7072	-87.5217	2.73E+09	5.58E+07	1.27E+07	4.21E+06	3.07E+05	7.90E+07	7.02E+03	1.85E+03	1.45E+04	7.05E+02
983	Indiana-Kentu	Clifty Creek	18077	38.7883	-85.4192	4.99E+09	4.97E+08	9.26E+07	5.55E+06	8.56E+05	5.36E+08	6.66E+03	1.42E+03	7.27E+03	3.52E+02
986	Indiana Michig	Tanners Creek	18029	39.0681	-84.8581	3.09E+09	3.09E+08	1.06E+07	1.70E+07	8.56E+05	3.37E+08	6.64E+03	1.93E+03	7.75E+03	3.76E+02
990	Indianapolis P	Harding Street	18097	39.7119	-86.1976	3.45E+09	9.68E+08	8.20E+06	2.41E+07	1.29E+08	4.01E+08	7.46E+03	1.52E+03	1.20E+04	6.22E+02
991	Indianapolis P	Pingle Valley	18109	39.4967	-86.4166	1.44E+09	1.51E+08	7.71E+06	9.74E+06	5.84E+05	8.47E+08	2.16E+03	1.44E+04	1.44E+04	7.34E+02
994	Indianapolis P	AES Petersburg	18125	38.5267	-87.2825	1.15E+10	2.24E+08	2.58E+07	8.97E+06	5.69E+05	2.59E+08	5.84E+03	1.66E+03	6.37E+03	3.13E+02
998	Northern Indi	Bailly	18127	41.6438	-87.1225	2.69E+09	9.57E+07	2.34E+07	6.94E+06	4.54E+05	6.54E+07	6.70E+03	1.89E+03	1.44E+04	6.52E+02
997	Northern Indi	Michigan City	18091	41.7203	-86.9097	2.29E+09	1.00E+08	8.19E+06	9.74E+06	5.29E+05	1.12E+08	5.86E+03	1.62E+03	7.70E+03	3.74E+02
1001	Duke Indiana I	Cayuga	18165	39.9239	-87.4372	2.64E+09	4.68E+08	2.00E+07	1.81E+07	9.55E+05	5.06E+08	6.04E+03	1.74E+03	7.12E+03	3.46E+02
1004	Duke Indiana I	Edwardsport	18083	39.0057	-87.2472	2.64E+08	4.46E+07	3.77E+06	1.97E+06	1.10E+05	5.04E+07	6.75E+03	2.43E+03	8.96E+09	4.49E+02
1008	Duke Indiana I	R Gallagher	18043	38.2656	-85.8981	2.65E+09	3.99E+08	6.62E+06	2.40E+07	1.28E+06	4.93E+08	7.03E+03	1.63E+03	9.76E+03	4.82E+02
1010	Duke Indiana I	Wabash River	18167	39.5800	-87.4147	4.52E+09	9.99E+08	1.46E+07	1.95E+07	1.03E+06	4.95E+08	6.02E+03	1.66E+03	6.52E+09	3.38E+02
1012	Vermon South	R D Culley	18173	37.9100	-87.9267	2.60E+09	3.52E+07	6.73E+06	3.08E+06	1.18E+07	1.41E+08	5.91E+07	7.30E+03	2.00E+09	1.03E+04
1040	Richmond City	Whitewater Va	18177	39.8028	-84.8853	5.46E+08	6.67E+07	1.56E+06	3.08E+06	1.50E+05	7.10E+07	5.56E+03	1.45E+03	4.68E+03	2.19E+02
1048	Hoosier Energy	Frank E Ratts	18125	38.5183	-87.7722	1.18E+09	6.78E+07	4.52E+06	4.24E+06	2.39E+05	9.18E+07	5.47E+03	1.87E+03	6.52E+09	3.32E+02
1046	Interstate Pow	Dubuque	19061	42.5069	-90.6507	3.43E+08	1.26E+07	3.67E+06	1.59E+06	8.04E+04	1.99E+07	6.47E+03	2.80E+03	8.43E+03	4.37E+02
1047	Interstate Pow	Lansing	19005	43.3339	-91.1700	1.40E+09	9.27E+07	7.92E+06	4.29E+06	2.82E+05	4.82E+07	5.68E+03	1.88E+03	6.05E+09	2.99E+02
1048	Interstate Pow	Milton L Kapp	19045	41.8117	-90.2300	1.22E+09	9.41E+07	2.65E+06	9.78E+06	5.09E+05	4.71E+07	6.41E+03	2.60E+03	9.40E+03	4.42E+02
1050	Interstate Pow	Sixth Street	19113	41.9839	-91.6686	1.24E+09	1.03E+07	2.78E+06	1.70E+06	9.04E+04	1.49E+07	6.80E+03	3.51E+03	1.04E+04	5.10E+02
1073	Interstate Pow	Prairie Creek	19113	41.9978	-91.6383	9.09E+08	2.67E+07	6.46E+06	2.86E+06	1.58E+05	3.92E+07	6.02E+03	2.82E+03	8.15E+03	4.00E+02
1077	Interstate Pow	Sutherland	19127	42.0472	-92.8637	6.69E+08	7.68E+06	9.15E+06	1.93E+06	6.68E+04	1.84E+07	2.22E+09	9.08E+03	9.97E+03	3.26E+02
1091	MidAmerican	Riverside	19163	41.5586	-90.4478	6.33E+08	1.59E+07	2.38E+06	8.26E+05	4.72E+04	1.90E+07	6.43E+03	2.69E+03	9.59E+03	4.59E+02
1092	MidAmerican	Council Bluffs	19155	41.2600	-95.8408	6.24E+09	3.61E+07	3.31E+07	3.26E+06	1.95E+05	7.26E+07	1.97E+03	2.28E+03	5.45E+03	2.97E+02
1093	MidAmerican	George Neal N	19193	42.3167	-96.3667	6.30E+09	3.57E+07	2.22E+07	3.76E+06	5.31E+05	7.31E+07	1.78E+03	1.92E+03	4.12E+03	2.07E+02
1104	Interstate Pow	Burlington	19057	40.7892	-91.1222	1.14E+09	2.79E+07	2.86E+06	3.55E+06	1.91E+05	3.93E+07	5.87E+03	2.37E+03	6.78E+03	3.34E+02
1122	Ames City of	Ames Electric	19169	42.0247	-93.6068	4.76E+08	2.54E+06	9.56E+06	4.63E+06	2.39E+05	1.40E+07	2.06E+03	2.58E+03	7.13E+03	3.36E+02
1131	Cedar Falls Uti	Streeter Statio	19013	42.5267	-92.4394	1.60E+08	8.46E+06	2.58E+06	9.70E+04	2.37E+04	1.11E+07	6.20E+03	9.38E+09	9.23E+02	4.28E+02
1167	Board of Water	Muscatine Pla	19139	41.3925	-91.0544	1.42E+09	1.89E+07	1.16E+07	2.22E+05	1.15E+04	9.07E+07	5.90E+03	2.44E+03	7.17E+09	3.48E+02
1175	Pella City of	Pella	19125	41.4073	-92.9805	1.10E+08	1.36E+06	9.58E+05	2.07E+05	1.48E+04	2.54E+06	2.20E+03	2.72E+03	6.12E+09	2.97E+02
1219	Central Iowa P	Fair Station	19139	41.4569	-90.8233	6.48E+07	2.41E+07	3.49E+06	7.09E+04	1.82E+04	6.04E+07	5.88E+03	2.44E+09	7.16E+03	3.47E+02
1239	Empire Dist Gd	Riverton	20021	37.0719	-94.6986	3.44E+07	9.27E+06	4.49E+05	9.74E+04	2.75E+07	5.54E+03	2.27E+03	6.55E+03	3.03E+02
1241	Kansas City Po	La Cygne	20107	38.3472	-94.6388	9.01E+09	5.76E+07	3.86E+06	2.04E+05	1.08E+06	1.70E+08	1.80E+03	4.61E+03	2.28E+02	
1250	Westar Energy	Lawrence Ener	20045	39.0014	-95.2764	3.99E+09	7.61E+06	1.38E+07	3.74E+05	3.66E+05	2.46E+07	2.02E+03	2.53E+03	6.60E+03	3.59E+02
1252	Westar Energy	Tecumseh Ene	20177	39.0522	-95.5869	1.40E+09	9.69E+06	7.89E+06	6.41E+05	1.18E+05	1.88E+07	1.88E+03	2.84E+03	5.66E+09	3.24E+02
1255	Kansas City Of	Quindaro	20209	39.1486	-94.6405	9.78E+08	1.20E+07	8.50E+06	6.39E+05	3.83E+04	2.16E+07	2.07E+03	2.62E+03	9.40E+03	4.88E+02
1369	Kentucky Pow	Big Sandy	21127	38.1686	-82.6208	9.14E+09	1.06E+08	1.59E+07	8.05E+06	3.41E+06	6.29E+08	8.47E+02	6.49E+09	3.01E+02	

1355 Kentucky Utilit E W Brown	21167	37.7889	-84.7139	8.22E+09	2.72E+00	5.87E+06	1.48E+07	7.39E+05	2.92E+06	6.89E+03	1.01E+03	7.17E+03	3.42E+02
1356 Kentucky Utilit Ghent	21041	38.7497	-85.0350	1.26E+10	3.93E+00	1.83E+07	1.55E+07	8.59E+05	3.68E+08	6.63E+03	1.35E+03	7.23E+03	9.49E+02
1357 Kentucky Utilit Green River	21177	37.3696	-87.1214	6.38E+08	9.01E+07	1.99E+06	4.26E+06	2.21E+05	9.66E+07	5.82E+08	1.28E+08	6.42E+08	8.19E+02
1361 Kentucky Utilit Tyrone	21285	38.0475	-84.8494	3.86E+08	2.20E+07	1.16E+06	1.48E+06	7.75E+04	2.54E+07	7.12E+03	1.20E+08	1.09E+04	5.24E+02
1363 Louisville Gas Cane Run	21111	38.1928	-85.8884	3.67E+09	1.49E+09	1.22E+07	7.95E+06	4.79E+05	1.69E+08	7.90E+03	1.73E+03	1.81E+04	7.54E+02
1364 Louisville Gas Mill Creek	21111	38.0591	-85.9100	1.01E+10	1.67E+08	2.09E+07	1.10E+07	6.07E+05	1.99E+08	6.94E+03	1.66E+03	9.94E+03	4.91E+02
1372 Henderson Ut Henderson I	21101	37.8425	-87.5911	7.46E+07	1.76E+07	1.17E+06	2.93E+05	1.25E+04	1.90E+07	7.79E+03	2.73E+03	1.52E+04	6.51E+02
1374 Owensboro Ut Elmer Smith	21059	37.7988	-87.0587	2.17E+09	9.11E+07	1.13E+07	1.89E+06	1.14E+05	4.44E+07	5.84E+03	1.50E+03	5.00E+03	2.84E+02
1376 Tennessee Val Paradise	21177	37.2600	-86.9788	1.40E+10	4.41E+08	3.94E+07	1.27E+07	6.41E+05	4.94E+08	5.22E+03	1.16E+03	5.37E+03	2.63E+02
1378 Tennessee Val Shawnee	21145	37.1517	-88.7780	9.99E+09	1.88E+08	9.04E+07	8.54E+06	1.86E+05	2.23E+09	5.00E+03	1.49E+03	4.98E+03	2.37E+01
1381 Western Kentu Kenneth C Colv	21091	37.5628	-86.7917	2.27E+09	9.29E+06	6.82E+06	1.96E+07	1.09E+06	3.37E+08	5.79E+03	1.33E+03	7.02E+03	3.54E+02
1384 East Kentucky Cooper	21199	37.0000	-84.5917	2.00E+09	1.23E+08	3.90E+06	5.92E+06	3.38E+05	1.38E+08	5.26E+03	8.45E+02	9.26E+03	2.51E+02
1385 East Kentucky Dale	21049	37.8307	-84.2684	1.23E+09	7.32E+07	4.13E+06	3.91E+06	1.95E+05	8.09E+07	6.57E+03	1.09E+03	9.20E+03	4.44E+02
1389 Entergy Gulf S R S Nelson	22019	30.2861	-93.3917	3.21E+09	4.38E+07	5.42E+06	2.59E+06	1.44E+05	5.20E+07	8.81E+03	1.18E+03	4.20E+03	1.80E+02
1582 Constellation IC P Crane	24005	39.4269	-76.3650	2.12E+09	2.77E+08	1.07E+07	2.67E+07	1.21E+06	9.15E+08	8.89E+03	1.30E+03	1.39E+04	5.9eE+02
1584 Constellation Herbert A Wag	24003	39.1781	-76.5268	2.97E+09	1.98E+08	6.57E+06	9.55E+06	4.74E+05	1.76E+08	7.21E+03	1.37E+03	1.11E+04	5.26E+02
1578 Allegheny Ene R Paul Smith P	24043	39.5556	-77.8288	3.89E+09	9.46E+07	1.47E+06	4.56E+06	2.87E+05	4.10E+07	1.03E+04	1.60E+03	2.22E+04	1.03E+03
1571 Mirant Corp Chalk Point LL	24033	38.5444	-76.6861	3.89E+09	9.25E+08	1.14E+07	3.92E+07	1.86E+06	3.61E+08	6.48E+03	1.17E+03	9.57E+03	4.58E+02
1572 Mirant Corp Dickerson	24031	39.2086	-77.4644	9.33E+09	2.06E+08	7.86E+06	5.59E+07	2.85E+06	3.63E+08	7.94E+03	1.48E+03	1.04E+04	8.35E+02
1573 Mirant Corp Morgantown	24017	38.3292	-76.9767	6.41E+09	5.15E+08	1.48E+07	3.48E+07	1.83E+06	5.57E+08	6.48E+03	1.11E+03	9.04E+03	4.60E+02
1606 Energy Capital Mount Tom	25013	42.2614	-72.6053	1.69E+09	1.75E+07	1.35E+06	2.47E+06	1.32E+05	2.14E+07	4.22E+03	9.43E+02	1.19E+04	5.59E+02
1613 NRG Energy Somerset Stati	25003	41.7370	-71.1400	7.46E+08	2.09E+07	1.04E+06	2.51E+06	1.41E+05	2.46E+07	4.81E+03	1.14E+03	1.32E+04	6.16E+02
1615 Dominion Ene Brayton Point	25005	41.7125	-71.1914	6.04E+09	2.05E+08	1.39E+07	9.16E+07	1.75E+05	2.52E+08	6.83E+03	1.40E+03	2.11E+04	1.01E+03
1626 Dominion Ene Salem Harbor	25009	42.5267	-70.8782	2.17E+09	9.20E+07	2.06E+06	6.11E+06	3.90E+05	4.06E+07	8.49E+03	9.53E+02	9.71E+03	4.76E+02
1695 Consumers En B C Cobb	26121	43.2542	-86.2417	2.01E+09	6.99E+07	4.03E+06	3.21E+06	1.86E+05	7.70E+07	5.64E+03	1.32E+03	6.43E+03	8.11E+02
1710 Consumers En J H Campbell	26139	42.8108	-86.2036	9.94E+09	2.54E+08	2.30E+07	9.60E+06	5.35E+05	2.86E+08	6.24E+03	1.35E+03	6.88E+03	3.32E+02
1728 Consumers En J R Whiting	26115	41.7917	-83.4486	2.82E+09	8.32E+07	6.46E+06	1.95E+07	1.12E+06	1.02E+08	7.66E+03	1.96E+03	1.91E+04	8.42E+02
1731 Detroit Edison Harbor Beach	26069	48.8492	-82.6572	3.95E+08	9.79E+06	8.76E+05	1.52E+06	2.01E+05	1.23E+07	4.91E+03	8.23E+02	4.76E+03	2.25E+02
1788 Detroit Edison Monroe	26115	41.8917	-83.3461	1.67E+10	7.25E+08	4.30E+07	2.28E+07	1.15E+06	7.91E+08	6.59E+03	1.22E+03	7.28E+03	3.48E+02
1740 Detroit Edison River Rouge	26163	42.2733	-83.1191	2.89E+09	8.57E+07	5.05E+06	4.19E+06	2.14E+05	9.81E+07	7.47E+03	1.34E+03	1.97E+04	6.65E+02
1745 Detroit Edison Trenton Chan	26163	42.1236	-83.1811	4.22E+09	1.74E+08	7.51E+06	6.47E+06	3.29E+05	1.86E+08	6.47E+03	1.30E+03	7.11E+03	3.56E+02
1769 We Energies Presque Isle	26103	46.5894	-87.3991	3.42E+09	7.39E+07	6.88E+06	2.26E+06	1.14E+05	8.91E+07	9.48E+03	9.53E+02	9.36E+03	1.65E+02
1825 Grand Haven Ut Stmr	26139	43.0722	-86.2242	4.39E+08	9.74E+08	1.61E+06	1.13E+06	7.41E+04	1.26E+07	9.26E+03	2.71E+03	1.02E+04	8.98E+02
1830 Holland City ofHomes De Yo	26139	42.7956	-86.1199	8.04E+08	8.09E+06	1.04E+06	1.13E+06	7.79E+04	1.09E+07	9.75E+03	2.71E+03	1.82E+04	8.47E+02
1831 Lansing City of Eckert Station	26065	42.7163	-84.5586	1.50E+09	5.41E+07	7.04E+06	2.99E+06	2.98E+05	6.39E+07	7.68E+03	2.06E+03	1.92E+04	7.09E+02
1832 Lansing City of Erickson Statio	26045	42.8913	-84.6572	9.81E+08	2.96E+07	2.06E+06	1.50E+06	9.57E+04	2.71E+07	7.58E+03	1.69E+03	1.16E+04	5.98E+02
1848 Marquette Ci Shiras	26103	46.5314	-87.3917	3.04E+08	1.49E+06	9.17E+05	1.57E+03	8.56E+03	1.97E+06	4.04E+03	9.79E+01	4.04E+03	2.01E+02
1886 Wyandotte Mu Wyandotte	26163	42.2091	-83.1470	2.67E+08	2.19E+07	1.38E+05	8.06E+06	1.58E+05	2.65E+07	1.48E+04	2.11E+03	5.33E+04	2.67E+03
1891 Minnesota Po Syl Ludin	27197	47.5306	-92.1619	2.17E+09	2.59E+08	1.81E+07	6.46E+05	3.95E+04	1.38E+07	5.52E+03	1.14E+03	4.21E+03	2.11E+02
1898 Minnesota Po Clay Boswell	27051	47.2669	-93.6531	7.24E+09	1.09E+08	1.80E+07	3.95E+06	5.13E+05	1.32E+08	5.58E+03	1.26E+03	3.92E+03	1.97E+02
1904 Northern State Black Dog	27037	44.8108	-93.2801	1.68E+09	2.17E+07	1.33E+07	8.21E+05	7.47E+04	1.56E+07	5.34E+03	1.73E+03	5.18E+03	2.73E+02
1912 Northern State High Bridge	27128	44.9931	-93.1075	1.53E+09	1.97E+07	6.50E+06	2.88E+05	1.84E+05	2.76E+07	5.93E+03	1.93E+03	4.46E+03	2.35E+02
1915 Northern State Allen S King	27163	45.0300	-92.7786	2.36E+09	1.32E+08	1.88E+07	5.62E+05	6.62E+04	1.49E+08	5.63E+03	1.53E+03	4.78E+03	2.44E+02
1527 Northern State Riverside	27059	45.0283	-93.2753	2.13E+09	1.57E+08	9.45E+07	1.58E+06	1.51E+05	5.56E+04	1.25E+04	7.46E+03	2.62E+04	2.06E+03
1949 Otter Tail Pow Hoot Lake	27111	46.2900	-96.0426	9.30E+08	1.68E+07	8.86E+06	1.71E+05	9.56E+04	2.07E+07	4.97E+03	1.67E+03	4.00E+03	2.05E+02
1961 Austin City of Austin Northe	27099	43.6978	-92.9693	1.92E+08	1.87E+07	1.73E+06	1.11E+05	5.46E+03	2.05E+07	7.42E+03	3.69E+03	8.54E+03	4.20E+02
2049 Mississippi Power& Watson	28047	30.4408	-89.0269	3.74E+09	6.39E+07	9.26E+06	4.00E+06	1.97E+05	7.74E+07	2.75E+03	6.00E+02	4.61E+03	1.93E+02
2076 Empire District Asbury	29097	37.3956	-94.5913	1.35E+09	6.28E+07	1.13E+07	5.85E+05	2.86E+04	7.42E+07	5.21E+03	2.04E+03	5.92E+03	2.59E+02
2079 Kansas City Po Hawthorn	29095	39.1317	-94.4799	8.71E+09	3.47E+06	2.44E+06	1.74E+06	1.46E+05	7.81E+06	1.63E+03	1.63E+03	4.18E+03	2.00E+02
2080 Kansas City Po Montrose	29089	38.3108	-93.9931	9.93E+09	8.25E+07	1.94E+07	1.42E+06	1.16E+05	9.75E+07	5.26E+03	2.06E+03	5.41E+03	2.55E+02
2094 Aquila Networ Sibley	29095	39.1778	-94.1661	2.68E+09	2.09E+07	2.71E+07	1.98E+06	5.05E+05	2.71E+04	5.80E+04	2.46E+03	8.53E+03	5.64E+02
2098 Aquila Networ Lake Road	29021	39.7278	-94.8786	5.93E+08	6.92E+06	1.14E+07	5.05E+05	2.71E+04	1.89E+07	2.21E+03	3.62E+03	5.93E+03	4.46E+02
2109 AmerenUE Labadie	29071	38.5583	-90.8861	1.86E+10	2.59E+08	1.61E+07	6.28E+06	5.20E+05	2.80E+07	4.65E+03	1.69E+03	5.42E+03	2.60E+02
2104 AmerenUE Meramec	29189	38.4017	-90.3359	5.66E+09	1.17E+08	2.98E+07	4.96E+06	3.82E+05	1.40E+08	6.51E+03	9.05E+03	1.17E+04	5.41E+02
2107 AmerenUE Sioux	29183	38.9158	-90.2917	6.55E+09	3.09E+08	1.71E+07	6.82E+06	4.70E+05	3.29E+08	5.92E+03	2.03E+03	6.99E+03	3.18E+02
2123 Columbia City Columbia	29019	38.9658	-92.3178	7.27E+07	5.93E+06	7.52E+05	5.36E+05	2.59E+02	6.68E+06	5.91E+03	2.71E+03	7.99E+03	3.86E+02
2132 Independence Blue Valley	29095	39.0919	-94.4261	3.22E+08	5.28E+07	8.61E+06	1.08E+07	5.54E+05	7.29E+07	4.56E+03	7.59E+03	9.14E+04	1.42E+03
2181 Springfield Ci James River Pc	29077	37.1088	-93.2592	1.65E+09	9.55E+07	1.27E+07	9.45E+05	1.87E+05	4.92E+07	6.66E+03	8.02E+03	1.08E+04	4.54E+02
2167 Associated Ele New Madrid	29143	36.5147	-89.5617	7.60E+09	6.82E+07	4.79E+07	1.91E+06	1.09E+05	1.18E+08	4.97E+03	1.45E+03	4.92E+03	2.35E+02
2168 Associated Ele Thomas Hill	29175	39.5591	-92.5352	4.17E+09	2.97E+07	2.34E+07	2.12E+06	1.42E+05	6.13E+07	1.71E+03	1.78E+03	4.27E+03	2.02E+02
2169 Central Electr Chamois	29151	38.6853	-91.7556	1.01E+09	9.38E+07	4.77E+06	1.61E+05	9.94E+03	3.87E+07	6.04E+03	2.22E+03	7.91E+03	3.86E+02
2187 PPL Generatio I E Cerrelto Pla	30111	45.7747	-108.4808	6.55E+06	2.05E+06	2.68E+05	2.68E+05	1.81E+04	4.83E+06	2.28E+03	1.24E+03	2.71E+03	1.56E+02
2277 Nebraska Publ Sheldon	31109	40.5836	-96.7242	1.55E+09	1.35E+07	2.42E+07	3.66E+05	2.73E+04	3.61E+07	2.34E+03	2.58E+03	7.42E+03	3.77E+02
2251 Omaha Public Fort Omaha	31055	41.3087	-95.9505	3.35E+09	3.10E+07	1.11E+07	3.68E+05	4.55E+04	4.24E+07	1.80E+03	1.71E+03	9.99E+03	2.18E+02
2224 Nevada Power Reid Gardner	32003	36.6831	-114.8964	3.92E+09	4.34E+06	8.03E+06	3.68E+06	2.91E+05	1.65E+07	2.07E+03	8.91E+02	6.72E+03	4.55E+02
2241 Southern Calif Mohave	32009	35.1458	-114.5917	1.06E+10	7.14E+07	1.87E+07	5.03E+06	8.62E+05	9.56E+07	1.72E+03	9.01E+02	2.01E+03	1.29E+02
2364 Public Service Merrimack	33013	43.1411	-71.4482	3.12E+09	9.97E+07	2.53E+06	1.02E+07	5.87E+05	1.19E+08	2.95E+03	5.22E+02	5.09E+03	2.66E+02
2367 Public Service Schiller	33015	43.0978	-70.7042	1.57E+08	6.90E+07	1.42E+06	8.62E+06	5.99E+05	7.42E+07	3.18E+03	9.14E+02	2.47E+04	1.28E+03
2378 Rockland Cap B L England	34009	39.2900	-74.6939	1.30E+09	6.77E+07	5.55E+06	1.05E+07	4.64E+05	6.39E+07	7.47E+03	1.42E+03	1.89E+04	6.30E+02
2384 Connectiv Energ Deepwater	34039	39.6891	-75.5083	6.51E+08	4.76E+07	2.93E+06	6.15E+06	3.02E+05	5.64E+07	1.61E+04	2.83E+03	5.85E+04	2.42E+03
2408 PSEG Fossil PSEG Hudson	34017	40.7478	-74.0719	9.14E+09	1.52E+08	6.02E+06	4.12E+07	1.98E+06	2.01E+09	6.65E+03	7.15E+02	2.00E+04	9.94E+02
2408 PSEG Fossil PSEG Mercer	34021	40.1797	-74.7825	3.13E+09	1.29E+08	9.18E+06	1.36E+07	7.86E+05	1.50E+08	7.58E+03	1.03E+03	1.87E+04	8.86E+02
2442 Arizona Public Four Corners	35049	36.6900	-108.4914	1.56E+10	3.41E+07	4.71E+07	1.00E+07	1.01E+06	5.22E+07	2.72E+03	1.15E+03	2.72E+03	1.67E+02
2451 Public Service San Juan	35045	36.8006	-108.4886	1.24E+10	4.59E+07	8.11E+07	4.45E+06	3.12E+05	8.17E+07	2.77E+03	1.16E+03	2.74E+03	1.66E+02
2480 Dynegy Inc Danskammer	36071	41.5736	-73.9747	2.32E+09	8.28E+07	5.69E+06	4.82E+06	4.56E+05	9.82E+07	8.30E+03	1.91E+03	2.26E+04	1.07E+03
2526 AES NUGS AES Westover	36007	42.1117	-75.9747	9.15E+08	6.17E+07	1.61E+06	5.22E+06	2.61E+05	6.89E+07	5.57E+03	1.05E+03	1.01E+04	4.72E+02
2527 AES NUGS AES Greenidge	36123	42.6789	-76.9488	6.85E+08	7.57E+07	1.54E+06	2.24E+06	1.09E+05	6.35E+07	7.25E+03	6.48E+03	8.50E+03	3.95E+02
2535 AES NUGS AES Cayuga	36109	42.6028	-76.6936	2.41E+09	1.65E+07	1.98E+06	2.96E+06	1.91E+05	2.10E+07	5.46E+03	8.39E+02	8.50E+03	4.07E+02
2549 NRG Energy CR Huntley Ge	36029	42.9700	-78.8900	2.52E+09	1.11E+08	4.68E+06	1.86E+07	8.91E+05	1.35E+08	5.56E+03	1.12E+03	1.08E+04	4.80E+02
2554 NRG Energy Dunkirk Gener	36013	42.4800	-79.3500	3.34E+09	1.26E+08	9.90E+05	2.29E+07	1.09E+06	1.55E+08	5.93E+03	9.13E+02	7.75E+03	3.96E+02
2629 Mirant Corp Lovett	36087	41.2578	-73.9797	1.82E+09	1.03E+08	1.04E+07	1.95E+07	1.00E+06	1.34E+08	1.08E+04	3.05E+03	3.31E+04	1.63E+03
2642 Rochester Gas Rochester 7	36055	43.2689	-77.6294	9.79E+08	7.70E+07	1.75E+06	1.71E+06	8.47E+04	2.55E+07	5.03E+03	5.64E+02	9.11E+03	4.04E+02
2682 Jamestown Bo S A Carlson	36019	42.0917	-79.2417	2.34E+09	2.91E+07	5.03E+05	1.74E+06	2.09E+05	8.42E+06	6.01E+03	1.08E+03	1.05E+04	4.72E+02
2706 Progress Ener Asheville	37021	35.4734	-82.5491	1.87E+09	1.09E+08	5.58E+06	2.09E+06	2.05E+05	1.17E+08	7.00E+03	1.16E+03	1.17E+04	4.94E+02
2708 Progress Ener Cape Fear	37017	35.5950	-79.0492	2.84E+09	1.04E+08	4.50E+06	5.51E+06	3.84E+05	1.14E+08	7.61E+03	1.36E+03	1.23E+04	5.36E+02
2709 Progress Ener Lee	37191	35.3775	-78.0875	1.48E+10	7.56E+07	5.38E+06	1.08E+06	1.30E+05	6.24E+07	5.06E+03	9.94E+02	5.29E+03	2.81E+02
2712 Progress Ener Roxboro	37145	36.4933	-79.0781	1.48E+10	6.83E+08	1.65E+07	8.82E+06	9.65E+05	6.59E+08	6.19E+03	8.30E+02	6.69E+03	9.17E+02
2719 Progress Ener L V Sutton	37129	34.2836	-77.9787	3.07E+09	9.49E+07	5.47E+06	1.61E+06	1.74E+05	1.02E+08	4.47E+03	6.62E+02	4.42E+03	2.06E+02
2716 Progress Ener W H Weathers	37155	34.5889	-78.9790	7.98E+08	5.10E+07	4.99E+06	1.07E+06	1.22E+05	5.73E+07	6.80E+03	1.25E+03	1.00E+04	4.88E+02
2718 Duke Carolina: C G Allen	37071	35.1657	-81.0122	6.40E+09	2.75E+08	8.61E+06	1.58E+07	8.79E+05	8.04E+08	6.16E+03	1.04E+03	8.10E+03	3.86E+02
2720 Duke Carolina: Buck	37159	35.7138	-80.3167	1.65E+09	8.80E+07	3.82E+06	5.99E+06	3.32E+05	9.31E+07	8.70E+03	1.71E+03	1.47E+04	6.61E+02
2721 Duke Carolina: Cliffside	37045	35.2200	-81.7594	3.73E+09	1.71E+08	9.72E+06	1.21E+07	7.06E+05	1.68E+08	6.09E+03	9.34E+02	6.59E+03	3.23E+02
2723 Duke Carolina: Dan River	37169	36.4461	-79.7244	6.49E+08	3.02E+07	1.92E+06	1.27E+06	6.98E+04	3.95E+07	7.18E+03	1.21E+03	9.60E+03	3.70E+02
2727 Duke Carolina: Marshall	37035	35.5975	-82.6458	1.55E+10	6.27E+08	1.63E+07	2.96E+07	1.72E+06	6.77E+08	6.24E+03	1.04E+03	6.89E+03	3.39E+02
2732 Duke Carolina: Riverbend	37071	35.3600	-80.9742	1.84E+09	1.00E+08	9.34E+06	1.01E+07	5.82E+05	1.20E+08	7.09E+03	1.25E+03	1.09E+04	6.18E+02
2790 MDU Resources M Heskett	38059	46.8869	-100.8839	6.05E+08	1.53E+07	1.16E+06	1.62E+05	1.55E+04	1.69E+07	5.71E+03	1.52E+03	3.85E+03	2.06E+02
2817 Basin Electric Iteland Olds	38057	47.2819	-101.3194	4.81E+09	2.62E+08	1.74E+07	3.64E+06	2.11E+05	2.84E+08	9.49E+03	1.31E+03	3.09E+03	1.61E+02
2823 Minnkota Pow Milton R Young	38065	47.0664	-101.2139	1.48E+09	1.69E+08	8.22E+07	3.80E+06	2.34E+05	1.99E+08	5.54E+03	1.36E+03	3.29E+03	1.80E+02
2824 Great River En Stanton	38057	47.2872	-101.3814	1.48E+09	1.50E+07	2.95E+06	9.72E+05	6.08E+04	1.48E+07	5.53E+03	1.39E+03	8.16E+03	1.73E+02
2828 Cardinal Oper Cardinal	39091	40.2522	-80.6486	1.13E+10	1.05E+09	1.94E+07	6.07E+07	3.87E+06	1.19E+09	5.38E+03	1.22E+03	1.00E+04	7.63E+02
2830 Duke Ohio Inc Walter C Beck	39025	38.9917	-84.2981	6.45E+09	5.00E+08	2.84E+07	3.37E+07	2.10E+06	5.56E+08	7.46E+03	1.56E+03	1.06E+04	5.54E+02
2832 Duke Ohio Inc Miami Fort	39061	39.1131	-84.8091	7.54E+09	9.15E+08	2.39E+07	3.61E+07	2.08E+06	5.76E+08	8.64E+03	1.50E+03	7.86E+03	3.82E+02

2885 First Energy Ge Ashtabula	89007	41.8589	-80.7667	1.41E+09	9.02E+07	1.99E+06	1.00E+06	8.99E+06	3.82E+07	7.23E+09	1.19E+09	1.10E+04	5.23E+02
2886 Reliant Energy Avon Lake	89093	41.5043	-82.0500	9.55E+09	2.09E+08	7.95E+06	1.66E+07	5.68E+05	3.15E+08	6.78E+09	1.07E+09	8.12E+03	4.18E+02
2887 First Energy Ge Eastlake	89085	41.6713	-81.4492	8.87E+09	5.49E+08	1.43E+07	3.40E+07	1.65E+06	5.97E+08	7.36E+09	1.17E+09	1.29E+04	5.89E+02
2888 First Energy Ge Lake Shore	89095	41.5933	-81.6875	9.35E+08	8.32E+07	4.75E+06	4.73E+06	2.84E+03	4.20E+07	1.08E+04	2.56E+09	2.46E+04	1.12E+09
2840 Columbus Sou Conesville	85031	40.1642	-81.5811	9.71E+09	7.51E+08	2.14E+07	5.67E+07	2.76E+06	8.31E+08	7.04E+09	1.01E+09	9.92E+03	4.13E+02
2842 Columbus Sou Picway	88129	39.7933	-83.0097	2.38E+08	5.80E+07	1.29E+06	4.49E+06	2.25E+05	5.86E+07	8.06E+09	1.89E+09	1.29E+04	6.47E+02
2848 Dayton Power O H Hutchings	89113	39.6694	-84.2931	6.65E+08	5.86E+07	7.59E+06	6.11E+06	3.56E+05	7.28E+07	1.01E+04	2.71E+09	2.01E+04	5.47E+02
2850 Dayton Power J M Stuart	89001	38.6861	-83.6939	1.44E+10	6.87E+08	2.39E+07	3.08E+07	1.76E+06	5.24E+08	6.28E+09	9.78E+02	6.44E+09	3.04E+02
2851 Reliant Energy Niles	89155	41.1667	-80.7500	1.84E+09	8.04E+06	2.06E+06	1.16E+05	1.45E+06	9.68E+03	1.45E+06	1.54E+04	6.87E+02
2864 First Energy Ge R E Burger	89019	39.9094	-80.7608	1.99E+09	2.76E+06	5.45E+05	2.99E+07	1.10E+06	8.05E+08	7.34E+09	1.02E+09	9.77E+03	4.38E+02
2865 First Energy Ge W H Sammis	89081	40.5308	-80.6611	1.47E+10	7.98E+08	2.96E+07	9.65E+07	2.83E+06	9.12E+08	6.69E+09	1.03E+09	9.24E+03	4.15E+02
2872 Ohio Power Ct Muskingum R	83167	39.5909	-81.6797	7.38E+09	6.57E+08	1.98E+07	4.24E+07	2.03E+06	5.55E+08	6.66E+09	8.58E+02	7.32E+03	3.35E+02
2876 Ohio Valley Elk Kyger Creek	89053	39.0151	-82.1261	3.13E+09	4.78E+08	1.57E+07	9.07E+07	1.57E+06	5.71E+08	6.52E+09	9.53E+02	6.73E+03	3.12E+02
2878 First Energy Ge Bay Shore	89095	41.6525	-83.4375	1.21E+09	1.20E+08	1.31E+07	7.57E+06	5.07E+05	1.41E+08	8.57E+09	1.89E+09	1.48E+04	7.09E+02
2917 Hamilton City Hamilton	89017	39.4069	-84.5542	7.86E+08	1.21E+07	8.80E+05	6.49E+05	3.47E+04	1.37E+07	9.66E+09	1.96E+09	2.23E+04	1.16E+09
2952 Oklahoma Gas Muskogee	40101	35.7617	-95.3847	1.02E+10	6.59E+07	1.53E+07	1.04E+06	1.15E+05	6.25E+07	5.12E+09	1.76E+09	1.52E+03	2.16E+09
2969 Public Service Northeastern	40131	36.4817	-95.7008	6.56E+09	7.58E+07	1.22E+07	7.40E+05	4.24E+04	6.83E+07	4.88E+09	1.89E+09	4.34E+03	2.10E+02
3096 Reliant Energy Efranx Power	42125	40.2580	-79.9167	1.58E+09	2.41E+07	5.60E+06	3.10E+06	2.62E+05	3.91E+07	7.51E+09	1.19E+09	9.89E+03	4.34E+02
3113 Reliant Energy Portland	42095	40.9100	-75.0789	2.16E+09	3.63E+08	7.06E+06	5.07E+07	2.75E+06	4.24E+08	1.25E+04	2.21E+09	3.34E+04	1.52E+09
3115 Reliant Energy Titus	42011	40.3061	-75.8081	1.27E+09	2.47E+06	7.29E+06	9.81E+07	1.85E+06	2.84E+09	1.69E+04	9.21E+09	4.20E+04	1.88E+09
3118 Reliant Energy Conemaugh	42069	40.3842	-79.0611	1.79E+10	5.10E+07	1.86E+07	1.52E+07	1.20E+06	8.60E+07	7.11E+08	9.44E+02	9.44E+09	4.39E+02
3122 Edison Mission Homer City Sta	42059	40.5110	-79.1068	1.36E+10	9.42E+08	1.79E+07	7.44E+07	3.91E+06	1.04E+09	7.13E+08	9.47E+02	9.47E+09	6.40E+02
3130 Reliant Energy Seward	42063	40.4081	-79.0389	2.79E+09	5.41E+07	1.37E+06	1.08E+07	1.05E+06	7.54E+07	7.11E+08	9.44E+02	9.44E+09	4.98E+02
3131 Reliant Energy Shawville	42033	41.0670	-78.3056	3.19E+09	3.32E+06	6.98E+06	2.28E+07	1.20E+06	3.68E+08	7.06E+09	1.03E+09	8.10E+03	4.27E+02
3136 Reliant Energy Keystone	42005	40.6604	-79.3411	1.55E+10	1.28E+08	1.43E+07	8.47E+07	4.27E+06	1.89E+09	7.12E+09	1.02E+09	8.89E+03	4.10E+02
3116 Reliant Energy New Castle Plt	42073	40.9378	-80.3681	1.31E+09	1.25E+06	2.29E+06	8.25E+06	3.89E+05	1.95E+09	6.59E+09	9.62E+02	8.20E+03	3.76E+02
3140 PPL Generatio PPL Brunner Is	42133	40.1000	-76.6917	1.01E+10	7.34E+08	1.49E+07	5.56E+07	3.40E+06	8.05E+09	7.02E+09	1.05E+09	1.16E+04	5.44E+02
3148 PPL Generatio PPL Martins Cr	42095	40.7917	-76.1083	7.45E+08	7.98E+07	1.93E+06	1.49E+07	8.78E+05	9.74E+07	7.70E+09	1.19E+09	1.19E+04	9.60E+02
3149 PPL Generatio PPL Montour	42093	41.0715	-76.6742	1.03E+10	8.21E+08	1.15E+07	8.35E+07	4.28E+06	9.19E+08	6.44E+09	8.54E+02	1.10E+04	5.12E+02
3152 Cerone Power Sunbury	42109	40.8791	-76.8280	1.52E+09	1.65E+08	2.43E+06	6.66E+06	3.69E+05	1.75E+08	6.00E+09	8.48E+02	8.84E+03	4.21E+02
3159 Exelon Energy Cromby Gener	42029	40.1514	-75.5306	6.79E+08	4.37E+07	8.05E+06	3.72E+06	2.09E+05	5.07E+07	1.27E+04	1.86E+09	3.32E+04	1.49E+09
3161 Exelon Energy Eddystone Ge	42045	39.8580	-75.3200	2.85E+09	7.61E+07	6.65E+06	1.91E+07	9.56E+05	9.75E+07	1.18E+04	1.25E+09	8.80E+04	1.71E+09
3176 UGI Developm Hunlock Powe	42079	41.2033	-76.0683	1.57E+09	5.61E+07	1.55E+06	9.76E+06	1.78E+05	6.11E+07	1.24E+04	2.48E+09	2.99E+04	1.31E+09
3178 Allegheny Ene Armstrong Pes	42005	40.5289	-79.4638	2.01E+09	2.18E+08	3.37E+06	1.47E+07	7.38E+05	2.98E+08	7.15E+09	1.03E+09	8.87E+03	4.05E+02
3179 Allegheny Ene Hatfields Ferry	42059	39.8528	-79.9278	8.67E+09	1.09E+09	1.58E+07	7.32E+07	1.12E+06	1.12E+09	7.08E+09	9.60E+02	8.51E+03	4.14E+02
3181 Allegheny Ene Mitchell Powe	42125	40.2228	-79.9664	1.79E+09	1.79E+07	3.08E+06	6.57E+06	2.92E+05	2.78E+07	1.18E+04	1.22E+09	2.87E+04	1.19E+09
3251 Progress Energ H Robinson	45031	34.4017	-80.1589	1.16E+09	6.25E+07	2.58E+06	4.70E+06	2.61E+05	7.04E+07	5.66E+09	1.07E+09	7.59E+03	3.40E+02
3264 Duke Carolina W S Lee	45007	34.6022	-82.4950	1.45E+09	6.85E+07	9.79E+06	1.01E+07	5.76E+05	1.03E+08	7.89E+09	1.50E+09	1.53E+04	6.58E+02
3280 South Carolina Canadys Stean	45029	33.0603	-80.5214	7.18E+09	8.96E+07	3.24E+06	1.08E+06	7.05E+04	9.99E+07	4.58E+09	6.58E+02	5.88E+03	2.71E+02
3287 South Carolina McMeekin	45069	34.0533	-81.2178	1.79E+09	8.65E+07	3.67E+06	9.17E+06	4.97E+05	9.98E+07	6.00E+09	1.17E+09	9.61E+03	4.27E+02
3295 South Carolina Urquhart	45009	33.4850	-81.9111	6.02E+08	3.84E+07	9.75E+05	2.54E+06	1.56E+05	3.71E+07	5.82E+09	1.10E+09	7.89E+03	3.77E+02
3297 South Carolina Wateree	45079	33.8264	-80.6211	5.18E+09	1.69E+09	5.75E+06	1.86E+07	1.26E+06	2.16E+08	5.02E+09	8.61E+02	5.69E+03	2.69E+02
3298 South Carolina Williams	45015	33.0163	-79.9265	4.78E+09	1.16E+09	4.67E+06	9.98E+06	1.96E+05	1.25E+08	4.19E+09	7.13E+07	4.15E+03	1.92E+02
3317 South Carolina Dolphus M Gr	45051	33.9253	-79.0528	1.13E+09	6.45E+07	2.87E+06	4.50E+06	2.40E+05	7.21E+07	5.00E+09	9.94E+02	6.00E+03	2.57E+02
3319 South Carolina Jefferies	45035	33.2412	-79.5675	1.91E+09	1.70E+08	5.67E+06	1.01E+07	1.84E+05	7.19E+07	4.01E+09	7.07E+02	6.81E+03	3.04E+01
3325 Black Hills Pow Ben French	46103	44.0972	-103.2614	1.52E+09	3.06E+06	1.04E+06	6.25E+04	7.79E+03	4.15E+06	5.92E+09	1.14E+03	2.31E+03	1.37E+02
3393 Tennessee Val Allen Steam Pl	47157	35.0742	-90.1488	5.15E+08	1.45E+08	2.93E+07	4.19E+06	1.75E+05	6.07E+09	2.92E+09	6.83E+03	4.04E+02
3396 Tennessee Val Bull Run	47001	36.0211	-84.1567	6.57E+09	2.09E+08	5.10E+06	1.06E+07	5.97E+05	2.25E+08	5.46E+09	7.92E+02	5.60E+03	2.61E+02
3399 Tennessee Val Cumberland	47161	36.3902	-87.6539	1.63E+10	8.95E+07	2.76E+07	1.10E+07	7.11E+05	1.26E+08	5.12E+09	1.01E+09	4.91E+03	2.37E+03
3403 Tennessee Val Gallatin	47165	36.3136	-86.4006	7.48E+09	1.39E+08	9.79E+06	3.13E+06	1.68E+05	1.52E+08	9.37E+09	1.14E+09	5.62E+03	2.70E+02
3405 Tennessee Val John Sevier	47073	36.3767	-82.5639	4.96E+09	2.06E+08	8.39E+06	6.82E+05	6.42E+04	2.06E+08	6.35E+09	6.52E+02	9.21E+03	4.19E+02
3406 Tennessee Val Johnsonville	47085	36.0278	-87.9861	7.53E+09	8.75E+08	1.45E+07	2.20E+07	1.15E+06	4.17E+08	5.02E+09	1.06E+03	4.85E+03	2.34E+02
3407 Tennessee Val Kingston	47145	35.8892	-84.5194	9.46E+09	3.04E+08	1.11E+07	1.67E+07	8.67E+05	3.38E+08	5.42E+09	7.75E+02	5.45E+03	2.57E+02
3470 NRG Energy W A Parish	48157	29.4828	-95.6311	1.85E+10	1.76E+09	5.16E+06	9.97E+06	4.95E+05	1.92E+08	3.19E+09	1.25E+03	4.91E+03	2.48E+02
3497 TXU Generatio Big Brown	48181	31.8206	-96.0561	8.54E+09	2.54E+08	1.45E+07	1.14E+07	7.11E+05	2.80E+08	2.80E+09	2.09E+03	4.99E+03	2.52E+02
3644 PacifiCorp-Roc Carbon	49007	39.7264	-110.8639	1.35E+09	9.24E+06	2.35E+06	5.60E+05	5.65E+04	1.25E+07	1.76E+09	6.85E+02	1.78E+03	1.39E+02
3775 Appalachian P Ceredo River	51157	96.9933	-82.1997	3.93E+09	1.59E+08	5.51E+06	5.36E+06	2.71E+05	1.61E+08	7.59E+02	6.60E+03	2.81E+02
3776 Appalachian P Glen Lyn	51071	37.3706	-80.8672	1.64E+09	7.02E+07	8.10E+06	2.80E+06	1.70E+05	7.67E+07	5.66E+09	7.75E+02	5.40E+03	2.64E+02
3788 Mirant Corp Potomac River	51510	38.8203	-77.0411	1.16E+09	2.48E+06	3.86E+06	1.69E+06	1.56E+05	1.38E+04	9.31E+02	4.61E+04	2.06E+09	
3796 Dominion Veg Brame Bluff	51065	37.7048	-78.2678	1.43E+09	6.84E+07	3.38E+05	5.20E+06	2.67E+05	9.72E+07	8.11E+09	9.23E+02	9.66E+03	4.67E+02
3797 Dominion Veg Chesterfield	51041	37.3823	-77.7839	8.31E+09	6.33E+08	1.92E+07	5.45E+07	2.76E+06	7.04E+08	9.06E+09	1.22E+03	1.29E+04	6.01E+02
3803 Dominion Virg Chesapeake	51550	36.7711	-76.3019	9.78E+09	2.89E+08	7.90E+06	2.02E+07	1.06E+06	2.65E+08	7.80E+09	1.19E+09	1.31E+04	6.88E+02
3809 Dominion Virg Yorktown	51199	37.2144	-76.4611	2.05E+09	1.99E+08	4.19E+06	1.02E+07	5.01E+05	2.20E+08	4.67E+09	9.96E+02	1.27E+04	6.92E+02
3845 TransAlta Enel Transalta Cent	53041	46.7625	-122.9567	1.05E+10	9.20E+08	3.06E+06	4.56E+06	3.87E+05	1.12E+07	9.77E+02	1.79E+02	1.51E+09	1.19E+01
3935 Appalachian P John E Amos	54079	38.4731	-81.8239	1.89E+10	7.15E+08	3.08E+07	2.77E+07	1.38E+06	7.74E+08	5.97E+09	8.67E+02	6.51E+09	3.04E+02
3936 Appalachian P Kanawha River	54039	38.2056	-81.4211	2.06E+09	8.54E+07	3.23E+06	4.97E+06	2.18E+05	9.28E+07	6.65E+09	8.59E+02	7.37E+03	3.94E+02
3939 Appalachian P Philip Sporn	54053	38.9669	-81.9231	2.60E+09	2.60E+08	7.81E+06	1.21E+07	5.75E+05	1.18E+07	6.62E+09	8.73E+02	6.94E+09	3.21E+02
3942 Monongahela Albright	54077	39.6883	-79.5367	1.06E+09	1.39E+08	2.32E+06	1.02E+07	5.02E+05	1.41E+08	7.59E+09	9.29E+02	1.15E+04	5.35E+02
3943 Monongahela Fort Martin Pe	54061	39.7107	-79.9275	1.32E+10	3.25E+07	1.88E+07	1.61E+01	1.09E+06	6.84E+08	5.80E+09	9.58E+02	9.61E+03	4.00E+02
3944 Allegheny Ene Harrison Powe	54033	39.3836	-80.3161	1.75E+08	1.68E+07	9.74E+05	1.84E+06	1.09E+05	1.98E+07	9.47E+09	1.30E+03	1.92E+04	8.43E+02
3945 Monongahela Rivesville	54049	39.5514	-80.1180	6.20E+08	3.40E+07	2.04E+06	2.88E+06	1.52E+05	3.92E+07	6.89E+09	8.05E+02	7.39E+09	3.36E+02
3947 Ohio Power Ct Kammer	54051	39.8458	-80.8189	4.00E+09	2.74E+08	1.68E+07	1.68E+07	7.78E+05	3.09E+08	6.45E+09	1.46E+09	7.97E+09	3.72E+02
3948 Ohio Power Ct Mitchell	54051	39.8297	-80.8153	6.69E+09	3.46E+08	2.91E+07	1.99E+07	6.86E+05	3.91E+08	6.45E+09	1.46E+09	7.97E+09	3.72E+02
3954 Dominion Virg Mt Storm	54023	39.2014	-79.2667	1.07E+10	2.29E+07	1.58E+07	4.94E+07	2.41E+06	9.43E+07	6.51E+09	8.75E+02	8.39E+03	3.96E+02
3982 Northern Stat Bay Front	55803	46.5869	-90.9017	2.12E+09	6.84E+06	2.16E+06	1.06E+05	6.35E+03	9.12E+06	5.72E+09	1.42E+03	5.38E+09	2.70E+02
3992 Madison Gas E Blount Street	55025	43.0792	-89.3799	3.63E+09	5.87E+07	5.84E+06	1.18E+07	6.04E+05	7.69E+07	9.89E+09	4.72E+03	1.75E+04	6.91E+02
4041 Wp Energies South Oak Cre	55079	42.6637	-87.8294	5.83E+09	1.05E+08	1.49E+07	6.67E+06	3.27E+05	1.25E+09	6.11E+09	9.12E+05	1.38E+04	9.51E+02
4042 We Energies Valley	55079	43.0003	-87.9217	1.44E+09	6.88E+07	1.21E+07	1.63E+07	8.94E+05	1.00E+08	6.11E+09	9.12E+01	1.59E+04	9.50E+02
4050 Wisconsin Pow Edgewater	55117	43.7150	-87.7004	4.25E+09	9.54E+07	9.81E+06	2.02E+06	1.07E+05	1.07E+08	5.66E+09	1.62E+03	7.15E+03	3.55E+02
4054 Wisconsin Pov Nelson Dewey	55043	43.7247	-91.0058	1.12E+09	9.20E+07	5.96E+06	7.34E+05	3.66E+04	8.95E+07	5.89E+09	1.97E+03	6.46E+03	3.18E+02
4072 Wisconsin Pub Pulliam	55009	44.5897	-88.0083	2.52E+09	6.96E+07	1.67E+07	1.07E+06	1.15E+05	8.68E+07	5.72E+09	1.83E+03	8.29E+03	4.55E+02
4078 Wisconsin Pub Weston	55079	44.8606	-89.6559	9.52E+09	7.00E+07	1.51E+07	1.81E+06	1.05E+05	8.72E+07	5.21E+09	1.85E+03	5.90E+03	3.03E+02
4143 Dairyland Pow Genoa	55123	43.5532	-91.2032	2.41E+09	7.14E+07	6.14E+06	4.99E+06	2.73E+05	8.28E+07	5.46E+09	1.64E+03	5.74E+03	2.83E+02
4140 WPS Power De E J Stoneman	55048	42.7033	-90.9052	6.50E+07	5.60E+06	4.57E+05	5.71E+05	3.73E+04	6.67E+06	6.49E+09	2.55E+03	6.71E+03	4.09E+02
4158 PacifiCorp-Roc Dave Johnson	56005	42.8351	-105.7767	5.68E+09	2.56E+07	4.11E+06	3.10E+05	2.35E+04	9.00E+07	1.29E+03	2.75E+02	3.93E+02	1.87E+01
4162 PacifiCorp-Roc Naughton	56023	41.7572	-110.5985	3.23E+09	7.89E+07	1.89E+07	2.92E+06	2.07E+05	1.09E+08	8.49E+09	1.28E+09	5.12E+03	2.09E+02
4229 Michigan Sout Endicott State	26059	42.0336	-84.3585	8.71E+08	9.67E+06	3.02E+02	1.03E+06	8.25E+04	1.08E+07	9.47E+09	2.16E+09	1.57E+04	7.70E+02
4271 Dairyland Pow John P Madgel	55011	44.9822	-91.9142	2.51E+09	1.09E+09	1.31E+07	2.55E+04	1.36E+04	1.18E+08	6.18E+09	1.72E+03	5.55E+03	2.71E+02
4941 Salt River Proj Navajo	04005	36.9125	-111.3917	1.70E+10	1.09E+07	5.52E+07	7.47E+06	6.23E+05	5.41E+07	2.77E+08	1.06E+03	2.65E+03	1.58E+02
6002 Alabama Pow James H Miller	01073	33.6919	-87.0597	2.13E+10	1.96E+08	2.06E+07	7.97E+06	3.52E+05	2.24E+08	3.86E+03	1.02E+03	4.25E+03	1.55E+02
6004 Allegheny Ene Pleasants Pow	54073	39.3668	-81.2944	8.84E+09	2.15E+08	7.52E+06	6.96E+06	3.77E+05	9.31E+08	6.67E+03	8.05E+02	7.32E+03	3.36E+02
6009 Entergy Arkan White Bluff	05069	34.2286	-92.1952	9.25E+09	1.62E+08	2.47E+07	2.64E+06	1.35E+05	1.89E+08	4.65E+03	1.51E+03	3.35E+03	1.85E+02
6016 AmerenEnerg Duck Creek	17057	##.4668	-89.7941	1.53E+09	5.22E+07	4.78E+06	2.27E+06	1.31E+05	3.94E+07	6.26E+03	2.29E+03	8.27E+03	8.91E+02
6017 AmerenEnerg Newton	17079	38.9961	-88.2779	1.29E+09	1.02E+08	7.52E+06	9.31E+06	1.96E+05	1.14E+08	4.85E+03	1.57E+03	5.26E+03	2.54E+02
6018 Duke Energy Kokst Bend	21015	38.9031	-84.8511	3.70E+09	2.47E+07	5.78E+06	9.16E+06	1.72E+05	3.99E+07	6.75E+09	1.46E+09	8.08E+03	3.50E+02
6019 Duke Ohio Inc W H Zimmer	39025	38.8689	-84.2286	1.03E+10	1.58E+08	2.16E+07	7.90E+06	4.52E+05	1.43E+08	6.86E+09	1.42E+09	7.88E+03	3.83E+02
6021 TN-Gate G A T Craig	09081	40.4627	-102.8912	1.01E+10	1.12E+07	2.25E+07	3.94E+06	2.84E+05	3.79E+07	2.78E+09	1.27E+05	2.73E+03	1.85E+02
6030 Great River En Coal Creek	38035	47.3761	-101.1567	6.71E+09	1.80E+08	1.58E+07	7.27E+06	4.68E+05	1.78E+08	5.46E+09	1.33E+05	3.05E+03	1.58E+02
6031 Dayton Power Killen Station	39001	38.6908	-83.4803	4.46E+09	1.23E+08	5.84E+06	4.27E+06	2.21E+05	1.93E+08	6.28E+09	9.78E+02	6.44E+03	3.04E+02
6041 East Kentucky H L Spurlock	21161	38.7000	-83.8175	6.95E+09	2.55E+08	7.64E+06	1.06E+07	5.50E+05	2.79E+08	6.32E+09	1.02E+03	6.59E+03	3.10E+02
6052 Georgia Power Wansley	13149	33.4112	-85.0941	1.29E+10	4.80E+08	1.22E+07	2.29E+07	1.30E+06	3.16E+08	4.79E+03	8.44E+02	5.40E+03	2.62E+02

6058 NRG Energy Big Cajun 2	22077	30.7251	-91.3569	1.16E+10	1.01E+06	1.10E+07	7.89E+06	4.79E+05	1.21E+08	2.40E+03	8.33E+02	2.98E+03	1.29E+02
6061 South Mississippi D Morrow	28078	31.2194	-89.3932	2.55E+09	2.46E+07	5.87E+06	5.97E+05	3.30E+04	3.32E+07	2.32E+03	8.35E+02	2.09E+03	9.41E+01
6064 Kansas City Pt Nearman Cree 20209		39.1714	-94.6958	1.47E+09	1.50E+07	1.09E+07	1.02E+06	7.11E+04	2.70E+07	2.09E+03	2.63E+03	9.41E+03	4.61E+02
6065 Kansas City Pe Hatan	23105	39.4464	-94.9856	4.85E+09	3.01E+07	1.35E+07	1.24E+06	1.03E+05	4.49E+07	1.57E+03	1.62E+03	9.58E+03	1.78E+02
6068 Westar Energy Jeffrey Energy 20149		39.2853	-96.1088	1.51E+10	1.04E+08	4.88E+07	1.07E+07	5.40E+05	1.64E+08	1.50E+03	1.55E+03	9.30E+03	1.67E+02
6071 Louisville Gas Trimble Count 21223		38.5847	-85.4117	9.86E+09	3.50E+07	4.55E+06	3.04E+06	1.71E+05	4.26E+07	6.68E+03	1.35E+03	7.66E+03	3.73E+02
6078 Mississippi Po Victor J Daniel 28059		30.5385	-88.5974	7.05E+09	6.84E+07	6.68E+06	1.62E+06	9.71E+04	7.38E+07	2.25E+03	6.12E+02	2.89E+03	1.05E+02
6076 PPL Generatio Colstrip	30087.0	45.8836	-106.6200	1.62E+10	8.85E+07	4.97E+07	5.70E+06	3.97E+05	9.64E+07	1.19E+03	2.87E+03	2.87E+03	1.47E+02
6077 Nebraska Publ Gerald Gentle 31111		41.0836	-101.1456	9.46E+09	4.36E+07	2.61E+07	1.58E+06	1.08E+05	7.74E+07	1.76E+03	1.16E+03	2.83E+03	1.38E+02
6092 AES NUGs AES Somerset	35069	43.9561	-78.6089	4.11E+09	1.43E+07	2.98E+06	2.68E+06	2.90E+05	2.04E+07	4.36E+03	8.94E+02	9.15E+03	2.40E+02
6085 Northern Indiana Pu Schaffer	18079	41.2175	-87.0298	1.04E+10	2.50E+06	2.97E+07	1.21E+07	9.07E+05	2.96E+06	6.27E+03	1.77E+03	9.79E+03	4.25E+02
6089 MGU Resource Lewis & Clark	30089	47.6784	-104.1593	2.83E+08	2.03E+06	1.01E+06	2.34E+05	1.98E+04	3.29E+06	2.47E+03	1.27E+03	9.00E+03	1.78E+02
6090 Northern State Sherburne Co.	27141.0	45.3792	-93.8888	1.36E+10	1.59E+08	3.73E+07	5.88E+06	5.90E+05	1.69E+08	5.48E+03	1.64E+03	4.66E+03	2.47E+02
6094 First Energy Ge Bruce Mansfie 42007		40.6344	-80.4200	1.99E+10	2.17E+09	2.84E+07	1.52E+07	7.28E+05	2.56E+08	6.62E+03	1.00E+03	8.50E+03	3.91E+02
6095 Oklahoma Gas Sooner	40109	36.4500	-97.0581	7.15E+09	1.47E+07	1.08E+07	7.29E+05	8.41E+04	2.64E+07	1.59E+03	1.54E+03	9.42E+03	1.71E+02
6096 Omaha Public Nebraska City	91131	40.6215	-95.7765	4.62E+09	3.84E+07	1.77E+07	1.81E+06	1.11E+05	5.31E+07	1.90E+03	1.78E+03	9.85E+03	1.95E+02
6098 Otter Tail Pow Big Stone	46051	45.3047	-96.5103	2.84E+09	2.22E+07	2.52E+07	1.29E+06	6.40E+04	4.67E+07	2.09E+03	1.68E+03	8.50E+03	1.77E+02
6101 PacifiCorp-Roc Wyodak	56065	44.2933	-105.4000	2.67E+09	2.62E+07	4.47E+06	9.88E+05	7.01E+04	9.17E+07	9.40E+03	9.04E+02	1.83E+03	1.11E+02
6113 Duke Indiana I Gibson	18051	38.3722	-87.7661	2.24E+10	7.82E+08	4.28E+07	3.01E+07	1.56E+06	6.58E+08	5.08E+03	1.51E+03	5.40E+03	2.67E+02
6124 Georgia Power Mcintosh	19189	32.3558	-81.1688	9.25E+09	2.80E+07	1.58E+06	1.58E+06	9.04E+04	2.61E+07	4.30E+03	6.48E+02	5.07E+03	2.37E+02
6126 Texas Municip Gibbons Creek 48185		30.6367	-96.0778	5.58E+09	2.91E+07	4.16E+06	1.50E+06	1.18E+05	2.45E+07	2.45E+03	1.80E+03	4.74E+03	2.39E+02
6127 Vectren South In A B Brown	18129	37.8053	-87.7150	8.81E+09	5.40E+07	9.45E+06	9.70E+06	2.40E+05	6.74E+07	5.97E+03	1.87E+03	8.82E+03	3.93E+02
6139 Southwestern Flint Creek	95007	36.2561	-94.5241	3.66E+09	4.23E+07	9.38E+06	1.18E+06	6.36E+04	5.29E+07	5.15E+03	2.03E+03	4.64E+03	2.21E+02
6109 Southwestern Welsh	48449	33.0588	-94.9458	9.52E+09	7.71E+07	2.05E+07	1.48E+07	6.99E+05	1.08E+08	2.54E+03	2.02E+03	9.40E+03	2.64E+02
6146 TKU Generatio Martin Lake	48401	32.2587	-94.5703	1.92E+10	1.95E+08	8.10E+07	1.25E+07	6.74E+05	2.40E+08	2.59E+03	1.87E+03	4.62E+03	2.22E+02
6147 TKU Generatio Monticello	48449	33.0917	-95.0417	1.48E+10	1.98E+08	2.73E+07	1.41E+07	1.12E+06	2.40E+08	2.47E+03	1.93E+03	4.44E+03	2.17E+02
6155 Ameren UE Rush Island	29099	38.1306	-90.2625	6.82E+09	1.35E+08	6.88E+06	9.19E+06	2.63E+05	1.46E+08	4.77E+03	1.69E+03	5.47E+03	2.56E+02
6165 PacifiCorp-Roc Hunter	49015	39.1667	-111.0281	9.73E+09	1.12E+07	1.15E+07	2.58E+06	2.62E+05	2.59E+07	1.78E+03	6.52E+02	1.71E+03	1.24E+02
6166 Indiana Michig Rockport	19147	37.9556	-87.0972	1.79E+10	8.59E+08	2.89E+07	8.04E+06	7.60E+05	3.93E+08	5.89E+03	1.86E+03	5.75E+03	2.81E+02
6170 We Energies Pleasant Prairi 59059		42.5981	-87.9033	8.46E+09	2.34E+08	2.43E+07	7.59E+06	4.39E+05	2.65E+08	6.89E+03	2.16E+03	1.38E+04	7.16E+02
6177 Sol River Proj Coronado	04001	34.5778	-109.2717	6.07E+09	3.21E+07	1.69E+07	2.65E+06	1.70E+05	5.18E+07	9.06E+03	1.19E+03	9.08E+03	1.78E+02
6178 ANP Cuyote Creek	49139	29.7697	-97.2083	5.10E+09	4.22E+07	3.87E+06	1.19E+06	8.40E+04	4.72E+07	2.99E+03	1.00E+03	9.01E+03	1.75E+02
6179 Lower Colorad Fayette Power 48149		29.9172	-96.7508	1.10E+10	8.94E+07	7.60E+06	3.54E+06	9.87E+05	1.01E+08	9.08E+03	1.11E+03	9.13E+03	1.84E+02
6183 San Miguel Elc San Miguel	48013	28.7094	-98.4722	2.83E+09	4.56E+07	4.44E+06	4.42E+06	3.28E+05	5.49E+07	9.66E+03	1.21E+03	1.02E+04	6.01E+02
6150 Cleco Power Ll Rademacher	22079	31.3950	-92.7167	8.37E+09	9.98E+07	1.01E+07	6.88E+05	5.67E+04	5.03E+07	2.80E+03	1.26E+03	2.30E+03	9.87E+01
6193 Southwestern Harrington	48375	35.2972	-101.7475	7.44E+09	3.94E+07	1.73E+07	1.95E+06	4.09E+05	5.89E+07	1.75E+03	1.31E+03	2.93E+03	1.69E+02
6194 Southwestern Tolk	48279	34.1647	-102.5698	7.41E+09	9.82E+07	1.86E+07	1.40E+06	7.98E+05	5.96E+07	1.68E+03	1.24E+03	2.97E+03	1.71E+02
6195 Springfield Cit Southwest Pow 29077		37.3519	-93.3692	1.22E+09	1.80E+07	5.75E+06	6.72E+05	6.71E+04	2.44E+07	5.55E+03	2.16E+03	6.54E+03	2.55E+02
6204 Basin Electric I Basin Electric I 56091		42.1109	-104.8979	4.85E+09	4.59E+07	2.72E+07	7.07E+06	5.25E+05	8.07E+07	9.50E+03	1.39E+03	9.23E+03	2.11E+02
8219 Hoosier Energy Merom	19153	39.0594	-87.5108	3.67E+09	1.12E+08	1.68E+07	5.70E+06	4.59E+05	1.35E+08	5.30E+03	1.67E+03	6.41E+03	2.58E+02
6238 Seyland Power Pearl Station	17149	39.6200	-90.5000	1.74E+09	1.21E+07	5.06E+06	8.02E+06	1.08E+05	1.85E+07	7.12E+03	2.75E+03	1.60E+04	4.67E+02
6248 Public Service Pawnee	08007	40.2217	-103.5803	2.98E+09	2.88E+07	5.29E+06	1.10E+06	1.19E+05	5.47E+07	2.51E+03	1.46E+03	9.06E+03	1.88E+02
6249 South Carolina Wateree	45043	33.9503	-79.3611	7.84E+09	1.73E+08	4.84E+06	1.62E+07	1.02E+06	1.96E+08	4.38E+03	6.69E+02	4.65E+03	2.23E+02
6250 Progress Energ Mayo	37145	36.5278	-78.8917	4.94E+09	1.68E+08	4.85E+06	3.17E+06	3.47E+05	1.76E+08	6.11E+03	8.25E+02	6.67E+03	3.16E+02
6284 Interstate Pow Ottumwa	19179	41.0561	-92.4856	3.23E+09	6.34E+07	1.22E+07	6.48E+06	3.45E+05	8.19E+07	5.21E+03	1.88E+03	5.03E+03	2.45E+02
6257 Georgia Power Scherer	13207	33.0583	-83.8072	2.41E+10	3.58E+08	1.92E+07	1.44E+07	7.77E+05	3.87E+08	4.82E+03	7.23E+02	4.61E+03	2.20E+02
6264 Appalachian P Mountaineer	54059	38.5794	-81.9044	1.05E+10	2.89E+08	1.11E+07	1.01E+07	5.14E+05	3.04E+08	6.55E+03	6.72E+02	6.99E+03	3.20E+02
6469 Basin Electric I Antelope Valle 38057		47.3714	-101.8344	6.49E+09	7.21E+07	1.67E+07	2.82E+06	1.88E+05	9.18E+07	5.57E+03	1.32E+03	9.15E+03	1.72E+02
6481 Los Angeles Cl Intermountain 49027		39.5108	-112.5792	1.87E+10	6.46E+06	1.61E+07	2.78E+06	2.13E+05	2.54E+07	1.80E+03	6.35E+02	1.75E+03	1.27E+01
6639 Western Kent R D Green	21239	37.6457	-87.5005	2.10E+09	1.26E+07	9.52E+06	2.84E+06	1.56E+05	2.54E+07	5.64E+03	1.67E+03	6.75E+03	9.26E+02
6641 Entergy Arkan Independence 05069		35.6739	-91.4081	1.00E+10	1.05E+08	1.98E+07	2.67E+06	1.47E+05	1.27E+08	4.69E+03	1.43E+03	4.15E+03	1.59E+01
6658 TXU Generatio Sandow No 4	48391	30.5842	-97.0639	4.90E+09	8.47E+07	1.20E+07	8.44E+06	4.71E+05	1.06E+08	3.20E+03	2.83E+03	6.94E+03	3.60E+02
6664 MidAmerican Louisa	19115	41.3139	-91.0036	3.79E+09	6.72E+07	9.32E+06	1.87E+06	7.26E+04	7.80E+07	5.45E+03	2.02E+03	5.79E+03	2.81E+02
6705 Alcoa US Warrick	18173	37.8089	-87.3822	4.39E+09	4.85E+08	1.79E+07	4.88E+07	2.72E+06	5.53E+08	8.84E+03	1.64E+03	7.89E+03	3.66E+02
6761 Platte River Po Rawhide	08069	40.8511	-105.0306	1.92E+09	2.08E+06	5.40E+06	6.90E+05	7.66E+04	8.44E+06	2.37E+03	1.45E+03	3.34E+03	2.38E+02
6768 Silkenton City o Silkeston Powe 29201		38.8766	-89.6149	1.94E+09	4.37E+07	6.82E+06	9.40E+05	1.06E+05	5.16E+07	8.78E+03	2.54E+03	7.84E+03	9.72E+02
6772 Western Farm Huge	40023	34.0158	-95.3206	3.02E+09	1.26E+07	4.06E+06	1.29E+05	7.02E+03	1.68E+07	2.44E+03	2.00E+03	4.40E+03	2.16E+02
6823 Western Kent O B Wilson	21193	37.4497	-87.0803	1.81E+09	6.62E+07	8.70E+06	2.43E+06	1.24E+05	7.75E+07	6.02E+03	1.37E+03	7.69E+03	9.80E+02
7098 PNM Al Luna Twin Oaks Pow 48355		31.0978	-95.6922	2.49E+09	1.47E+07	4.42E+06	1.08E+06	5.28E+04	2.04E+07	2.70E+03	1.94E+03	5.12E+03	2.70E+02
7097 CPS Energy J K Spruce	48029	29.3054	-98.9203	2.95E+09	6.26E+07	1.50E+07	1.59E+06	1.06E+05	1.14E+08	3.76E+03	1.73E+03	1.19E+04	6.17E+02
7216 South Carolina Cope	45075	33.3642	-81.0300	3.95E+09	1.23E+07	3.41E+06	1.37E+06	1.74E+05	1.97E+07	5.45E+03	8.05E+02	5.95E+03	2.75E+02
7343 MidAmerican George Neal 5 19193		42.3922	-96.3522	3.95E+09	2.44E+07	1.22E+07	1.21E+06	6.81E+04	3.80E+07	1.75E+03	1.80E+03	3.44E+03	1.37E+02
7504 Black Hills Pw Neil Simpson 1 56065		44.2859	-105.3641	6.68E+08	1.69E+06	5.68E+05	5.25E+05	5.57E+04	2.84E+06	3.40E+03	5.04E+02	1.85E+03	1.11E+02
7557 Dominion Virg North Branch 54029		39.2693	-79.3308	5.61E+08	6.98E+06	1.19E+06	7.94E+05	9.75E+04	5.00E+06	6.55E+03	8.77E+02	8.41E+03	3.97E+02
7750 Deseret Gener Bonanza	49047	40.0894	-109.2844	3.71E+09	3.05E+06	7.76E+06	1.31E+06	1.07E+05	1.22E+07	2.48E+03	1.05E+03	2.49E+03	1.64E+02
7502 Southwestern Pirkey	48203	32.4607	-94.4852	4.89E+09	2.90E+07	8.82E+06	5.32E+06	9.10E+05	4.34E+07	2.48E+03	1.83E+03	4.85E+03	2.20E+02
8023 Wisconsin Pw Columbia	55021	43.4654	-89.4208	5.69E+09	1.51E+08	1.02E+07	9.72E+06	2.07E+05	1.65E+08	5.80E+03	1.75E+03	7.08E+03	3.52E+02
8042 Duke Carolina I Belews Creek 37169		36.2811	-80.0603	1.53E+10	6.93E+08	1.79E+07	8.19E+07	1.71E+06	6.04E+08	6.58E+03	8.77E+02	7.05E+03	3.91E+02
8066 PacifiCorp-Roc Jim Bridger	56037	41.7500	-108.8000	1.48E+10	7.89E+07	4.56E+07	1.09E+07	7.94E+05	1.95E+08	9.62E+03	1.42E+03	9.84E+03	2.74E+02
8069 PacifiCorp-Roc Huntington	49015	39.3792	-111.0789	6.97E+09	9.09E+07	6.62E+06	1.06E+06	2.05E+05	3.97E+07	1.70E+03	6.51E+02	1.71E+03	1.24E+02
8102 Ohio Power Cr General James 43053		38.9347	-82.1158	1.91E+10	1.97E+08	1.38E+07	1.48E+07	7.41E+05	2.30E+08	6.52E+03	9.53E+02	6.72E+03	3.11E+02
8219 Colorado Spilr Ray D Nixon	08041	38.6108	-104.7056	1.49E+09	9.44E+06	8.41E+06	9.45E+05	2.59E+04	1.92E+07	2.52E+03	1.57E+03	4.04E+03	2.92E+02
8222 Otter Tail Pow Coyote	38057	47.2217	-101.8139	8.04E+09	7.38E+07	1.59E+07	1.17E+06	6.56E+04	9.10E+07	5.38E+03	1.30E+03	2.97E+03	1.84E+02
8223 Tucson Electri Springerville	04001	34.3186	-109.1636	5.57E+09	9.02E+07	7.20E+06	2.11E+06	1.43E+05	9.37E+07	3.08E+03	1.15E+03	3.07E+03	1.72E+02
8224 Sierra Pacific P North Valmy	32013	40.8891	-117.1542	3.95E+09	2.64E+07	9.11E+06	5.50E+05	9.89E+04	3.61E+07	2.74E+03	9.71E+02	2.67E+03	1.61E+02
8226 Reliant Energy Chesnick Pow 42003		40.5367	-79.7942	2.88E+09	2.78E+08	4.81E+06	5.11E+06	2.77E+05	2.88E+08	7.44E+03	1.23E+03	1.01E+04	4.84E+02
10043 US Operating I Logan General 34015		39.7914	-75.4081	1.68E+09	7.51E+06	2.64E+06	7.23E+06	3.80E+05	1.77E+07	1.06E+04	2.05E+03	2.88E+04	1.32E+03
10078 Minnesota Po Taconite Harb 27031		47.5914	-90.9111	1.41E+09	2.77E+07	3.04E+06	8.73E+05	6.10E+04	5.16E+07	5.37E+03	9.35E+02	3.61E+03	1.76E+02
10139 Gilberton Pow John R Rich Mi 42107		40.7900	-76.1584	7.11E+09	2.29E+07	6.64E+05	3.09E+06	6.87E+04	2.41E+07	1.46E+04	2.66E+03	3.59E+04	1.60E+03
10148 Inter-Power/A Culver Power 143021		40.8598	-79.7582	8.09E+08	1.81E+07	8.70E+05	9.11E+05	6.13E+04	2.00E+07	6.44E+03	1.17E+03	1.44E+04	6.45E+02
10151 Edison Missior Grant Town Pc 54049		39.5611	-80.1642	6.65E+09	1.75E+07	2.61E+03	4.25E+06	3.39E+03	1.75E+07	7.03E+03	1.03E+03	1.27E+04	5.69E+02
10348 Mount Carmel Mt. Carmel Co 42097		40.8092	-76.4439	3.95E+08	1.94E+06	8.33E+05	3.10E+05	1.54E+04	2.52E+06	7.59E+03	1.28E+03	1.44E+04	6.52E+02
10464 United States Black River Ge 39045		44.0961	-75.7712	2.24E+08	1.69E+06	1.59E+05	7.81E+00	9.37E-01	1.86E+06	4.17E+03	6.11E+02	6.49E+03	2.87E+02
10566 US Operating I Chambers Cog 34039		39.6949	-75.4838	1.80E+09	1.81E+07	3.14E+06	1.12E+07	7.20E+05	3.32E+07	1.08E+04	1.82E+03	2.99E+04	1.36E+03
10603 Ebensburg Pw Ebensburg Pow 42021		40.4650	-78.7472	4.99E+08	1.62E+07	4.28E+05	1.75E+06	1.06E+05	1.90E+07	1.05E+04	1.67E+03	2.51E+04	1.01E+03
10641 Northern Star Cambria Cogen 42021		40.4767	-78.7067	7.58E+09	2.26E+07	1.58E+06	1.12E+06	8.81E+04	2.54E+07	1.08E+04	1.67E+03	2.81E+04	1.01E+03
10671 AES NUGs AES Shady Poi 40078		35.1256	-84.8030	2.29E+09	3.29E+07	1.64E+06	9.85E+05	5.82E+04	9.57E+07	5.41E+03	1.74E+03	5.04E+03	2.40E+02
10675 AES NUGs AES Thames 05011		41.4317	-72.1089	1.80E+09	3.85E+07	5.23E+05	2.57E+06	9.10E+05	2.98E+07	9.81E+03	1.23E+03	2.62E+04	1.33E+03
10676 AES NUGs AES Beaver Va 42007		40.6558	-80.3595	8.29E+09	4.25E+07	2.12E+06	5.59E+06	2.62E+05	5.04E+07	1.17E+04	2.99E+03	2.87E+04	1.24E+03
10678 AES NUGs AES Warrior Ri 24001		39.5944	-79.7456	1.65E+09	8.99E+06	5.69E+05	9.73E+05	6.40E+04	1.02E+07	7.37E+03	9.66E+02	1.14E+04	5.98E+02
10773 Dominion Virg Altavista Powe 51031		37.1109	-79.2750	9.46E+08	5.30E+06	6.01E+05	1.85E+06	6.92E+04	9.01E+06	9.29E+03	9.80E+02	1.29E+04	6.05E+02
10774 Dominion Virg Southampton 51175		36.6906	-76.9967	3.42E+08	6.12E+05	4.17E+05	5.42E+05	2.68E+04	1.60E+06	8.30E+03	8.82E+02	1.13E+04	5.60E+02
50039 SUEZ Energy R Kline Township 42107		40.8750	-75.9914	2.86E+08	7.01E+06	1.90E+05	3.68E+05	7.09E+04	7.64E+06	1.07E+04	1.81E+03	2.80E+04	1.08E+03
50202 U S Renewable Niagara Gener 36063		43.0821	-79.0012	1.40E+08	5.71E+05	5.01E+05	4.98E+05	3.66E+04	6.75E+06	5.89E+03	1.31E+03	1.21E+04	5.91E+02
50611 WPS Power Dt WPS Westwood 42107		40.8175	-75.4542	2.32E+08	9.88E+06	7.52E+05	4.99E+05	4.26E+04	5.17E+06	1.07E+04	1.81E+03	2.86E+04	1.08E+03
50776 Panther Creek Panther Creek 42025		40.8569	-75.8778	6.43E+08	7.57E+06	8.81E+05	1.34E+06	6.63E+04	9.85E+06	1.37E+04	1.78E+03	3.56E+04	1.55E+03
50835 TES Filer City S TES Filer City S 26101		44.2118	-86.2053	2.47E+08	9.63E+06	2.03E+06	1.85E+05	1.10E+04	6.11E+06	5.44E+03	1.22E+03	7.00E+03	3.44E+02
50988 US Operating I Northampton 42095		40.6925	-75.4789	8.59E+08	6.16E+06	8.86E+05	2.54E+06	1.42E+05	9.74E+06	1.25E+04	2.20E+03	8.23E+04	1.52E+03
50951 Sunnyside Cog Sunnyside Cog 49007		39.5472	-110.3917	4.16E+08	1.64E+06	2.65E+05	6.87E+04	5.38E+03	1.98E+06	1.76E+03	6.84E+02	1.78E+03	1.39E+02
50974 US Operating I Scrubgrass Ge 42121		41.2678	-79.8134	6.45E+08	1.05E+07	4.84E+05	9.25E+03	9.97E+02	1.10E+07	7.27E+03	5.43E+02	1.04E+04	4.75E+02
54144 Cabrae Clarion Piney Creek Pr 42031		41.1776	-79.4418	2.67E+08	8.77E+06	2.32E+05	2.08E+03	1.63E+04	9.29E+06	9.11E+03	1.63E+03	1.63E+04	7.36E+02
54634 Schuylkill Ener St. Nicholas Co 42107		40.8222	-76.1796	3.36E+08	1.67E+07	4.82E+05	1.59E+06	1.43E+05	2.08E+07	1.07E+04	1.83E+03	2.36E+04	1.08E+03