The Brattle Group

# Supply Chain and Outage Analysis of MISO Coal Retrofits for MATS

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**Prepared for**

MISO

**Midwest Independent Transmission System Operator**

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## EXECUTIVE SUMMARY

The Environmental Protection Agency's (EPA's) new Mercury and Air Toxics Standard (MATS) will require the coal and oil fleet in the U.S. to comply with certain emissions standards by April 2015, with a potential 1-year extension from permitting authorities. This standard will require much of the U.S. coal fleet to install retrofit controls for compliance or face retirement. Nation-wide estimates project that 93-248 GW of coal (measured in Wet Flue Gas Desulfurization (FGD) equivalent GW) will require environmental controls upgrades, while the Midwest Independent Transmission System Operator (MISO) projects 51-58 Wet FGD equivalent GW will require upgrades in the Midwest alone. Many coal units will retire rather than make the required capital investments, with about 30 GW having already announced retirement plans nationwide. To replace this retiring generation and meet load growth requirements by 2015, another 30-84 GW of new generation may be needed nationally, while 5-26 GW may be needed in MISO.

MISO asked us to help evaluate the feasibility of the large number of simultaneous environmental retrofits and new generation that may be needed in conjunction with the MATS rule. In particular, MISO asked us to:

- Evaluate the scale of the retrofit and new build requirements for MATS by 2015/16 relative to the capability of the retrofit and construction industry;
- Identify potential labor supply chain bottlenecks to meeting these requirements;
- Estimate the level of outages needed on the existing fleet for installing and testing new environmental retrofits; and
- Evaluate the extent to which these retrofits, new generation, and required outages can be implemented by the MATS compliance date of April 2015 with possible extensions to 2016.

To evaluate these questions, we surveyed existing literature, interviewed retrofit project developers and electric utilities, evaluated historical simultaneous project installations, and examined retrofit outages. With respect to the timeline needed for retrofits, we find that some types of upgrades can be implemented before 2015 without difficulty, including activated carbon injection (ACI) and dry sorbent injection (DSI), which can be implemented within approximately a year and a half. However, most projects have a longer lead time of approximately 3-4 years, including wet and dry FGD, baghouse, electrostatic precipitator (ESP), and selective catalytic reduction (SCR), as well as new gas combustion turbines (CTs) and combined cycles (CCs).

Some of these long-lead projects will be able to come online prior to the MATS deadline, particularly as many of them are already under development. Many plant owners have already announced upgrade plans, although many others are likely still in the scoping phase. For the retrofit projects that need state commission approval of cost recovery to move forward, their ability to meet the MATS deadline will in part depend on the states' speed of approval when evaluating a large number of projects at once. These long lead times introduce a substantial concern for any long-lead projects that are initiated late, both due to the timing constraint and due to the potential for difficulty in obtaining the necessary engineering and construction support during a period of very high demand.

To evaluate the scale of the supply chain demands from MATS, we compared projected retrofit and new build demands against the historical maximum for the industry in the U.S. and nationally. We separately looked at retrofits and new builds on a Wet FGD-equivalent basis, converting the MW of upgraded or built capacity into one equivalent unit based on capital costs. This approach reflects our assumption that capital costs are a reasonable indicator of the demands that a particular retrofit will impose on labor and equipment supply chains. We find that MATS will require retrofit and new build activities that exceed the historical industry maximum in the Midwest by 51%-162% based on MISO's projected retrofit requirements and individual plant owner announcements. For the nationwide retrofits, the needs imposed by MATS could be substantially below historical maximums if the EPA's projections are correct, or up to 93% above historical maximums if industry estimates are more accurate. We believe that the EPA estimates may be optimistic while industry estimates may be pessimistic, especially in the highest retrofit cases.

It appears that MATS will require a ramp up in labor, engineering, equipment, and construction that is likely to introduce substantial bottlenecks locally or nationally. These bottlenecks are likely to introduce delays or cost escalation, for example, if certain craft labor categories or qualified engineering, procurement, and construction (EPC) firms are in short supply. The competitive marketplace will find opportunities to mitigate such concerns (*e.g.*, by increasing labor supply with training, relocation, and overtime) but such measures are costly and time-consuming.

We evaluated the potential for craft labor to become a bottleneck that could introduce project delays. Based on our estimates of typical craft labor requirements for retrofits and new construction, we projected a time profile of craft labor required for MATS compliance. Comparing projected labor needs against the current labor supply for each craft revealed that boilermakers are the most likely bottleneck. As many as 7,590 boilermakers (or 40% of boilermakers currently employed nationally) could be needed to complete the projected retrofits and new generation construction by 2015. This potential demand is more than four times the number of boilermakers (1,850) currently employed in the Utility System Construction Industry.[1] Therefore, meeting the projected demand for boilermakers will likely require a combination of adjustments on the supply side, including training new labor, relocation, extending work hours, and attracting craft labor from other industries.

Finally, we examined the potential impacts of MATS on MISO's outage scheduling process by examining the length of planned outages that coal units need in typical years compared with the duration of outages associated with plant retrofits. Based on our interviews with project developers and electric utilities, we understand that most of the construction and installation associated with retrofits can be completed while the plant is operating, although final tie-in to major plant systems can only be done during a plant outage. These tie-ins will usually be scheduled concurrently with other standard maintenance during a planned outage but will require a longer than typical outage for completion. Based on an analysis of historical plant operations for coal plants, we estimate that some upgrades such as Dry FGD, DSI, SNCR, and ACI require that the outage duration need only be extended a few days or a week, although some types of

[1] According to the Bureau of Labor Statistics definitions, the Utility System Construction Industry includes utility construction activities in power, communication, oil, gas, water and sewer sectors, see U.S. Census Bureau (2012).

upgrades impose much longer outages. Wet FGD, baghouse, and SCR retrofits are likely to require outages be extended by approximately three weeks.

Considering the fleet-wide impacts of these outages, it appears that MISO may have to schedule approximately 45% more MW of coal outages per season for MATS compliance by Fall 2015 (which assumes many plants will gain a 1-year compliance extension). The impact of these additional outages is further exacerbated by the fact that a substantial fraction of coal plants are likely to retire rather than comply with MATS, hence reducing the system's ability to absorb additional outages. Based on MISO's initial analysis of the fleet's ability to absorb outages, it appears that the total quantity of outages for MATS could be easily absorbed and scheduled in its low retirement scenarios. However, in MISO's 12 GW retirement scenario, it appears that MISO may only be able to absorb these outages by extending its typical 6-month (fall and spring) outage season to a 9-month (fall, winter, and spring) season. In MISO's even higher 19 GW retirement scenario, it appears likely that the RTO would not be able to schedule all of the needed outages even in a 9-month window without facing reliability concerns or gaining an additional 1-year reliability extension to 2017.

Overall, meeting MATS will be a major challenge for the industry, states, and MISO for a number of reasons. The industry will need to install retrofits at a pace and scale that exceeds the historical demonstrated capability, while the system operator is likely to experience a substantial operational challenge in the transition.

# I. BACKGROUND

## A. PURPOSE OF STUDY

The Midwest Independent Transmission System Operator (MISO) asked us to assess the feasibility of a large simultaneous deployment of environmental retrofits and new generation prior to the compliance deadline of the Environmental Protection Agency's (EPA's) new Mercury and Air Toxics Standards (MATS). Specifically, MISO asked us to:

- Evaluate the scale of the retrofit and new build requirements for MATS by 2015/16 relative to the capability of the retrofit and construction industry;
- Identify potential labor supply chain bottlenecks to meeting these requirements;
- Estimate the level of outages needed on the existing fleet for installing and testing new environmental retrofits; and
- Evaluate the extent to which these retrofits, new generation, and required outages can be implemented by the MATS compliance date of April 2015 with possible extensions to 2016.[2]

MISO asked us to evaluate the implications for the Midwestern system, as well as nationally, to help inform their and stakeholders' planning activities over the coming years. We do not present here an independent estimate of the retrofit, retirement, and new build impacts of MATS, which is a substantial analytical effort beyond our scope. Instead, we rely on the previously-completed studies of MISO, the EPA, and Edison Electric Institute (EEI). As we document in the following sections, MISO has analyzed a range of potential impacts on its coal fleet from MATS, while for national MATS impacts we draw on EPA and EEI studies that represent relatively low and high impact estimates respectively.

## B. MISO'S ASSESSMENT OF MATS RETIREMENT AND RETROFIT CHALLENGE

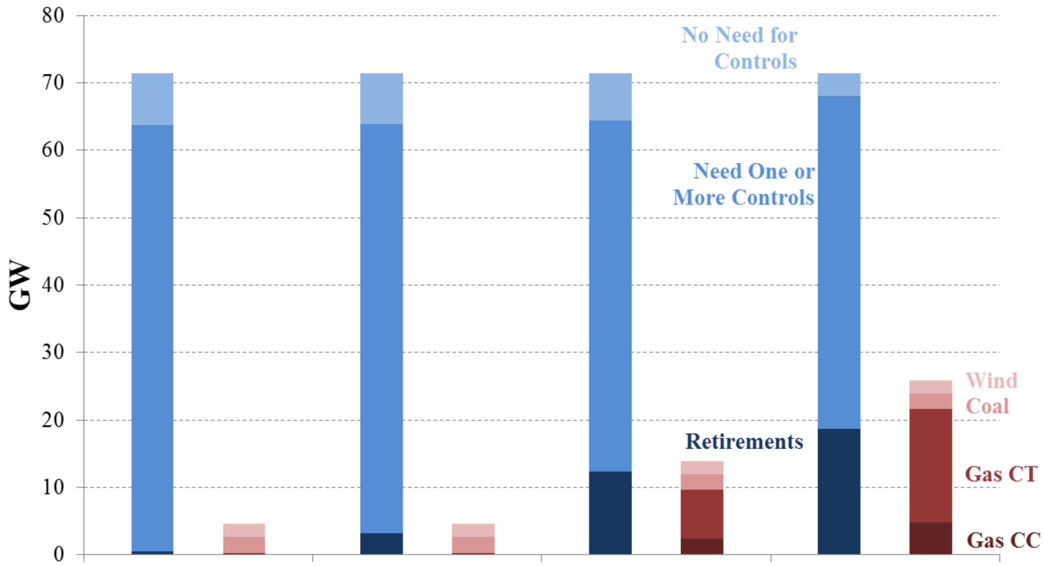
MISO has screened the characteristics of the current coal fleet to project the likely retirement and retrofit impacts of MATS. MISO has also projected the total new generation capacity that will be needed to replace projected coal retirements. MISO assessed these questions under four retirement scenarios through 2016: (i) a no retirement case; (ii) a 3 GW retirement case; (iii) a 12 GW retirement case; and (iv) a 19 GW retirement case. In all cases, except the 19 GW retirement case, MISO also assumed that none of the units would need to install Selective Catalytic Reduction (SCR) control equipment to comply with MATS or the Cross State Air Pollution Rule (CSAPR). We supplemented MISO's projections of needed retrofits with the most recent owner announcements of environmental control equipment installations to be online by 2016.[3]

[2] The compliance deadline is 60 days plus 3 years from the date of publication in the *Federal Register*, which was February 16, 2012. See *Federal Register* (2012), p. 9407.

[3] In addition, because coal units smaller than 25 MW are not covered by MATS, we eliminated coal units smaller than 25 MW from the list of units that MISO had initially projected to need retrofits. Additional information on MISO's retrofit, retirement, and new build projections is available in MISO (2011).

Figure 1 summarizes MISO's projected environmental retrofits and new generation in the Midwest by 2016 under the four scenarios. Out of MISO's existing 71 GW coal generation fleet, 49-63 GW are expected to install at least one environmental retrofit by 2016. A large fraction of these coal units (28-38 GW) are projected to require two or more controls systems for compliance. In addition, MISO expects 5-26 GW of mostly gas-fired new generation capacity will need to be built by 2016 to replace the retiring coal units and to meet load growth. A more detailed summary of the projected retrofits and new generation plants in MISO region is provided in Appendix B.

**Figure 1**
**MISO Projection of Midwestern Retrofits and New Builds in Four Scenarios**
(Existing Coal Fleet in Blue; Projected New Generation in Red)



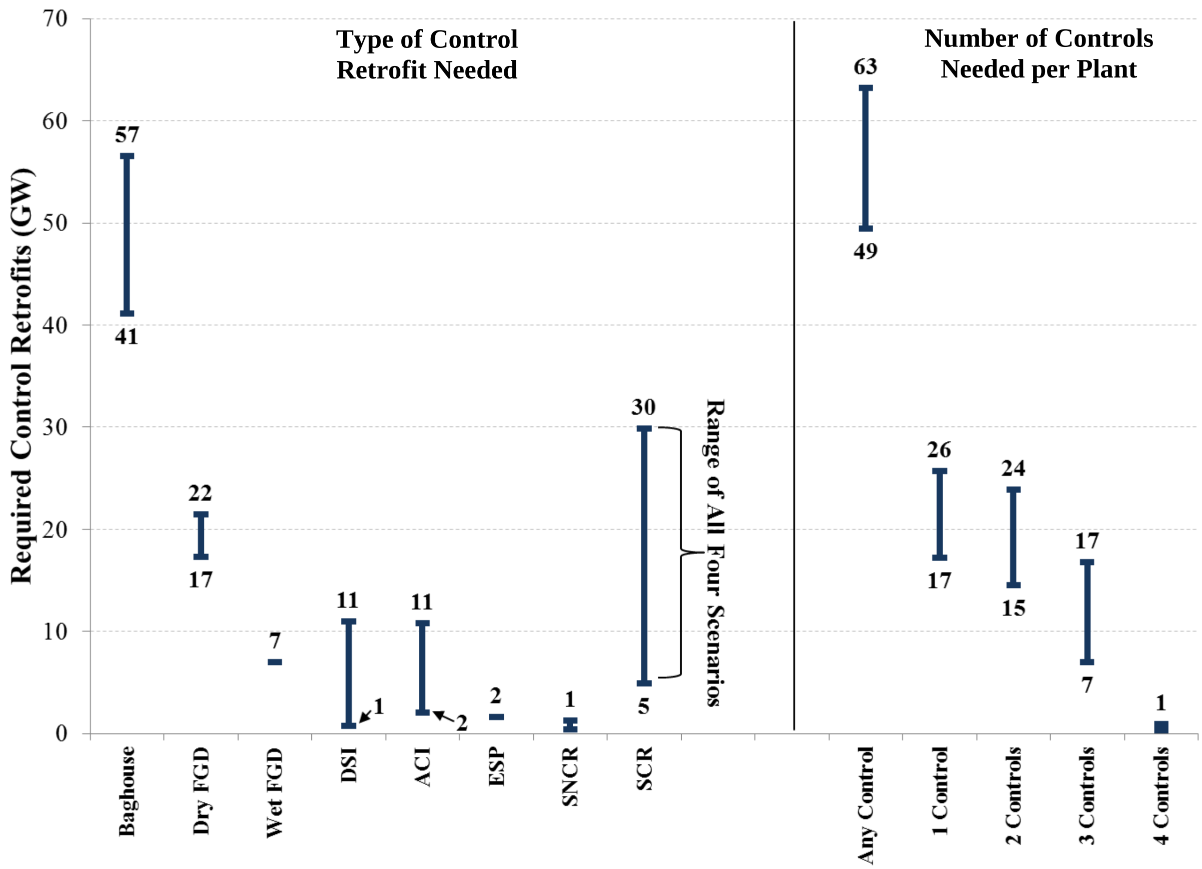

| | Scenario 1 Existing Coal Fleet | Scenario 1 New Builds | Scenario 2 Existing Coal Fleet | Scenario 2 New Builds | Scenario 3 Existing Coal Fleet | Scenario 3 New Builds | Scenario 4 Existing Coal Fleet | Scenario 4 New Builds |
|---|---|---|---|---|---|---|---|---|
| No Need for Control | 8 | | 7 | | 7 | | 3 | |
| Need 1 or More Control | 63 | | 61 | | 52 | | 49 | |
| Retirement | 1 | | 3 | | 12 | | 19 | |
| **Total** | **71** | | **71** | | **71** | | **71** | |
| Renewable - Wind | | 2 | | 2 | | 2 | | 2 |
| Coal | | 2 | | 2 | | 2 | | 2 |
| Gas - CT | | 0 | | 0 | | 7 | | 17 |
| Gas - CC | | 0 | | 0 | | 2 | | 5 |
| Other | | 0 | | 0 | | 0 | | 0 |
| **Total** | | **5** | | **5** | | **14** | | **26** |

*Sources and Notes:*
Data from MISO (2011) and Ventyx (2012).
New generation includes all plants currently under construction as well as all MISO-projected new builds.
Original MISO projected retrofits updated with most recent plant owner announcements.

Figure 2 shows the breakdown of projected environmental control retrofits in MISO by type of control and number of control systems required. Data from announced retrofit projects combined with MISO's predictions indicate that 49-63 GW of coal capacity is likely to require at least one control retrofit to comply with MATS. These projections include dry flue gas desulfurization (FGD) on 17-22 GW, wet FGDs on 7 GW, baghouses on 41-57 GW, dry sorbent injection (DSI) on 1-11 GW, activated carbon injection (ACI) on 2-11 GW, SCRs on 5-30 GW, and selective non-catalytic reduction (SNCR) on less than 1 GW of coal capacity. Note that MISO's screening study did not explicitly evaluate whether SNCR, Wet FGD, or electrostatic precipitator (ESP) upgrades would or should be installed. For this reason, the summary in Figure 2 includes only announced upgrades for those types of controls.[4]

Single-equipment retrofits are expected to be in the range of 17-26 GW, with the majority of the coal fleet requiring multiple equipment installations for compliance, including: 15-24 GW installing two controls, 7-17 GW installing three controls, and less than 1 GW installing four controls.

**Figure 2**
**Estimated Breakdown of Coal Retrofits by Control Type in MISO**




*Sources and Notes:*
Data from MISO (2011) and Ventyx (2012).
Original MISO projected retrofits updated with most recent plant owner announcements.

4 For controls such as Wet FGD and Dry FGD that would be redundant between MISO's original projection and more recently-announced upgrades, we relied on the owner's announcements.

## II. REVIEW OF PREVIOUS RETROFIT SUPPLY CHAIN STUDIES

As a starting point to our analysis, we summarize the findings from existing studies and industry positions on industry's capability to install all needed controls in time to comply with MATS.[5] We summarize these "capability" assessments in two key dimensions. The first is a comparison of estimated timelines for installing various individual retrofits against the regulatory compliance timeline. The second is the capability of the supply chain in the environmental retrofit industry with respect to available labor force in key occupations and manufactured equipment to meet the large simultaneous demand for retrofits.

The EPA finalized the MATS rule in December 2011, requiring coal and oil-fired power plants to reduce emission rates of mercury, acid gases, and non-mercury metals below specific limits by April 2015.[6] In addition to the three-year statutory requirement, the EPA allows a potential 1-year extension of the deadline if approved by state permitting agencies, and a further 1-year extension under the circumstances where a power plant would need to continue operations in order to maintain reliability.[7]

The MATS rule will require coal plants to install various combinations of controls depending on the unit's existing controls, boiler type, type of coal used, and economic factors. The control equipment needed to comply with MATS may include Wet or Dry FGD, SCR, fabric filter (or baghouse), DSI, or ACI. The estimated mix and number of the needed retrofits is uncertain for two reasons. First, it is uncertain which coal units will be retired to avoid investing in retrofits. Second, the estimated removal efficiency of certain equipment such as DSI to meet the MATS requirements is not yet fully known because this equipment has not yet been widely used.

5 See EPA (2011a).

6 The compliance deadline is 60 days plus 3 years from the date of publication in the *Federal Register*, which was February 16, 2012. See *Federal Register* (2012), p. 9407.

7 EPA states that it expects that few or no reliability exceptions of this type to be needed, see EPA (2011d).

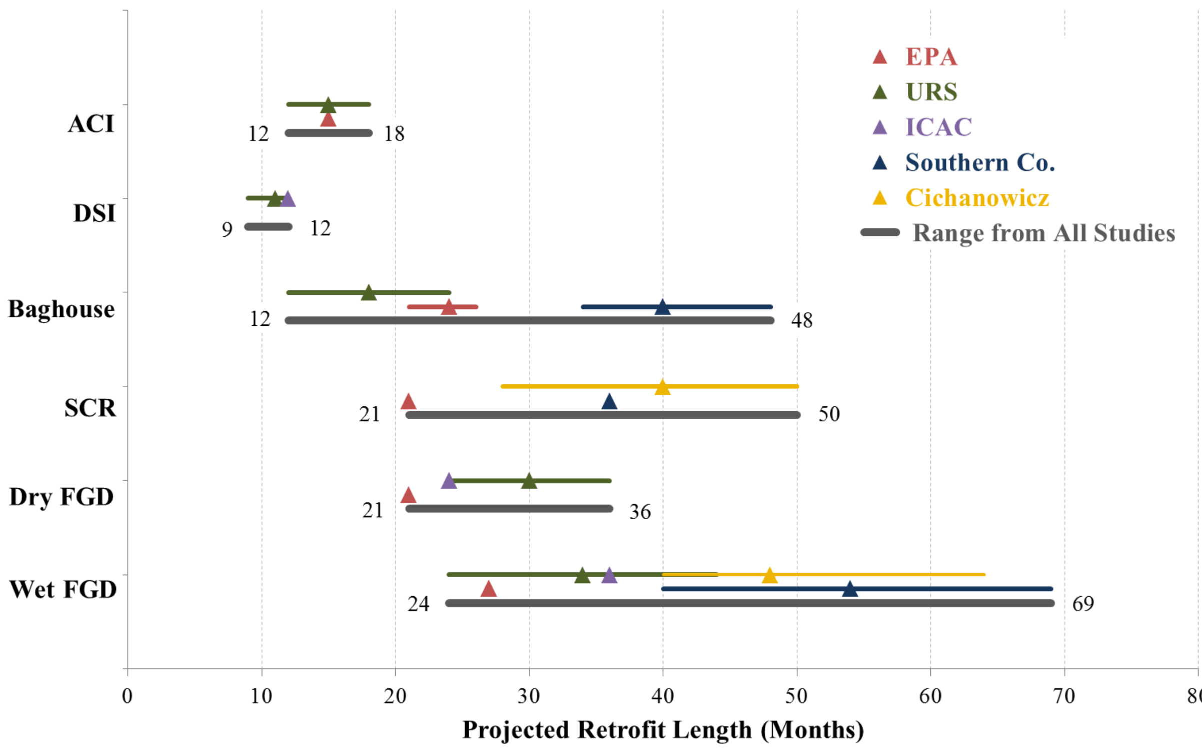
We reviewed the studies listed in Table 1 on the estimated capability of the environmental retrofit industry to install the control equipment necessary to comply with EPA regulations, and summarize the major findings from these studies in the following sections.

**Table 1**
**Reviewed Literature on Feasibility and Timelines of Environmental Retrofits**

| Study | Author | Title | Date |
|---|---|---|---|
| **EPA (2011b)** | U.S. EPA | An Assessment of the Feasibility of Retrofits for the Mercury and Air Toxics Standards Rule | December 2011 |
| **DOE (2011)** | U.S. DOE | Resource Adequacy Implications of Forthcoming EPA Air Quality Regulations | December 2011 |
| **IEc (2011)** | Industrial Economics, Inc. | Employment Impacts Associated with the Manufacture, Installation and Operation of Scrubbers | March 2011 |
| **Southern (2011a)** | Southern Company | Southern Company's Comments on EPA's Proposed Utility MACT Rule | August 2011 |
| **Southern (2011b)** | Thomas Fanning (Southern Company) | Recent EPA Rulemakings Relating to Boilers, Cement Manufacturing Plants, and Utilities | April 2011 |
| **Cichanowicz (2010)** | Edward Cichanowicz | Implementation Schedules for Selective Catalytic Reduction (SCR) And Flue Gas Desulfurization (FGD) Process Equipment | October 2010 |
| **URS (2011)** | URS Corporation | Assessment of Technology Options Available to Achieve Reductions of Hazardous Air Pollutants | August 2011 |
| **ICAC (2010)** | Institute of Clean Air Companies | Letter to Senator Carper on Labor availability and the Capacity of the Electric Power Industry to Install Air Pollution Control Systems | November 2010 |
| **Andover (2010)** | James Staudt (Andover Technology Partners) | Availability of Resources for Clean Air Projects | October 2010 |
| **EPA (2005a)** | U.S. EPA | Feasibility of Installing Pollution Controls to Meet Phase I Requirements of Various Multi-Pollutant Legislative Proposals | October 2005 |
| **EPA (2005b)** | U.S. EPA | Boilermaker Labor Analysis and Installation Timing | March 2005 |
| **EPA (2002)** | U.S. EPA | Engineering and Economic Factors Affecting the Installation of Control Technologies for Multipollutant Strategies | October 2002 |

Estimates of the "typical" timelines for design, construction. and installation of environmental retrofits vary considerably. As shown in Figure 3, a typical Wet FGD installation is estimated to take as little as 27 months according to the EPA, or as long as 54 months according to Southern Company. Similar differences among estimates apply to typical timelines for other control equipment: 21-30 months for Dry FGD, 21-40 months for an SCR, 18-40 months for a baghouse, 11-18 months for DSI, and 15 months for ACI. A more detailed description of these estimated timelines from the literature is available in each of the source studies.

**Figure 3**
**Estimated Months to Design, Permit, Construct, and Install Retrofit Equipment**




*Sources and Notes:*

EPA (2002) and EPA (2011b); URS (2011); ICAC (2010); Cichanowicz (2010); Southern Company (2011a) and Southern Company (2011b).

There is disagreement among existing studies with respect to the feasibility of meeting all needed MATS upgrades, including the potential for shortages in in key labor occupations and manufactured equipment. On one side of this debate, studies by the EPA and Andover Technology Partners argue that the required retrofits are lower than the historical deployments of retrofits and new generation plants, and that installation timelines necessary to complete these projects are short enough to bring the projects online before the MATS compliance date in 2015 (or 2016 with a one-year extension).

On the other side of the debate, studies by EEI, Southern Company, and Edward Cichanowicz argue that the EPA has severely underestimated the number of expensive and resource-intensive retrofits that will be required including scrubbers, baghouses and SCRs. These studies project that a larger share of the coal fleet will retire and that more new generation capacity will be needed to maintain system reliability. In addition, these studies estimate substantially longer timelines necessary to bring the retrofit equipment and the new generation plants online.

We more fully summarize the primary arguments in select studies that we consider representative of these two differing viewpoints in the remainder of this Section.

### A. EPA Study of the Feasibility of MATS Retrofits (December 2011)

The EPA conducted a study on the feasibility of retrofitting coal plants for compliance with MATS, and concluded that the majority of needed retrofits can be completed by January 2015 with some coal plants potentially needing an additional year for compliance.[8] The study approach was to compare maximum historical simultaneous retrofits and new coal builds against the quantity of retrofits that the EPA projects will be needed for MATS. The EPA estimated that simultaneous installations of new and retrofit SCR and FGD installations over 1990-2011 reached an approximate maximum of 38 GW in 2009. The EPA also converted historical equipment retrofits and new coal generation addition to a single metric ("equivalent wet FGD capacity") based on the ratio of capital costs for each type of retrofit. This calculation resulted in <u>an annual maximum of approximately 70 GW in 2009 for the simultaneous deployment of environmental retrofits and new coal units</u>.[9] The EPA also noted that there were large additional deployments of new gas combined cycles (CCs) during the period 2009-2011, relying on some of the resources that are used in retrofit projects. Finally, the EPA commented that the historical data on retrofit deployments show the industry was able to ramp up retrofit activity by 45% per year over 2006-2009.

In comparison to these data on historical total retrofits and new coal generation, the EPA projects that a total 64 GW (wet FGD equivalent) of coal retrofits will be needed nationally. The EPA's estimated mix of retrofit projects include: 85 GW of baghouses, 44 GW of DSI, 99 GW of ACI, 20 GW of dry FGD with baghouse, 63 GW FGD upgrades and 34 GW ESP upgrades. We also note that the EPA does not include any wet FGD upgrades in its projection. Since the industry's historical demonstrated capability of 70 GW wet FGD-equivalent exceeded the MATS requirement of 64 GW, the EPA concluded that meeting MATS is likely feasible even if nearly all MATS retrofits must be installed in the same year.

In addition, the EPA argued that other factors work in favor of the power sector's ability to meet MATS compliance deadlines. These include the EPA's expectation that many coal unit owners have already done retrofit planning for their units, and that some "early movers" will start retrofitting their plants before others to avoid potential increases in retrofit costs. In addition, the EPA expects that the construction timeline for retrofits can be substantially accelerated compared to historical experience, and result in wet FGD and dry FGD projects being completed in 27 months and 21 months, respectively. Finally, the EPA expects owners of coal units to be better-motivated to move early on retrofit decisions compared to historical experience with other environmental regulations because MATS does not offer trading flexibility and requires plant-level compliance unlike the Clean Air Interstate Rule that was applicable until 2011.

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8 EPA (2011b).

9 Note that this comparison covered the shorter period of 2005-2011, compared to the SCR and FGD comparison that covered the longer period of 1990-2011.

### B. EPA Study of Boilermaker Supply for CAIR (March 2005)

The EPA released a study in March 2005 that assessed the feasibility of installing control equipment retrofits for $SO_2$ and $NO_X$ control as required by Clean Air Interstate Rule (CAIR).[10] That study focused on the likely availability of boilermakers, which were considered a potential bottleneck in completing the required retrofits. In order to complete the projected retrofits of 70 GW of FGDs and 46 GW of SCRs by 2010 in one of the scenarios (over approximately four years), the study estimated that the required boilermakers would exceed available boilermakers by about 25%.[11] The number of boilermakers available for the environmental retrofits (26,185 boilermaker-years) was derived by assuming 35% of the total projected boilermakers in the nation would be available to be employed for retrofits, supplemented by labor from Canada, non-union sources, and from the estimated additional boilermakers due to fewer projected new generation plants. The assumed boilermaker requirements for retrofits on 1 GW of coal capacity were 260 boilermaker-years for FGDs and 343 boilermaker-years for SCRs.

In retrospect and with the benefit of hindsight, this study appears to have over-estimated the scale of the problem of boilermaker bottlenecks at that time. While the EPA's estimate of 70 GW of FGD installations was very close to the realized retrofits over 2005-2010, the SCR estimate of 46 GW was approximately twice the realized number as shown in Figure 7 below. Further, according to labor data from the Bureau of Labor Statistics (BLS), while the number of boilermakers employed in the "utility system construction" industry increased almost threefold from 680 in 2006 to 1,850 in 2011, this maximum employment is still far below the level originally estimated by the EPA.[12] Further, utility system construction has never drawn more than 11.7% of the total national employment of boilermakers.[13]

### C. Andover Retrospective on Retrofits for CAIR (October 2010)

Dr. James Staudt of the Andover Technology Partners authored this study to compare projections against actual performance regarding the ability of power plants to install retrofit equipment for CAIR.[14] The projected combined retrofits of FGDs and SCRs were in the range of 73-89 GW over a five-year period to meet the CAIR I deadline in 2010. Staudt's whitepaper provides a summary of various projections by the EPA and industry organizations such as the Utility Air Resources Group (UARG) and the Institute of Clean Air Companies (ICAC) on retrofit project timelines and potential resource bottlenecks.

The study concludes that the actual performance of the retrofit supply-chain to meet CAIR deadlines exceeded most of the projections without being constrained by the assumed "hard

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10 EPA (2005b).

11 We should note that the estimated mix of 70 GW of FGDs and 46 GW of SCRs in the scenario described above would correspond to about 78 GW in Wet FGD-equivalent measure by using the equivalency factors we derive in Table 5 below.

12 Note that the EPA's estimate of 26,185 boilermaker-years would amount to 6,546 on average over four years or almost three times the number actually employed in the utility system construction industry. See BLS (2011).

13 In 2010, 2,220 boilermakers were employed in the utility system construction industry while the national employment of boilermakers was 19,030. Note that national employment of boilermakers in 2010 was actually down in 2010 from the higher employment of 22,400 in 2009. See BLS (2010).

14 Andover (2010).

caps" in some studies on the total labor force in specialized construction labor such as boilermakers. The whitepaper argues that there are no "hard caps" on boilermakers that can be employed in retrofit projects since the market for labor is dynamic. Staudt attributes the dynamic nature of the labor market to: (i) the ability to work overtime during periods of high demand; (ii) the availability of non-union labor to supplement boilermakers from unions; (iii) the option of relying on non-local boilermakers including from Canada; (iv) the possibility of shifting boilermakers from other sectors such as refining, petrochemical, shipbuilding, etc.; (v) new boilermakers joining the labor force as demand picks up; and (vi) alternative fabrication methods such as off-site construction.

### D. Southern Company Comments on Feasibility of MATS (August 2011)

The Southern Company submitted comments to the EPA in August 2011 on the initial proposed version of MATS.[15] With respect to the feasibility of complying within the three-year compliance period, Southern argued that the proposed timeline is unachievable and unrealistic for three reasons. First, that the electric industry will face the challenge of complying with multiple and overlapping environmental regulations in addition to MATS. Second, that implementing the retrofits that the EPA estimated as necessary for compliance is not feasible in three years because these projects typically require more than three years to complete. For example, Southern pointed to its own experience with FGD retrofits that took an average of 54 months (over a range of 40-69 months) to complete. Similarly, Southern expects that baghouse retrofits would need 40 months to complete (over a range of 34-48 months) based on 17 baghouse projects that Southern is considering.

Third, Southern argued that the EPA under-estimated the number of retrofits that would be needed for compliance. Southern pointed to studies that estimated far higher numbers of retrofits and new generation needs than the EPA projected, and argued that this scale of retrofits and new generation could not be completed at any cost within the three-year deadline. For example, Southern pointed to the results of an EEI/ICF study in 2011 estimating more than 80 GW of scrubbers, over 160 GW of baghouses, and 80 GW of new generation capacity would be needed to comply with EPA regulations.

### E. Cichanowicz Estimate of FGD and SCR Retrofit Timelines (October 2010)

In a study prepared for UARG, Edward Cichanowicz provided typical schedules for recently implemented projects, including 22 FGD retrofits and 14 SCR retrofits.[16] According to these data, Mr. Cichanowicz concluded that the average time to retrofit FGD on a single unit would be 48 months (over a range of 40-64 months), and the average time to retrofit an SCR on a single unit would be 40 months (over a range of 28-50 months). Mr. Cichanowicz challenged the substantially shorter timelines estimated by the EPA (27 months for FGD and 21 months for SCR) on the grounds that the sample projects that the EPA relied on were constructed a long time ago when the total demand for retrofits was low and permitting was easier.

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15 Southern (2011a).
16 Cichanowicz (2010).

## III. TIME AND LABOR NEEDS FOR NEW BUILD AND RETROFIT PROJECTS

As an input to our supply chain and outage analysis, we examine the labor, timing, and outage duration requirements for implementing each of a number of different types of coal retrofit and new generation projects. To evaluate labor inputs and project timelines, we conducted interviews with ten electric utility companies and eight engineering and equipment manufacturing companies. To evaluate outage needs for retrofit installations, we analyze publicly-available data on outage timing and duration for plants during normal conditions and at times when new controls were being installed.

### A. LABOR INPUTS

Retrofit and new generation projects require various types of labor throughout the permitting, design, construction and installation phases. Based on interviews with ten electric utility companies and eight engineering and equipment manufacturing companies, we identified the categories of labor (consistent with the definitions in the Bureau of Labor Statistics databases) that are typically employed in environmental retrofit and new generation projects. The categories of labor we evaluated include boilermakers, design engineers, plumbers, electricians, and welders among others.

We compiled information on full-time equivalent labor-months necessary from each labor category in each phase of the projects. This information is based on our interviews with utility companies and engineering and equipment manufacturing companies, and is supplemented with information compiled by the Electric Power Research Institute (EPRI).[17] In addition to labor data, we tracked plant sizes on which the retrofits were implemented in order to specify a typical plant size consistent with our estimated labor needs. We then normalized the estimated labor requirements on a plant sized at 1,000 MW.

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[17] EPRI (2000), (2001), and (2007).

Table 2 shows our estimate of the person-months of labor required for a typical dry FGD retrofit project installed at a coal plant with 1000 MW capacity. As shown in Table 2, this project would require a total of 217 person-months from design engineers, 979 from plumbers, pipefitters and steam fitters, and 671 from boilermakers among others. Similar tables for each type of retrofit are provided in Appendix C.

**Table 2**
**Person-Months Needed for a Typical Dry FGD Project**

| Labor Type | Permitting | Design Engineering | System Interface / Site Engineering | Procurement | Construction | Testing | Outage | Total Project |
|---|---|---|---|---|---|---|---|---|
| Design Engineers | 3 | 38 | 18 | 46 | 112 | 0 | 0 | 217 |
| Construction / Site Engineers | 0 | 10 | 148 | 31 | 699 | 16 | 6 | 910 |
| Licensing Engineers | 4 | 7 | 12 | 31 | 56 | 0 | 0 | 109 |
| Procurement Engineers | 0 | 17 | 0 | 76 | 140 | 0 | 0 | 233 |
| Project Managers | 2 | 7 | 0 | 31 | 56 | 2 | 1 | 98 |
| Construction Managers | 0 | 7 | 0 | 0 | 224 | 3 | 0 | 233 |
| First Line Supervisors | 0 | 0 | 0 | 0 | 224 | 0 | 0 | 224 |
| Plumbers, Pipefitters and Steam Fitters | 0 | 0 | 0 | 0 | 979 | 0 | 0 | 979 |
| Boilermakers | 0 | 0 | 0 | 0 | 671 | 0 | 0 | 671 |
| Electronic and Control Systems Specialists | 0 | 0 | 0 | 0 | 364 | 0 | 0 | 364 |
| Pipe Layers | 0 | 0 | 0 | 0 | 615 | 0 | 0 | 615 |
| Electrician - In-House Systems | 0 | 0 | 0 | 0 | 224 | 0 | 0 | 224 |
| Electrician - Power Line Installers | 0 | 0 | 0 | 0 | 224 | 0 | 0 | 224 |
| Iron/steel Workers | 0 | 0 | 0 | 0 | 419 | 0 | 0 | 419 |
| Brickmasons and Blockmasons | 0 | 0 | 0 | 0 | 615 | 0 | 0 | 615 |
| Concrete Finishers | 0 | 0 | 0 | 0 | 196 | 0 | 0 | 196 |
| Operator Pile Drivers | 0 | 0 | 0 | 0 | 112 | 0 | 0 | 112 |
| Carpenters | 0 | 0 | 0 | 0 | 531 | 0 | 0 | 531 |
| General Construction Labor | 0 | 0 | 0 | 0 | 1,566 | 0 | 0 | 1,566 |
| Insulation Workers | 0 | 0 | 0 | 0 | 224 | 0 | 0 | 224 |
| Reinforcing Iron and Rebar Workers | 0 | 0 | 0 | 0 | 224 | 0 | 0 | 224 |
| Welders, Solderer | 0 | 0 | 0 | 0 | 364 | 0 | 0 | 364 |
| Construction Equipment Operators | 0 | 0 | 0 | 0 | 280 | 0 | 0 | 280 |
| Power Plant Operators | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 9 |

*Sources and Notes:*

Based on interviews with electric utilities (AEP, Dairyland Power Cooperative, Detroit Edison, Dominion, Duke, First Energy, Indianapolis Power & Light, TVA, Tucson Electric Power, and Wisconsin Electric) and equipment manufacturing and construction companies (Babcock and Wilcox, Bechtel, Washington Group, Alstom, IHI Corporation, and Foster Wheeler).

## B. OUTAGE DURATION ASSOCIATED WITH ENVIRONMENTAL COAL RETROFITS

One of the objectives of our analysis is to evaluate the scale of impacts from a large number of simultaneous retrofits on MISO's outage planning for the MATS compliance years. A first step in this analysis is to determine the need for planned outages for a coal plant during normal years, and compare this with the longer outages needed when installing environmental retrofits.

An important point to note when analyzing outages associated with coal retrofits is that most of the construction activities associated with these retrofits may be completed while the plant is operating. However, any portion of the upgrade that involves a tie-in to the facility's major systems will need to be done during a unit outage. Most of these final installation steps will typically be scheduled at the same time as other major maintenance activities that would have required a normal planned outage in any case. Overall, we would not expect most upgrades to require an entirely new planned outage, but will likely require longer outages than in typical years.

To characterize the magnitude of this impact, we analyzed outage patterns in the U.S. coal fleet over the past decade using data from the EPA's Continuous Emissions Monitoring System (CEMS) database.[18] We identified outages that coincided with specific types of controls retrofits and those that were typical outages during which no retrofits were completed. Note that because the CEMS database that we used as our source does not distinguish between planned outages and other outages, we must assume that the outages in our sample will also include some quantity of maintenance outages and economic outages. We account for this inclusion of non-planned outages in Section V.D below by supplementing this analysis with average outage rates from the North American Electric Reliability Corporation (NERC) Generating Availability Data System (GADS).

Figure 4 and Table 3 summarize the average and range of outage lengths for coal plants that were and were not installing retrofits. The figure shows that all types of outages can span a relatively large range of durations, but that retrofits can extend the outage durations for days or weeks depending on the control type being installed. For SNCR, ACI, DSI, and Dry FGD upgrades, the impact is relatively minor with the needed outage extending only up to 8 days longer than a typical outage. For SCR, baghouse, and wet FGD retrofits the impact is much more substantial in that these upgrades impose approximately 19-24 days of additional outages.

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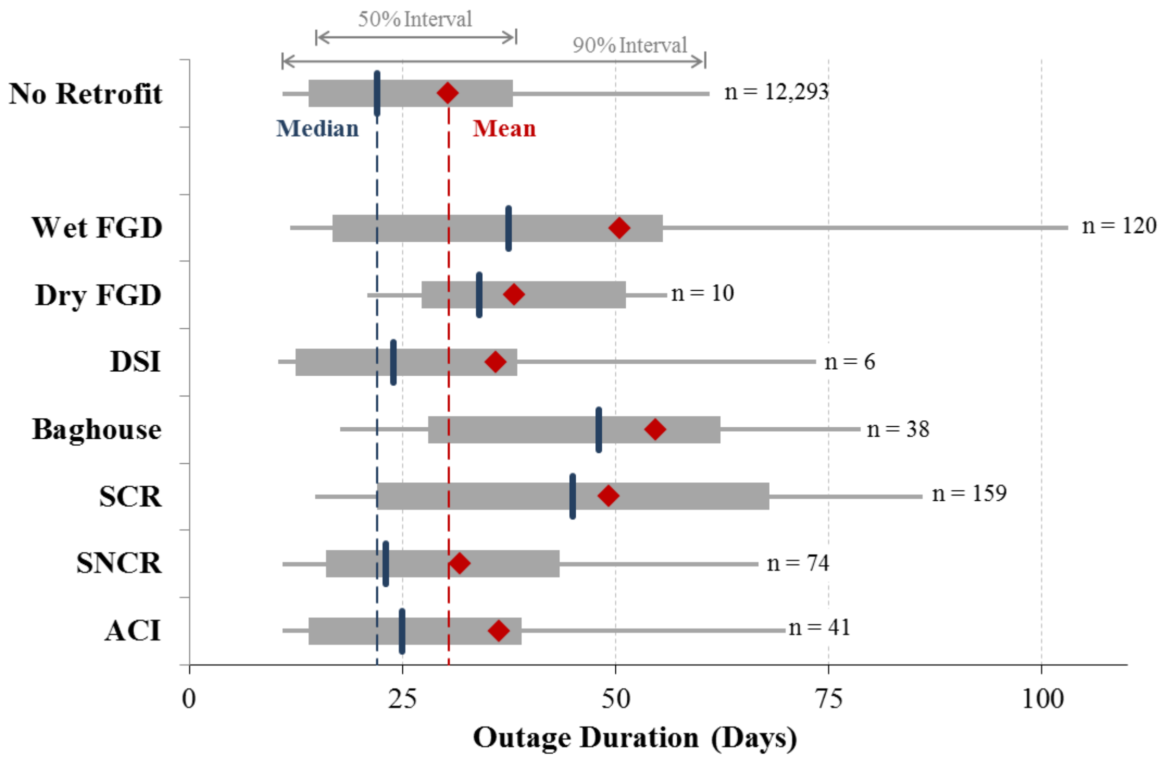
[18] The CEMS database does not identify outage hours, but instead reports the hourly generation output for every monitored facility. We identified planned outages as those data series for which generation output was zero for at least 10 consecutive days, and filtered out certain categories of plants that may have anomalous outage patterns including plants more than 56 years old, smaller than 75 MW or within a few years of online or retirement date.. Compiled from Ventyx (2012).

**Figure 4**
**Historical Controls Retrofits in the U.S. on a Wet FGD Equivalent Basis**




*Sources and Notes:*
Outage duration data compiled from EPA CEMS database, Ventyx (2012).
Outages ≥ 10 days' duration included in summary.
Outages associated with major equipment upgrades identified based on outage start/end dates and upgrade online date.

**Table 3**
**Average and Incremental Average Outage Days Needed For Each Type of Control Retrofit**

| Outage Type | Average Outage Length *(days)* | Incremental Outage Time *(days)* |
|---|---|---|
| **Without Retrofit** | 30.4 | n/a |
| **With Retrofit** | | |
| Wet FGD | 50.5 | 20.1 |
| Dry FGD | 38.2 | 7.8 |
| DSI | 36.0 | 5.6 |
| Baghouse | 54.7 | 24.2 |
| SCR | 49.3 | 18.8 |
| SNCR | 31.8 | 1.3 |
| ACI | 36.4 | 6.0 |

*Sources and Notes:*
Data compiled from EPA CEMS database, Ventyx (2012).

## C. PROJECT TIMELINES

We estimated the typical timelines needed for permitting and building new gas CCs and combustion turbines (CTs), as well as for retrofitting coal plants with various environmental controls. We compiled this timeline information from our interviews with ten electric utility companies and eight engineering and equipment manufacturing companies. Table 4 is a summary of our estimates for total months to complete each type of retrofit. Note that our approach to estimating these project timelines results in project durations that are closer to industry estimates of retrofit lead time than to EPA estimates, putting our estimates on the higher end of the numbers that we compiled from literature and reported in Figure 3 above. Further, our estimates will tend to be on the high end compared to some other sources (including the EPA) because they are compiled to the extent possible from industry participants' experiences on a selection of actual projects, some of which have experienced various permitting, contracting, or installation delays.

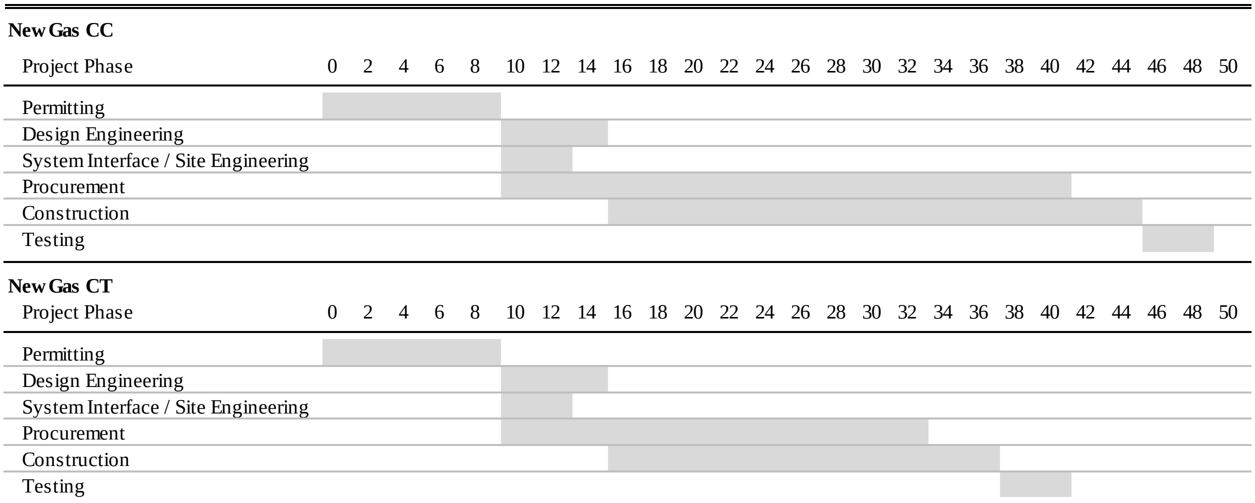
**Table 4**
**Estimated Duration of New Generation and Retrofit Projects**

| **Project** | **Duration** *(months)* |
|---|---|
| **New Generation** | |
| New CC | 50 |
| New CT | 41 |
| **Retrofit** | |
| Wet FGD | 56 |
| Dry FGD | 46 |
| DSI | 19 |
| ACI | 19 |
| Baghouse | 38 |
| ESP | 39 |
| SCR | 47 |

*Sources and Notes:*
Based on interviews with electric utilities (AEP, Dairyland Power Cooperative, Detroit Edison, Dominion, Duke, First Energy, Indianapolis Power & Light, TVA, Tucson Electric Power, and Wisconsin Electric) and equipment manufacturing and construction companies (Babcock and Wilcox, Bechtel, Washington Group, Alstom, IHI Corporation, and Foster Wheeler).

Figure 5 shows our estimate of the typical timeline for building new gas CC and CT plants. Starting with the permitting process, it would take approximately 50 months and 41 months to complete a new gas CC and a new gas CT respectively, according to our interviewees.

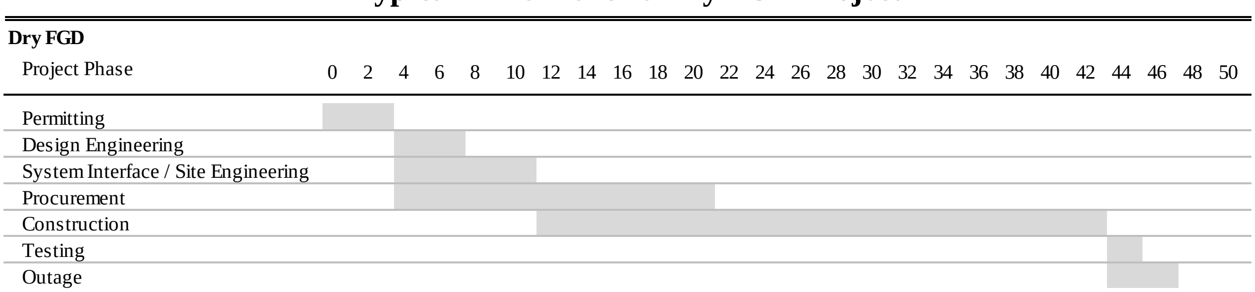
**Figure 5**
**Typical Timelines for New Gas CC and Gas CT Projects (Months)**




*Sources and Notes:*
Based on interviews with electric utilities (AEP, Dairyland Power Cooperative, Detroit Edison, Dominion, Duke, First Energy, Indianapolis Power & Light, TVA, Tucson Electric Power, and Wisconsin Electric) and equipment manufacturing and construction companies (Babcock and Wilcox, Bechtel, Washington Group, Alstom, IHI Corporation, and Foster Wheeler).

For a Dry FGD retrofit project, we estimate that the total project duration starting with permitting would be 46 months, as shown in Figure 6 below. Similar detailed timelines for other retrofit projects are provided in the Appendix A.

**Figure 6**
**Typical Timeline for a Dry FGD Project**




*Sources and Notes:*
Based on interviews with electric utilities (AEP, Dairyland Power Cooperative, Detroit Edison, Dominion, Duke, First Energy, Indianapolis Power & Light, TVA, Tucson Electric Power, and Wisconsin Electric) and equipment manufacturing and construction companies (Babcock and Wilcox, Bechtel, Washington Group, Alstom, IHI Corporation, and Foster Wheeler).

## IV. HISTORICAL MAXIMUM LEVELS OF CONSTRUCTION AND RETROFITS

To characterize the industry's capability for a large simultaneous set of retrofit and new construction projects, we evaluate the maximum quantity of construction projects that have been implemented historically. If the demand on the supply chain that will be imposed by MATS is on a large scale far beyond historical maximums, then we expect that shortages and bottlenecks will arise in the supply chain that prevent some projects from going ahead on schedule.

Even in the case of a shortage arising, we stress that this analysis is only indicative and cannot be considered a "hard cap" on the industry's capability. All markets, including those representing the supply chain for retrofits and generation construction, have the ability to adapt and respond to market demands. For example, a shortage in skilled craft labor may be partially addressed by increasing labor availability through training new skilled workers, recruiting from other industries, moving individuals in from other regions, or requesting overtime work. However, such measures will likely increase project costs or cause delays relative to a typical timeline. For these reasons, we characterize the industry's capability to construct a large number of projects simultaneously as a "soft cap" above which cost and delay concerns are likely to arise.

We report a summary of the total quantities of retrofits and generation plant construction that have been implemented in the U.S. and Midwest by type of project. We derive "soft caps" on the industry's capability to construct similar projects in a single year based on the maximum of the annual historical retrofit and construction projects. Because some retrofit and construction projects are more resource-intensive than others, we report the caps for retrofits on a wet FGD-equivalent basis, the cap for generation construction on a CC-equivalent basis, and a combined cap on a wet FGD-equivalent basis.[19]

### A. Environmental Controls Retrofits

Meeting the requirements of MATS is a major challenge for the industry, but comes after decades of environmental restrictions that required previous retrofits to existing units and tighter controls on new units. For our purposes, it is important to scale the impact of MATS relative to the quantity of retrofits achieved in response to earlier state and federal regulations. We show here the historical quantity of all types of retrofits installed for all fuel types in the U.S. and Midwest in response to various regulatory drivers.

#### 1. National Historical Control Retrofits

Figure 7 shows the timeline of major controls retrofits added to the U.S. generation fleet since 1990.[20] The figure summarizes retrofits for all types of generation plants but excludes controls installations on new units. The MW of capacity impacted is represented based on the units' installed capacity (ICAP) values; note that individual units may be represented more than one time in this figure if the unit was retrofitted with multiple types of controls.

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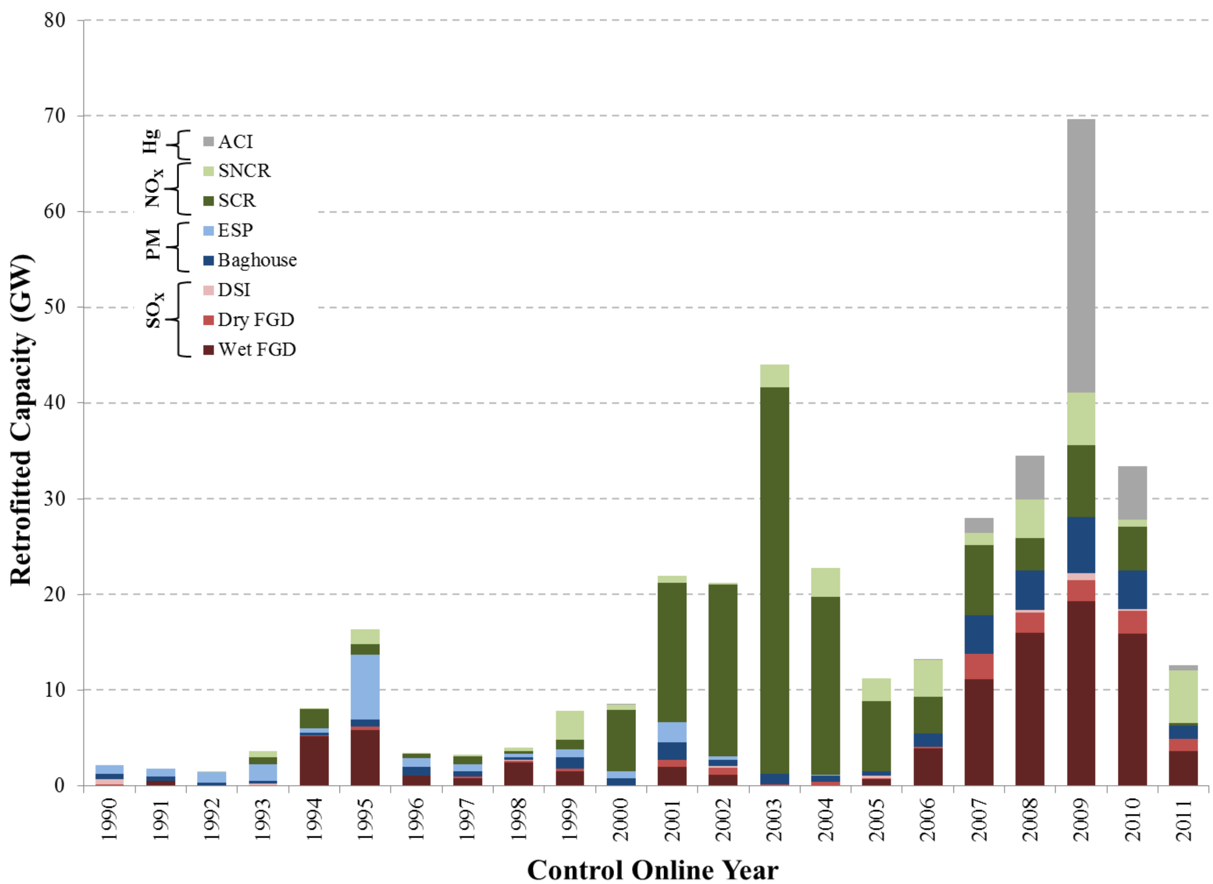
[19] For calculating the FGD-equivalency factors, we used the relative estimated capital costs, according to the convention used by the EPA in its December 2011 study on the feasibility of retrofits needed to comply with the MATS rule. See EPA (2011b).

[20] Compiled from Ventyx (2012).

The figure shows that relatively few retrofits were added in the early 1990s, with most control installations at the time being implemented on new units but not existing units. The vast majority of all the retrofits shown in the figure are on coal units, although a substantial minority of the SCR upgrades in the early 2000s was on gas-fired units.[21] Overall, the largest historical simultaneous retrofit efforts occurred in 2003 when a large number of SCRs were retrofitted on more than 40 GW of capacity and in 2009 when approximately 70 GW of capacity were retrofitted with a variety of different controls. The 2009 retrofits included approximately 29 GW of ACI retrofits and 19 GW of costly wet FGD systems.

**Figure 7**
**Historical Quantities of Controls Retrofits in the U.S.**




*Sources and Notes:*
Data from Ventyx (2012).
All generation fuel types are represented; individual units may be represented more than once if subject to multiple retrofits.

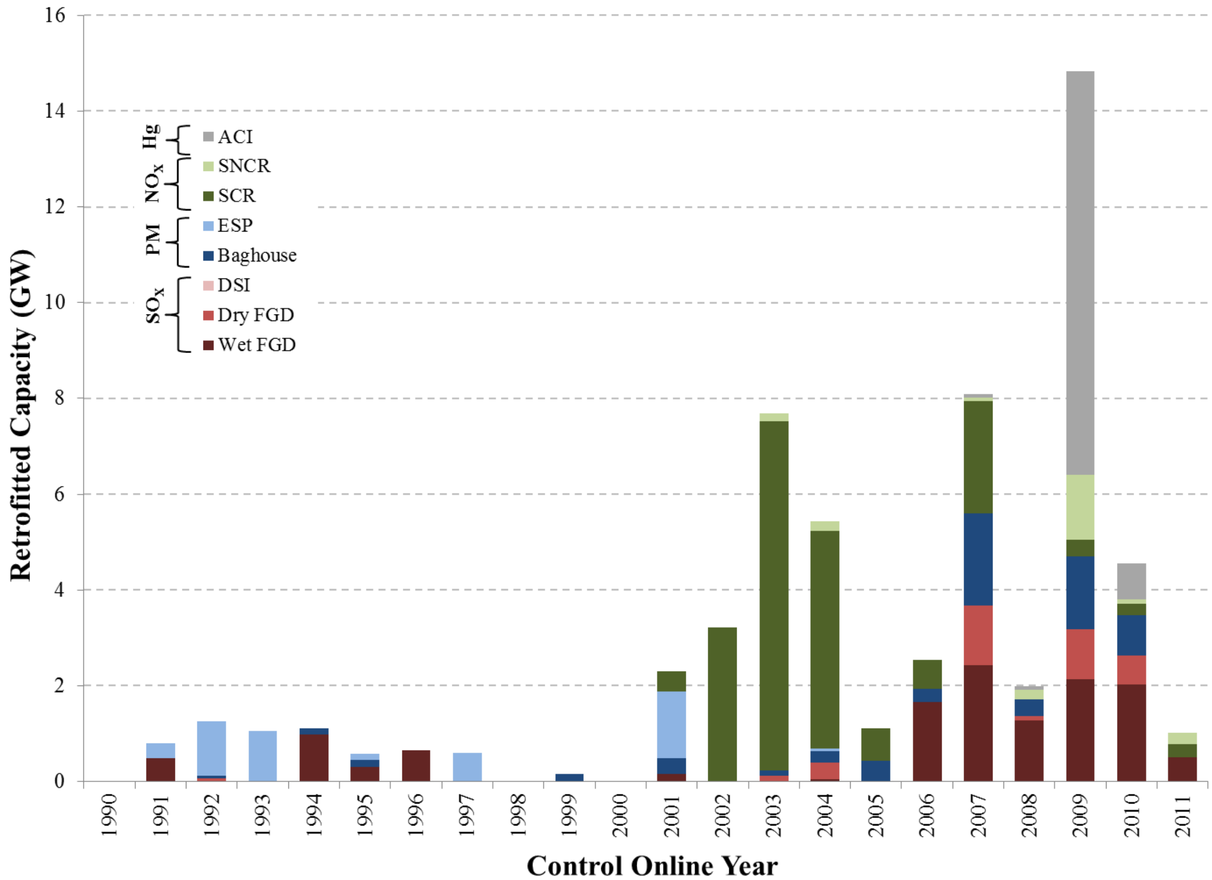
### 2. Control Retrofits in the Midwest

Figure 8 shows historical controls retrofits in the Midwest, defined according to MISO's current footprint. The figure shows a similar pattern to the national retrofit trends with 2003 having more than 7 GW of SCR retrofits and 2009 having almost 15 GW of retrofits. In the Midwest, however, a relatively greater proportion of the upgrades in 2009 were from ACI and relatively

[21] There are also a selection of gas units fitted with SNCR and oil units fitted with an ESP, SCR, or SNCR.

fewer from wet FGD systems. The year 2007 also stands out as having a relatively large number of upgrades including SCRs, baghouses, and wet and dry scrubbers.

**Figure 8**
**Historical Quantities of Controls Retrofits in the Midwest**




*Sources and Notes:*
Data from Ventyx (2012).
All generation fuel types are represented; individual units may be represented more than once if subject to multiple retrofits.

## B. Generation Construction

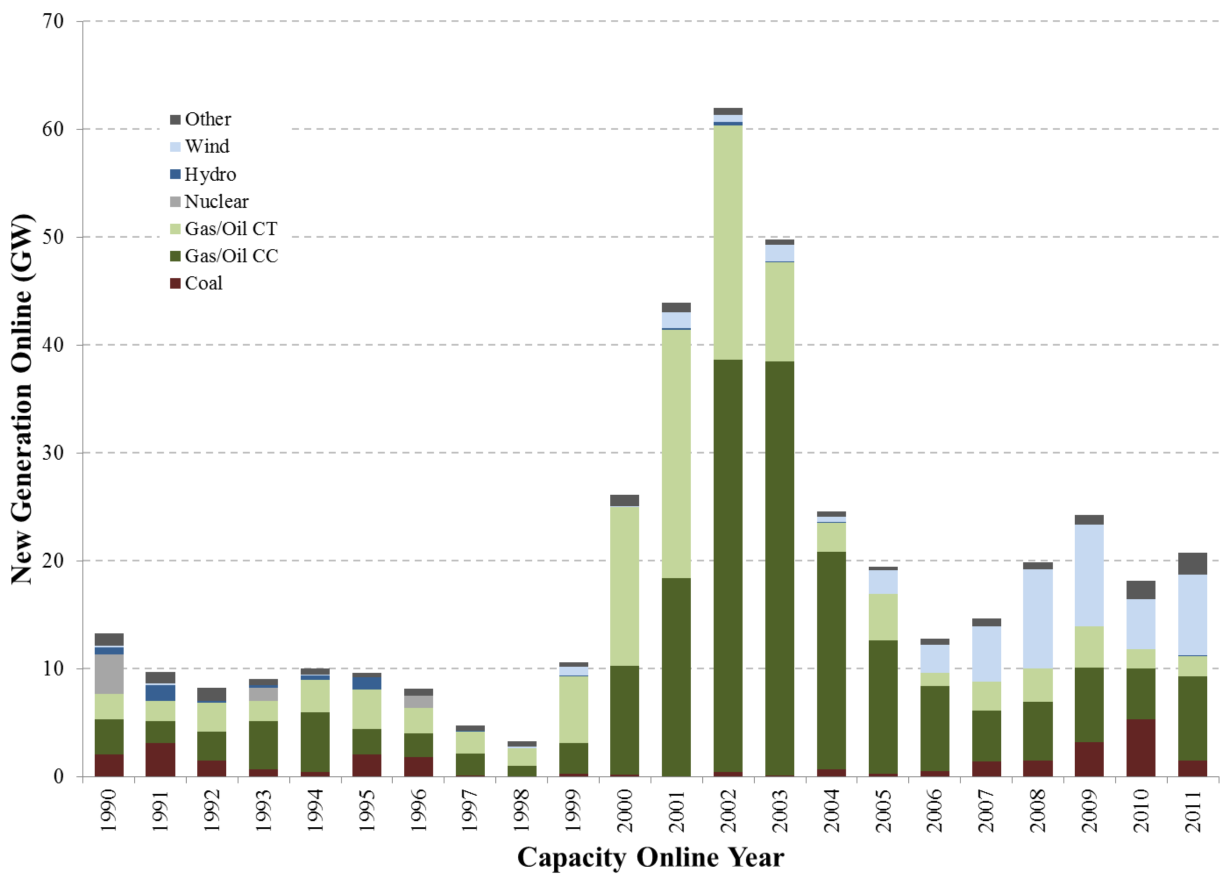
Many of the same engineering, contracting, and labor inputs needed for retrofitting plants are also needed for building new plants. To the extent that new generation construction must be completed at the same time as retrofit upgrades, there will be additional demands placed on a largely overlapping supply chain. For this reason, we examine historical trends not only in retrofits but also in new generation construction in the Midwest and nationally.

### 1. National Historical Generation Construction

Figure 9 shows the total quantity of newly constructed plants in the U.S. over time, represented at plant nameplate capacity. We report these installations based on online date, although we recognize that large construction projects are multi-year efforts that will introduce substantial demands on the supply chain over several years. The most prominent feature of the new construction chart is the large build-out of gas in the early 2000s and peaking in 2002.[22] More than 38 GW of gas CCs and almost 22 GW of gas CTs came online in 2002. This large build-out of the gas fleet reflected the optimism of merchant developers as much of the U.S. wholesale electric industry deregulated and expanded opportunities for competition.

Another important trend starting in the mid-2000s is an increase in wind construction in response to demand introduced by states' renewable portfolio standards (RPS). Wind plant construction was the highest in 2008 and 2009 with more than 9 GW of wind plants coming online nationally in those years. We expect construction of wind turbines to continue at high levels, with almost 9 GW likely to come online in 2012 alone.[23]

**Figure 9**
**Historical Generation Construction in the U.S.**




*Sources and Notes:*
Data from Ventyx (2012).

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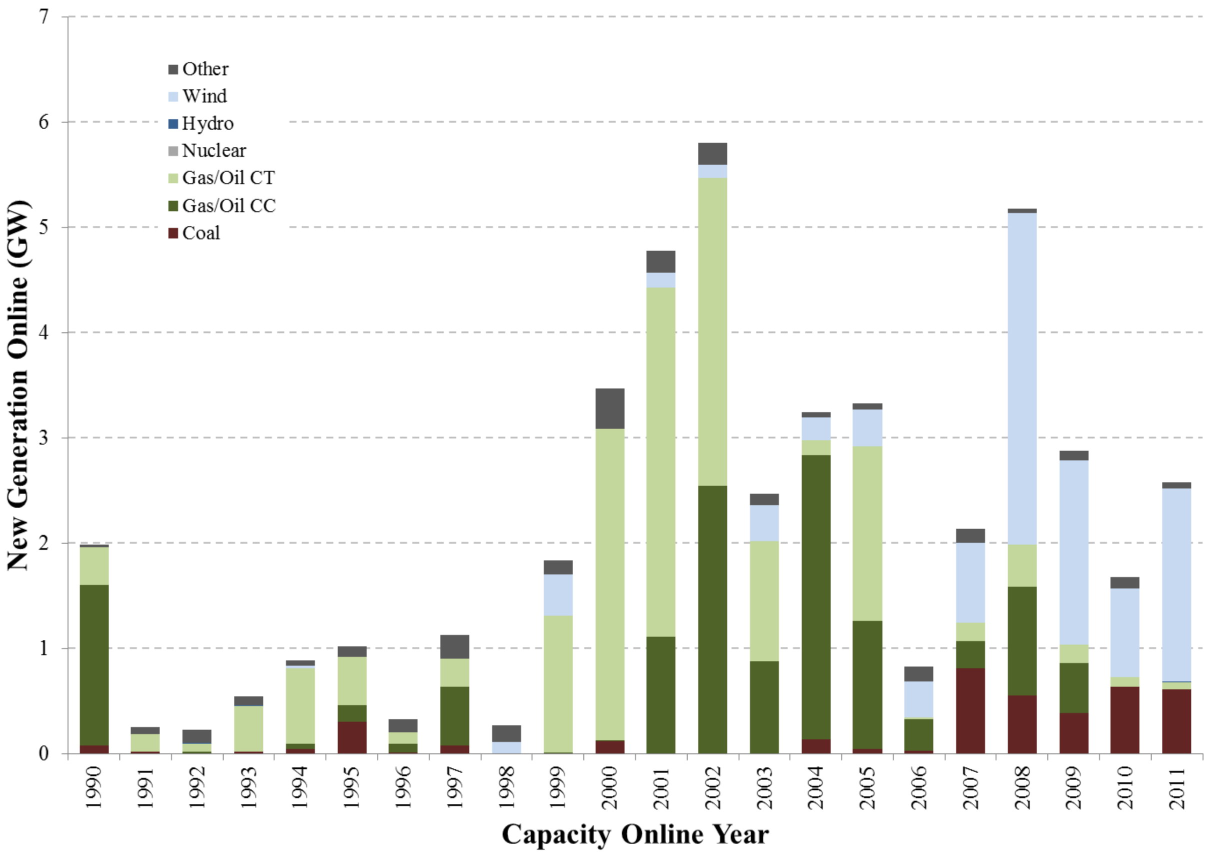
[22] Gas and oil CCs and CTs are plotted together because these technologies have very similar capital costs but almost all of these units rely on gas as their primary fuel source.

[23] Based on the number of U.S. turbines that have already come online in 2012 plus the additional units that are already under construction and projected for completion this year.

### 2. Generation Construction in the Midwest

As shown in Figure 10, construction trends in the Midwest are similar to those nationally. The year 2002 showed a large quantity of gas-fired construction, with 2.5 GW of CCs and 2.9 GW of CTs coming online. Relative to the historical maximums, wind plant construction has been substantially more important in the Midwest than nation-wide. This is primarily because the Midwest has more sites that are attractive locations for wind development than other parts of the country. Wind plant construction was the highest in the Midwest in 2008 at 3.2 GW, a year that had 5.2 GW total construction after accounting for gas and coal units that came online at the same time.

**Figure 10**
**Historical Generation Construction in the Midwest**




*Sources and Notes:*
Data from Ventyx (2012).

## C. "SOFT CAP" ON INDUSTRY CAPABILITY BASED ON HISTORICAL MAXIMUMS

As we explained previously, there is no hard limit on the industry's capability to achieve a large number of simultaneous retrofit and new build projects. However, as the draw on skilled laborers, contractors, and equipment manufacturers becomes large, it is likely that the industry will reach some supply chain bottlenecks that can cause substantial delays or cost increases. To indicate the total capability of the industry to achieve a large quantity of simultaneous projects, we estimate a "soft cap" on the ability to achieve a large number of projects simultaneously based on historical maximums. Simultaneous projects substantially in excess of these historical maximums will likely give rise to the types of supply chain bottlenecks that may concern suppliers attempting to meet the MATS compliance timeframe.

Since some retrofit and new build projects are substantially more expansive in their scope, cost, and inputs than others, it is important to express all of these projects in a single metric so that we can evaluate the overall implications. For this reason, we use the convention that the EPA has used in previous studies and evaluate all types of retrofits on a "wet FGD equivalent" basis. Generally, one MW of retrofits on this basis will impose the same capital costs (and approximately similar supply chain impacts) as one MW of a costly wet FGD upgrade. We also present a soft cap on new construction upgrades on a CC equivalent basis and a combined retrofit and new build cap on a wet FGD equivalent basis.

### 1. Retrofits on a Wet FGD Equivalent Basis

We convert all types of major retrofit projects into their wet FGD equivalent MW according to the conversion rates in Table 5. Following the convention used by the EPA in a recent study, we make this conversion based on the capital costs of each type of control upgrade as listed.[24] Using these conversions, one MW of upgrades from any type of control technology would have the same capital cost and approximate supply chain implications.

**Table 5**
**Wet FGD Equivalence of Retrofit Technologies**

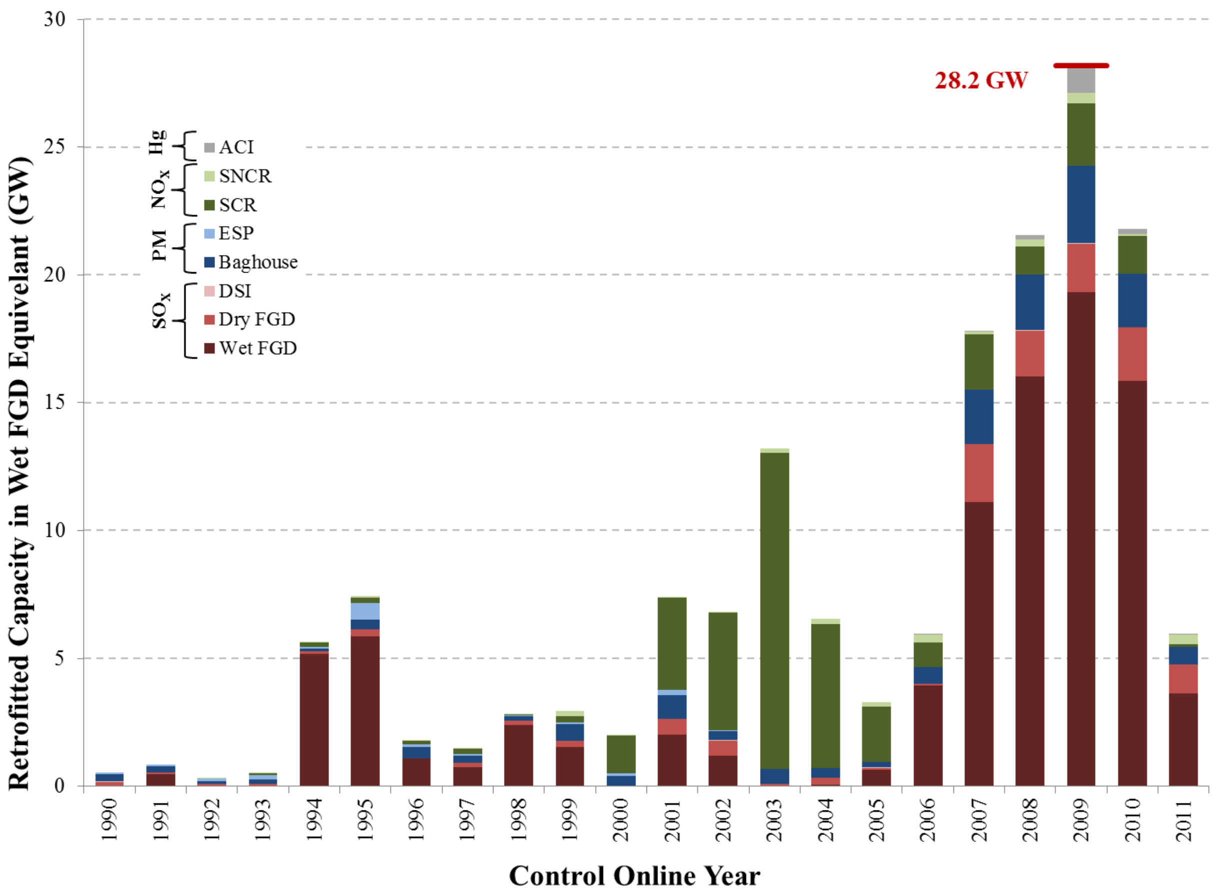
| Retrofit Equipment | Capital Cost *(2011$/kW)* | Wet FGD Equivalent *(MW)* |
|---|---|---|
| **Coal** | | |
| SCR | $227 | 0.32 |
| SNCR | $51 | 0.07 |
| Dry FGD | $601 | 0.86 |
| **Wet FGD** | **$702** | **1.00** |
| DSI | $41 | 0.06 |
| Baghouse | $366 | 0.52 |
| ESP | $70 | 0.10 |
| ACI | $27 | 0.04 |
| **Oil/Gas** | | |
| SCR | $66 | 0.09 |
| SNCR | $13 | 0.02 |

*Sources and Notes:*
Capital costs of retrofit on coal plants from EPA (2010) and EEI (2011), pp. 33-34
Oil/gas costs from year 2004 estimate inflated by ratio of coal SCR and SNCR cost inflation between 2004 and 2011 from the same sources.
1 MW of FGD Equivalent represents the same capital costs.

[24] See EPA (2011b).

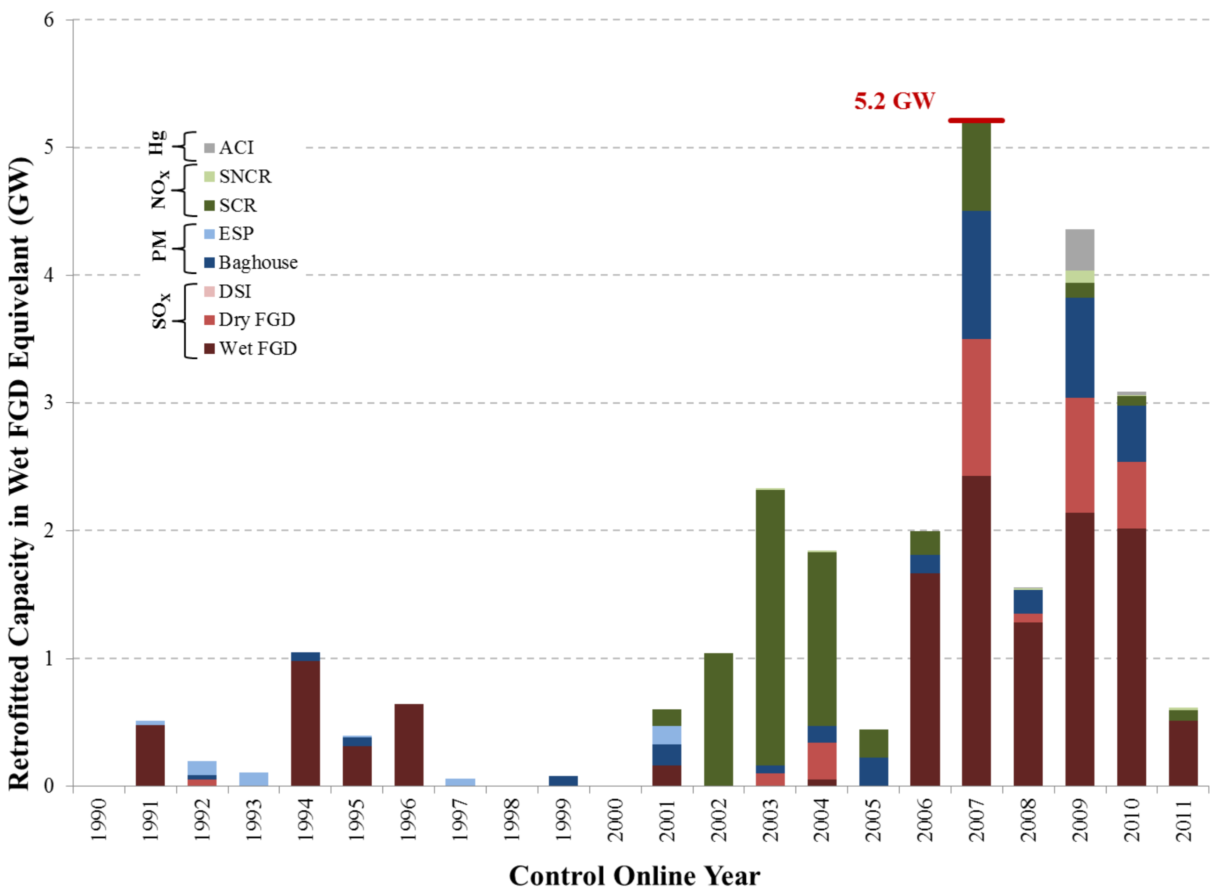
The total control retrofits reported in Section IV.A above can be converted into their wet FGD equivalent values as shown in Figure 11 for the U.S. and in Figure 12 for the Midwest. The figures show a smaller quantity of retrofit MW than the previous charts because most retrofits are less expensive than wet FGD upgrades. Additionally, some inexpensive upgrades such as ACI have a substantially lower impact when viewing on this basis, while the most expensive upgrades such as wet FGDs, dry FGDs, and SCRs are relatively more important. Nationally, the largest quantity of simultaneous retrofits occurred in 2009 with 28 GW of wet FGD equivalent retrofits. In the Midwest, the maximum simultaneous retrofits were in 2007 with 5.2 GW of wet FGD equivalent retrofits.

**Figure 11**
**Historical Controls Retrofits in the U.S. on a Wet FGD Equivalent Basis**




*Sources and Notes:*
Data from Ventyx (2012).
Retrofitted MW converted into Wet FGD equivalent basis from Table 5.
All generation fuel types are represented; individual units may be represented more than once if subject to multiple retrofits.

**Figure 12**
**Historical Controls Retrofits in the Midwest on a Wet FGD Equivalent Basis**




*Sources and Notes:*
Data from Ventyx (2012).
Retrofitted MW converted into Wet FGD equivalent basis from Table 5.
All generation fuel types are represented; individual units may be represented more than once if subject to multiple retrofits.

## 2. New Generation Construction on a CC Equivalent Basis

For new generation construction projects, we convert these projects into their CC equivalent MW according to the conversion factors presented in Table 6. Again, we develop these conversions based on the ratio of capital costs and therefore approximate supply chain impacts. We also present a conversion of these projects into their wet FGD equivalent MW for later use when evaluating the combined implications of retrofits and new construction.

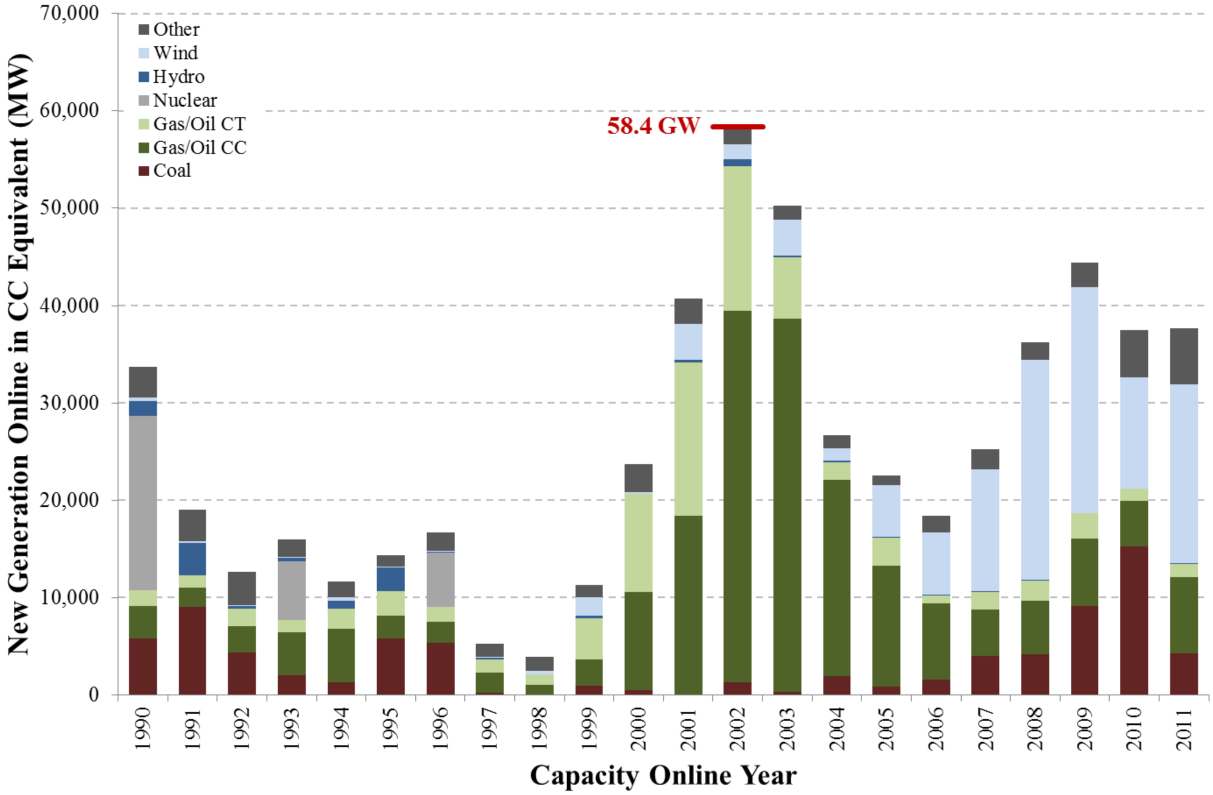
**Table 6**
**Wet FGD Equivalence of New Generation Technologies**

| Type of Project | Capital Cost *(2011$/kW)* | CC Equivalent *(MW)* | Wet FGD Equivalent *(MW)* |
|---|---|---|---|
| **Wet FGD** | **$702** | n/a | 1.00 |
| **New Construction** | | | |
| Coal | $2,752 | 2.86 | 3.92 |
| **Gas/Oil CC** | **$961** | **1.00** | **1.37** |
| Gas/Oil CT | $656 | 0.68 | 0.93 |
| Nuclear | $4,788 | 4.98 | 6.82 |
| Hydro | $2,117 | 2.20 | 3.02 |
| Wind | $2,360 | 2.45 | 3.36 |
| Other | n/a | 2.86 | 3.92 |

*Sources and Notes:*
Capital costs from EIA (2011), p. 97.
"Other" category is small, and assumed at the coal equivalence factor.
1 MW equivalent represents the same capital costs.

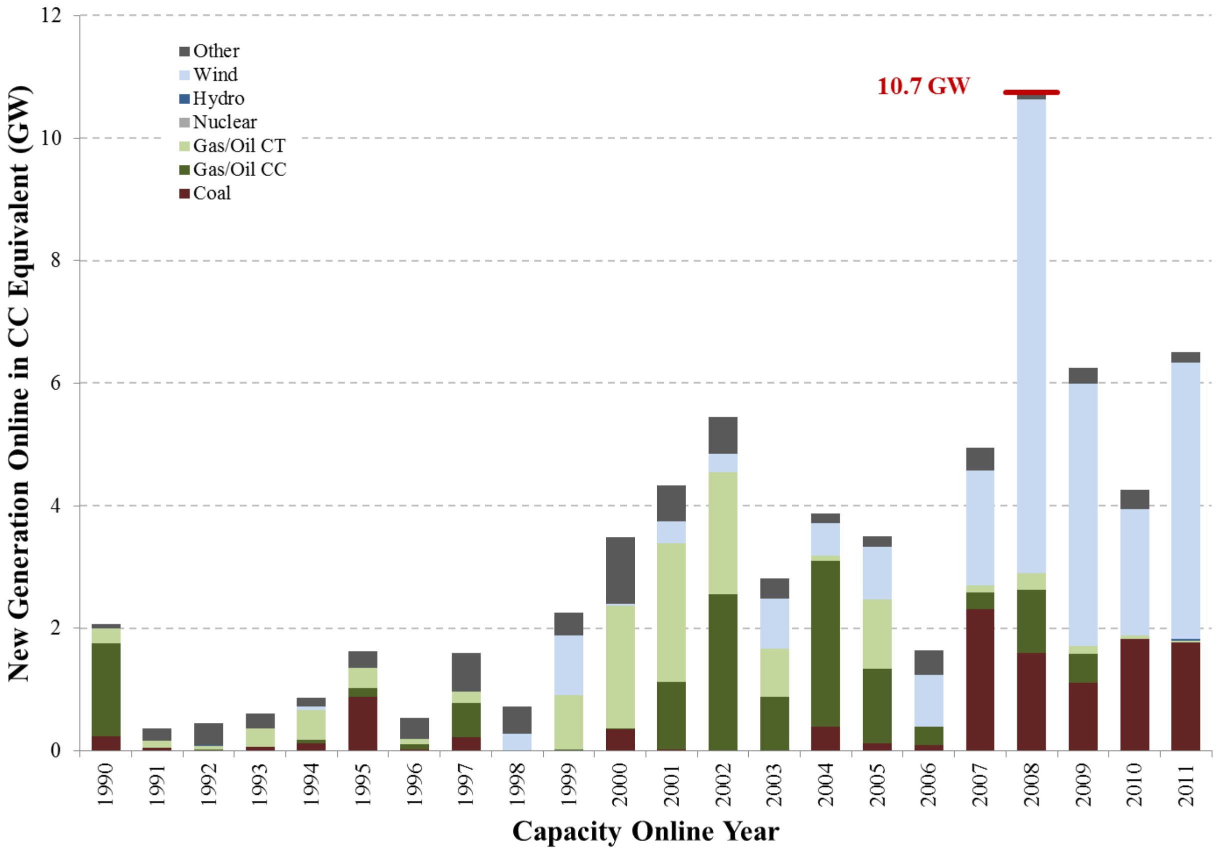
Figure 13 and Figure 14 present historical new generation construction in the U.S. and Midwest, respectively. While the figures show similar overall trends as presented previously, including substantial gas construction in the early 2000s, we note that the relatively high capital costs of wind and coal make these technologies more important here. This is particularly true for the Midwest chart, which shows the dominant importance of the large amount of wind capacity additions in recent years. Overall, the soft cap on new generation construction is 58.4 CC-equivalent GW nationally based on year 2002 and 10.7 GW CC-equivalent GW in the Midwest based on 2008.

**Figure 13**
**Historical Generation Construction in the U.S. on CC Equivalent Basis**




*Sources and Notes:*
Data from Ventyx (2012).
CC equivalence factors from Table 6.

**Figure 14**
**Historical Generation Construction in the Midwest on CC Equivalent Basis**

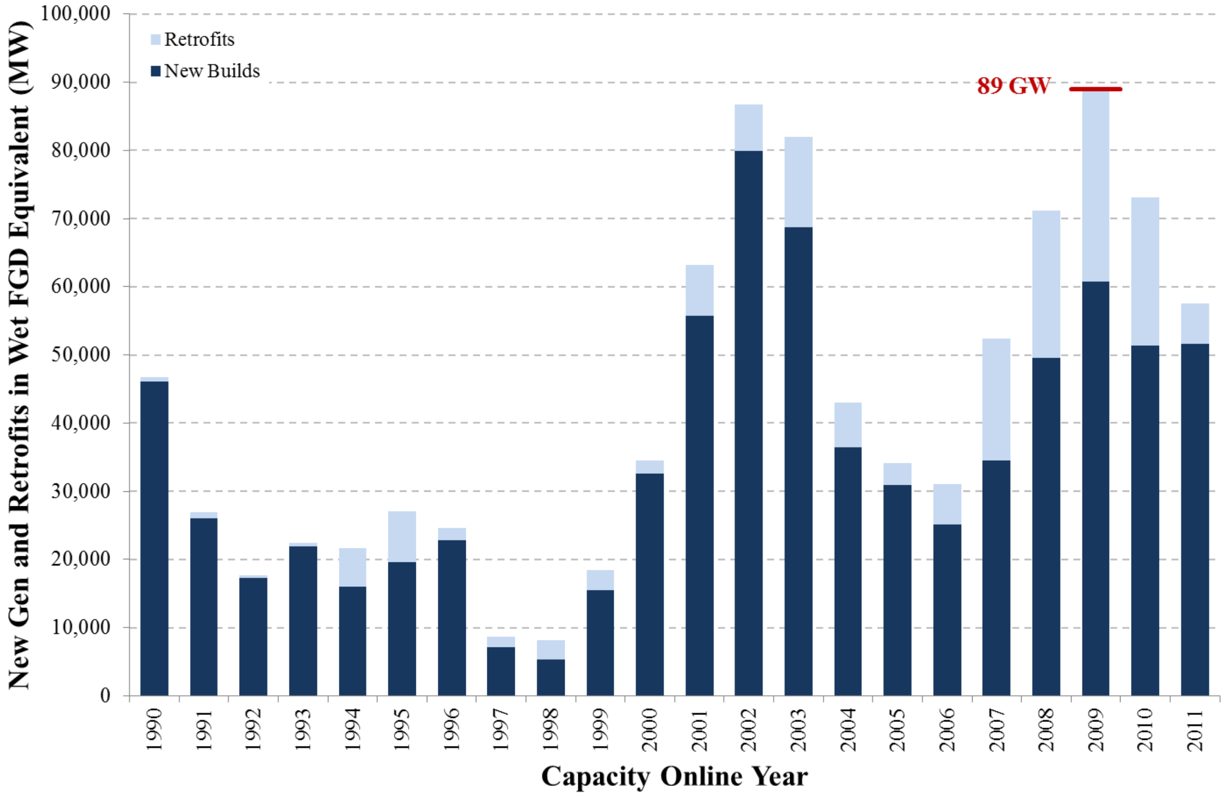



*Sources and Notes:*
Data from Ventyx (2012).
CC equivalence factors from Table 6.

### 3. Retrofits and New Generation on a Wet FGD Equivalent Basis

By combining the total retrofit and new construction activities presented above, we can evaluate the total demand as presented in Figure 15 and Figure 16 below for the U.S. and Midwest. These figures are presented on a wet FGD equivalent MW basis. Because the capital costs of new construction are generally substantially higher than the costs of a retrofit, this conversion results in total quantities that are relatively high compared to the nominal capacity built. The higher capital costs of new construction also translate into a greater impact on the combined total. Overall, the historical maximum combined new build plus retrofit quantities were 89.0 GW wet FGD equivalent nationally in 2009, and 16.3 GW of wet FGD equivalent in the Midwest in 2008.

**Figure 15**
**Historical Retrofits and New Builds in the U.S. on a Wet FGD Equivalent Basis**

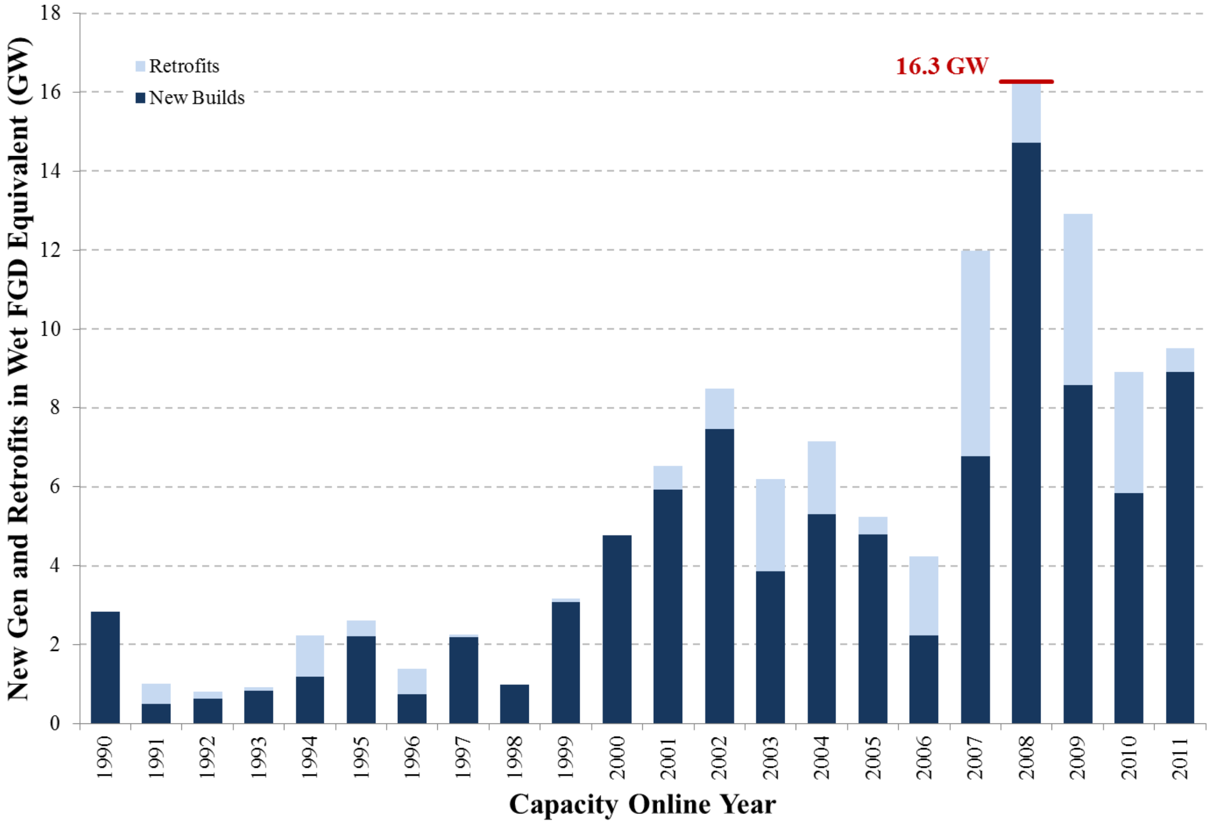



*Sources and Notes:*

Data from Ventyx (2012).

Retrofit and new construction MW retrofitted converted into Wet FGD equivalent basis from Table 5 and Table 6.

**Figure 16**
**Historical Retrofits and New Builds in the Midwest on a Wet FGD Equivalent Basis**




*Sources and Notes:*
Data from Ventyx (2012).
Retrofit and new construction MW retrofitted converted into Wet FGD equivalent basis from Table 5 and Table 6.

## V. PROJECTION OF MATS COMPLIANCE IMPACTS

In this Section, we evaluate the overall timing, labor, supply chain, and outage implications of MATS for the Midwest and nationally. We first examine the timeline needed to install retrofits relative to the MATS compliance deadline. We then examine projected retrofit and new installation impacts on the supply chain relative to historical maximums. Finally, we estimate the potential fleet-wide seasonal outage impacts from these retrofits.

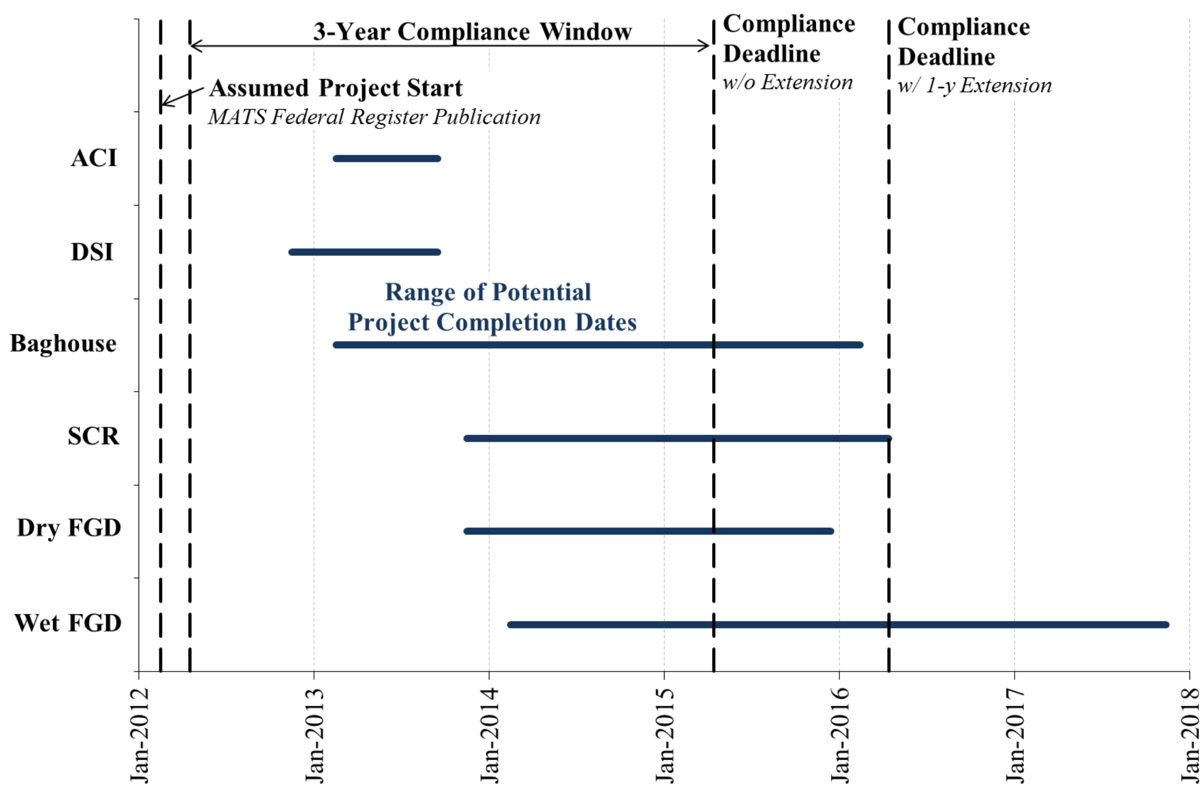
### A. TIMELINE FOR MATS COMPLIANCE RELATIVE TO CONSTRUCTION TIMELINES

Depending on the type of control retrofit that a particular coal unit will require to meet MATS, it may or may not experience difficulty in completing the project in time. Figure 17 shows the range of estimates for retrofit timelines against the MATS compliance window, assuming that the unit started its retrofit project in February 2012 when the final MATS rule was published in the *Federal Register*. However, many coal plant owners began their scoping and retrofit planning activities far earlier, including in the summer of 2011 when the proposed rule was announced or in December 2011 when the final version of the rule was published by the EPA.

Other entities may not yet have decided what upgrades would be needed and most economic for their assets.

The figure shows that short lead-time projects such as ACI and DSI should be achievable within the 3-year MATS compliance deadline, even if those projects are not started immediately. However, all other types of retrofit projects are likely to have difficulty being completed within the MATS compliance deadline if industry representatives' longer estimates of project lead times are more accurate than the shorter lead-time estimates of the EPA. For baghouse, SCR, and dry FGD upgrades, these upgrades should be achievable with a 1-year extension as long as they have already been started. Wet FGD upgrades are potentially more problematic. If the lower EPA estimates are correct then even these projects should be achievable with the 1-year extension, but the high-end estimates indicate a risk that even this extension may not be sufficient.

**Figure 17**
**Retrofit Project Timeline Relative to MATS Compliance Deadlines**




*Sources and Notes:*

Range of retrofit timelines from Figure 3 and Table 4.

Retrofit projects assumed to start the day that MATS was published in the *Federal Register*, or two months after the rule was finalized by EPA. The compliance deadline is 60 days plus 3 years from the date of publication in the *Federal Register*, which was February 16, 2012. See *Federal Register* (2012), p. 9407.

## B. NEEDS RELATIVE TO "SOFT CAP" ON INDUSTRY CAPABILITY

### 1. Projected National MATS Requirements on a Wet FGD Equivalent Basis

To evaluate total nation-wide MATS requirements, we rely on EPA and EEI studies projecting required retirement, retrofit, and new construction, with the EPA estimate forming a relatively low impact estimate and the EEI forming a high impact estimate relative to other studies. The EPA projected 64 GW wet FGD-equivalent retrofits on existing coal units nationally to comply with MATS.[25] The EPA's mix of retrofit projects includes 85 GW of baghouses, 44 GW of DSI, 99 GW of ACI, 20 GW of dry FGD with baghouse, 63 GW of FGD upgrades and 34 GW of ESP upgrades. We also note that the EPA includes no wet FGD upgrades in its projection.

According to a January 2011 study by the EEI, a substantially larger number of coal units will need to install FGDs and baghouses.[26] The EEI study projected FGD retrofits on approximately 100 GW (42-43 GW of wet FGDs and 57 GW of dry FGDs) of coal capacity, 194-201 GW of ACI with baghouses, 18 GW of SCRs, and 46-48 GW of ACI retrofits under two of the relevant regulation scenarios.[27] This amounts to a projected 207-212 GW of wet FGD equivalent retrofits, or more than three times the quantity projected by the EPA.

With respect to new generation, the EPA projects that 30 GW of new generation will be needed by 2015 under MATS.[28] This includes 21 GW of wind capacity additions, 1 GW of gas CCs, 2 GW of gas CTs, 2 GW of coal plants, and 3 GW of other renewables. The EPA's forecast of new generation capacity by 2015 is equivalent to a total of 93 GW of wet FGD retrofits.

In contrast, the EEI study projects a much larger 73-84 GW of new generation capacity by 2015 under the two regulation scenarios we consider here.[29] The composition of this new capacity projection is 13 GW coal, 16-25 GW gas CCs, 31-32 GW wind, and 13-14 GW other. This is equivalent to a total of 228-248 GW of Wet FGD retrofits, or approximately 2.5 times the quantity projected by the EPA. Some of the difference between the EEI and EPA new build estimates is driven by the EEI's higher coal retirement estimate that would require a greater number of replacement projects, while some of the difference is simply related to a higher projection of renewables penetration. Recent announcements of coal plant retirements (about 30 GW) and our assessments suggest that the need for new generation will be closer to the EEI estimates.

Table 7 compares the EPA and EEI projected retrofits and new generation capacity on an FGD-equivalent basis. According to the EPA, 64 GW of retrofits and 93 GW of new generation capacity will be needed under the MATS rule by 2015, for a combined total of 157 GW on a Wet FGD-equivalent basis. The EEI projects a substantially greater impact of 207-212 GW of retrofits and 228-248 GW of new generation capacity on an FGD-equivalent basis or almost three times the EPA's estimates.

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25 EPA (2011b), p. 6.

26 EEI (2011), p. 52.

27 Referred to as "Scenario 1" and "1-Alt Air" in the original study. EEI study defined Scenario 1 as all coal units to be controlled with a scrubber (dry or wet), ACI and Baghouse. Under "Scenario 1 - Alt Air", the scrubber requirement in Scenario 1 is relaxed for units smaller than 200 MW with a requirement (if economic) for a DSI retrofit, in addition to ACI and Baghouse. The study also projected other retrofits in small amounts, but we did not include those in our calculations.

28 EPA (2011c).

29 EEI (2011), p. 55.

**Table 7**
**EPA and EEI Projected Retrofit and New Generation in the U.S. by 2015**
(in Wet FGD Equivalent GW)

| Scenario | Retrofits *(GW)* | New Generation *(GW)* | Total *(GW)* |
|---|---|---|---|
| EPA | 93 | 84 | **177** |
| EEI Low | 228 | 207 | **435** |
| EEI High | 248 | 212 | **459** |

*Sources and Notes:*
Retrofit estimates from EPA (2011b), p. 6, and EEI (2011), p. 52.
New generation estimates from EPA (2011c) and EEI (2011), p. 55.
Conversions to Wet FGD equivalent from Section 0 above.

### 2. Projected Midwest MATS Requirements on a Wet FGD Equivalent Basis

To determine the total projected MATS-required retrofits and new builds in the Midwest, we converted MISO's estimates of the total requirements from Section I.B above. Depending on the scenario, MISO projects a total of 74-91 GW of wet FGD equivalent upgrades and new generation will be required by 2015. Fewer upgrades are required in the higher retirement scenarios, but these scenarios still have greater overall impact because they require more replacement capacity to be built.

**Table 8**
**MISO Projected Retrofit and New Generation in the Midwest by 2015**
(in Wet FGD Equivalent GW)

| MISO Scenario | Retrofits *(GW)* | New Generation *(GW)* | Total *(GW)* |
|---|---|---|---|
| 1: 0 GW Retire | 58 | 16 | **74** |
| 2: 3 GW Retire | 56 | 16 | **73** |
| 3: 12 GW Retire | 51 | 25 | **76** |
| 4: 19 GW Retire | 53 | 38 | **91** |

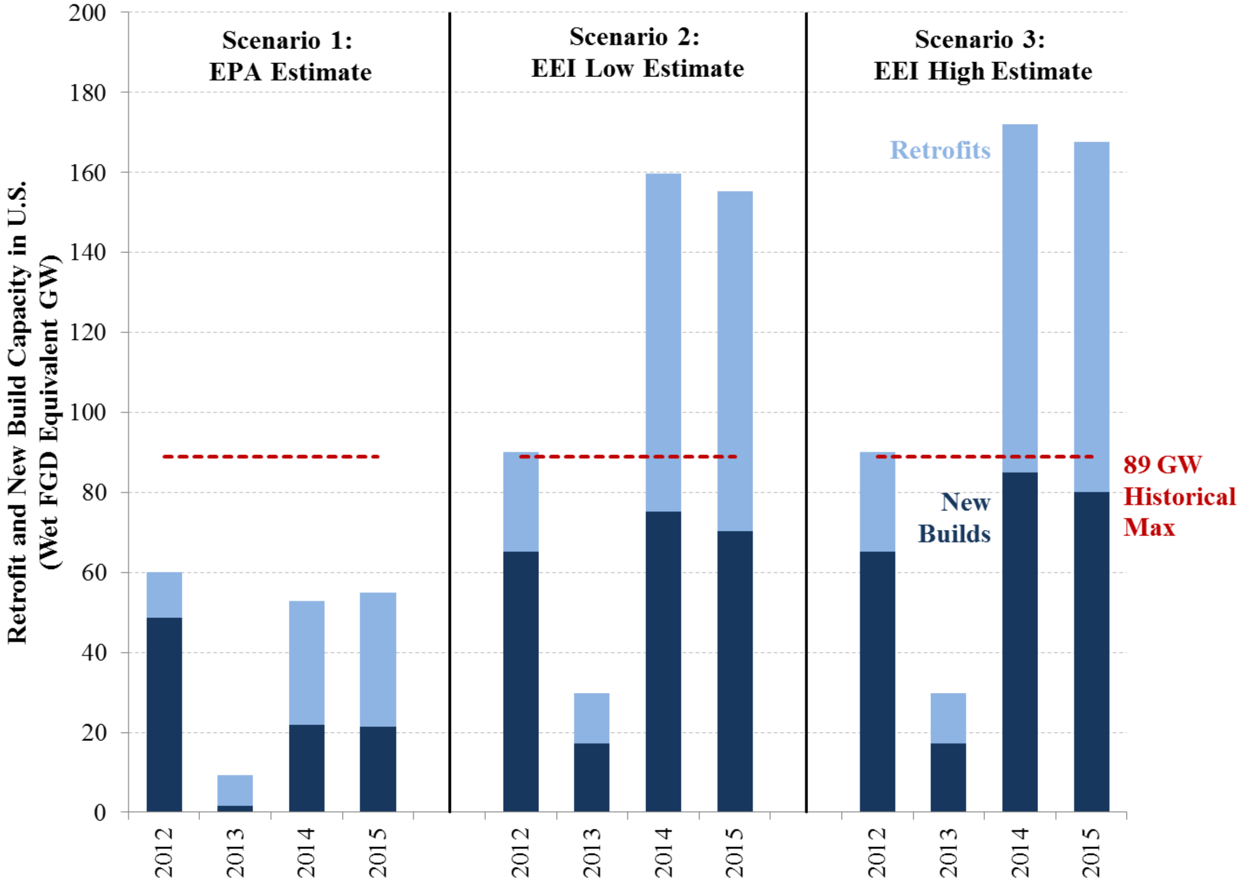
*Sources and Notes:*
Estimated by MISO as reported in Section I.B and Appendix B.
Conversions to Wet FGD equivalent from Section 0 above.

### 3. Comparison of Projected MATS Requirements to "Soft Cap"

The following figures compare the projected new builds and retrofits against the historical "soft cap" nationally and in the Midwest.[30] Nationwide, maximum annual projected retrofits and new generation according to EPA projections (about 60 GW per year of wet FGD equivalent capacity) is substantially below the historical annual maximum of 89 GW annual wet FGD equivalent capacity, while maximum annual projected retrofits and new builds based on EEI estimates (160-170 GW per year of wet FGD equivalent capacity) are roughly double the historical soft cap. If the EPA's relatively optimistic estimate of MATS impacts is more accurate, it appears that the industry will be well-equipped to meet demand; conversely, if EEI's projections are more accurate then it appears that MATS represents an unprecedented challenge that will require industry to more than double its historical maximum deployment. In the EEI case, even with a 1-year extension for MATS compliance the simultaneous demand would be more than 20% above the historical maximum. We believe that the actual MATS impact is likely in between the two extremes represented by the EPA and EEI studies, although our internal estimates are somewhat closer to those presented by EEI.

[30] Note that the timing of retrofits and some new generation builds have not been reported in the source studies. So we estimated this timing based on: (i.) plant owner announcements of retrofit online dates where available; (ii.) plant owners' announcements of construction completion dates for all plants currently under construction; (iii.) study-projected online dates for new generation (available only for MISO's study); and (iv.) assuming all other retrofit and new build projects come online split equally between 2014 and 2015. The reason for the dip in 2013 in the two figures is that most projects that are currently under construction or announced have online dates of 2012 with relatively fewer coming online in 2013.

**Figure 18**
**Projected New Build and Retrofits in the U.S. Relative to Historical "Soft Cap"**

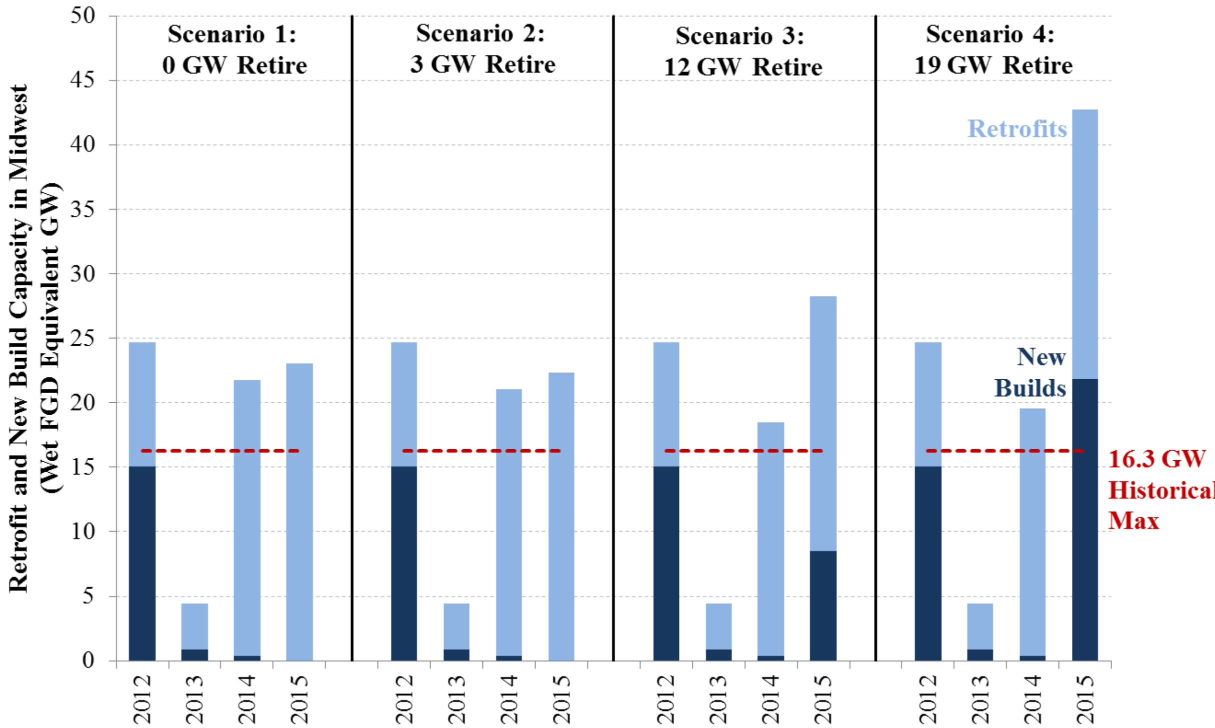



*Sources and Notes:*

Retrofit estimates from EPA (2011b), p. 6, and EEI (2011), p. 52.
New generation estimates from EPA (2011c) and EEI (2011), p. 55.
Conversions to Wet FGD equivalent from Section 0 above; historical maximum estimate from 0.

In the Midwest, maximum annual projected retrofits and new generation in all four scenarios (in the range of 25-43 GW wet FGD equivalent) substantially exceed the historical soft cap of 16.3 GW. However, in this case, the flexibility of the 1-year extension to MATS would be likely to substantially solve the problem and bring Midwestern demands just within the bounds of historical maximums in three of the four scenarios as long as retrofits are deployed evenly over the three years 2014-16. Because retrofits and new builds are likely to be lumpy and possibly back-loaded, it still appears likely that historical maximums may need to be exceeded in at least one year even with the 1-year extension. The potential for a high-retrofit case such as MISO's Scenario 4 indicates an even greater concern in that even the 1-year extension would result in demand approximately 30% greater than historical maximums.

**Figure 19**
**Projected New Build and Retrofits in MISO Relative to Historical "Soft Cap"**




*Sources and Notes:*

Estimated by MISO as reported in Section I.B and Appendix B.

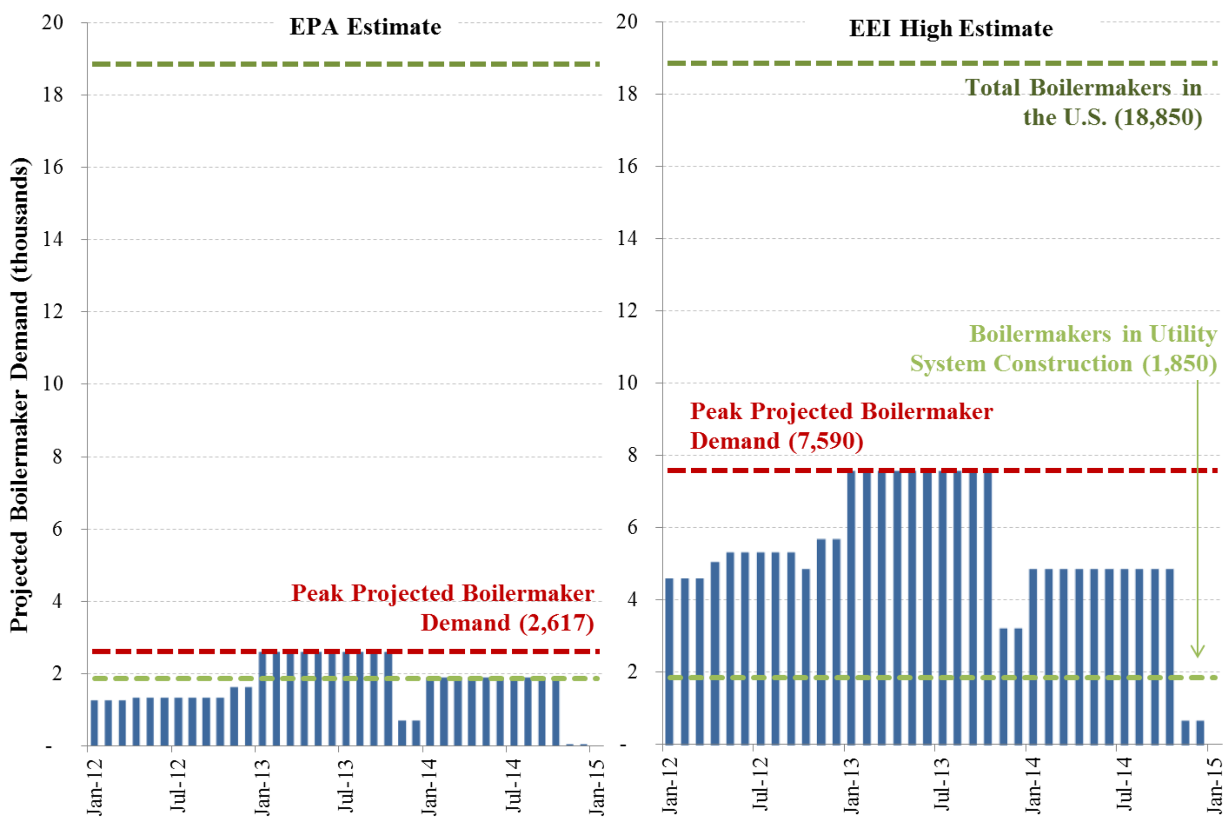
Conversions to Wet FGD equivalent from Section 0 above; historical maximum estimate from 0.

## C. Demand from MATS Relative to Labor Supply

To evaluate the total labor supply chain demand associated with MATS, we projected monthly schedules of labor demands associated with retrofits and new gas CCs and CT generation through 2015. We derived these schedules by combining project timelines and labor requirements from Section III above with the total amount of capacity to be retrofitted and built in the MISO region and in the U.S from Section V.B. We then compared these projected monthly labor requirements against the total available labor based on Bureau of Labor Statistics data for 2011, the most recent year available.[31] By comparing total labor needs against total supply, we concluded that among those labor categories we examined, boilermakers are most likely to create a bottleneck in deploying needed retrofits and new builds. Therefore, we present in this section our projection of demand for boilermakers against measures of total supply.

To project demand for boilermakers in the U.S., we used the EPA estimates and EEI high case estimates for coal retrofits and new generation. As described in Section V.B, the EPA study projected 64 GW of wet FGD-equivalent retrofits, 1 GW of gas CCs, and 2 GW of gas CTs would be needed. In contrast, the EEI study projected that 212 GW of wet FGD-equivalent retrofits and 25 GW of gas CCs would be needed by 2015 in its high case. As shown in Figure 20, we estimate the maximum monthly demand at 2,617 boilermakers using EPA projections and 7,590 boilermakers using the EEI projections. Compared to a total of 18,850 boilermakers employed in the U.S. in 2011, these projected needs represent 14% of total supply using EPA's projections or 40% of total supply using EEI projections.

**Figure 20**
**Projected Need for Boilermakers in the U.S.**



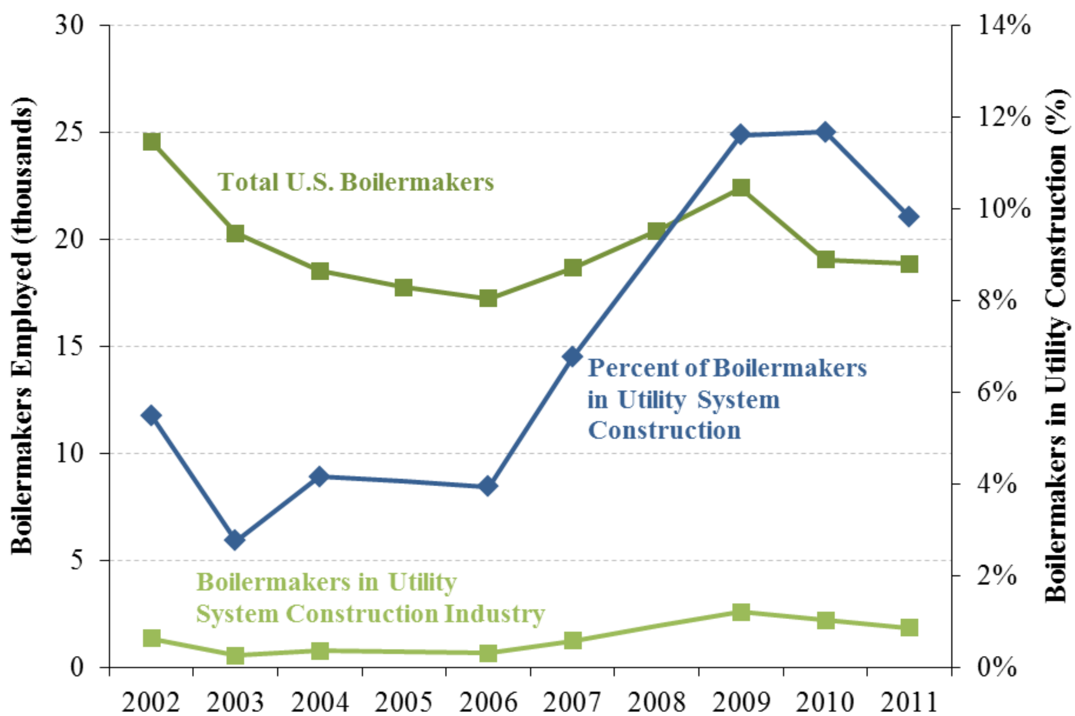

*Sources and Notes:*
Boilermaker demand consistent with MATS scenarios from V.B and labor requirements from Section III.A and Appendix C. Current boilermaker employment data from BLS (2011).

[31] BLS (2011).

Figure 20 also shows the total number of boilermakers currently employed in the in the Utility System Construction Industry, which includes utility construction activities in the water, sewer, petroleum, gas, power and communication utility industries.[32] In 2011, BLS data indicated that there were 1,850 boilermakers employed in the Utility System Construction Industry, representing 9.8% of all U.S boilermakers. Therefore, the projected demand for boilermakers for retrofits and new generation projects exceeds the number of boilermakers currently employed in this industry. This comes at a time when demand for boilermakers in this sector have already increased substantially over the past several years as shown in Figure 21, possibly related to the large number of coal retrofits that have been implemented over the past few years. Despite this relatively high demand for boilermakers in utility construction, total employment of boilermakers actually dropped in 2010 (as did employment in many fields, related to the economic downturn).

Overall, it appears that the small incremental demand for boilermakers that would be needed in the EPA scenarios would not appear to be a pressing concern. However, the more than three-fold increase in boilermaker demand consistent with the EEI high case would likely be a substantial challenge and could result in substantial concerns from boilermaker availability or cost increases as boilermakers would have to be hired in against competition from other industries or developed as new skilled laborers.

**Figure 21**
**U.S. Boilermakers Employed in Utility System Construction and All Industries**



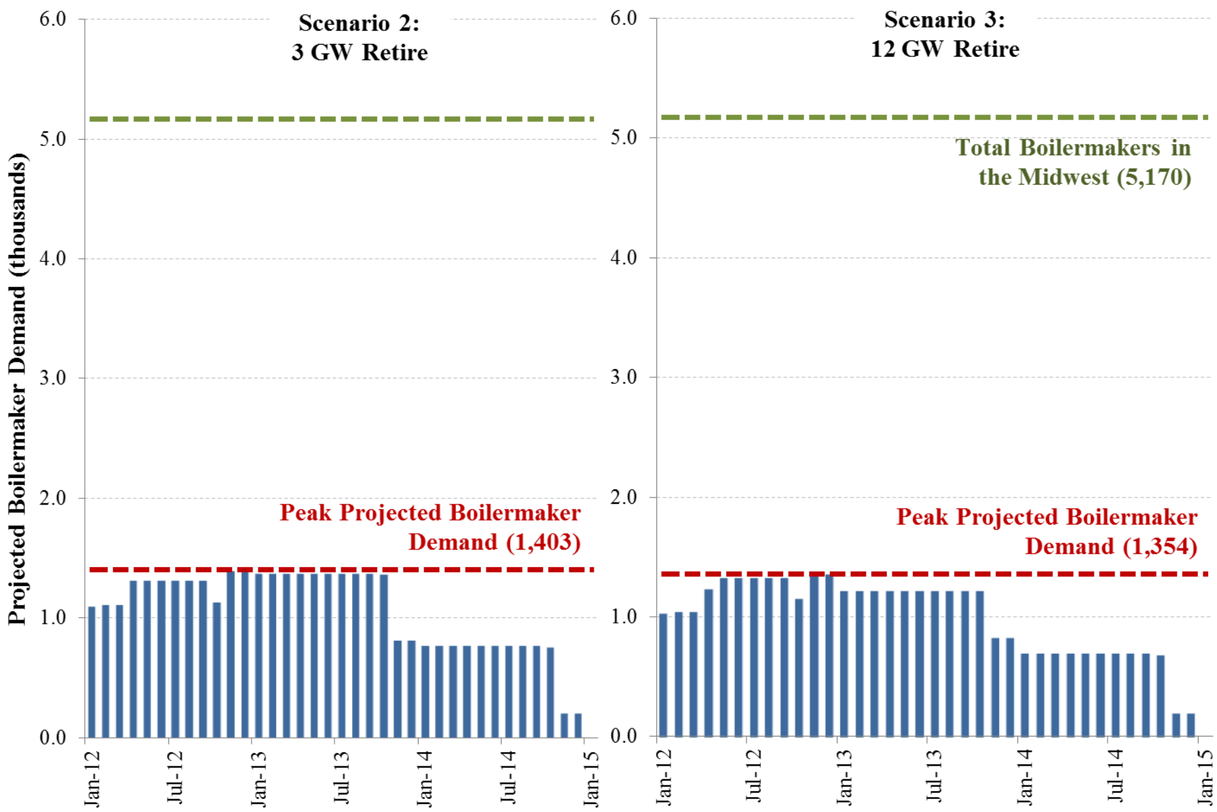

*Sources and Notes:*
Compiled from BLS data from 2002-2010, see BLS (2011).
Industry-specific boilermaker employment unavailable for 2005 and 2008.

32 Industry definition is based on North American Industry Classification System (NAICS). Definition for the Utility System Construction industry can be found in U.S. Census Bureau (2012).

In the Midwest, we used the projected retrofits and new generation capacity in MISO's Scenarios 2 and 3. As described in Appendix B, MISO projects in Scenario 2 that 61 GW of the coal fleet will need to install retrofits, but that no new gas CCs or CTs will be needed beyond those already under construction. In Scenario 3, due to higher coal retirements, MISO expects fewer retrofits (52 GW of the coal fleet) but expects more new generation (7 GW of new gas CCs and 2 GW of new gas CTs). As shown in Figure 22, we project the maximum monthly demand for boilermakers in the Midwest at 1,403 in Scenario 2 and 1,354 in Scenario 3, compared to a total of 5,170 boilermakers employed in Midwestern states as of 2011. Therefore, our projected maximum monthly demand for boilermakers in the MISO region represents about 30% of total supply in the region.

Requiring 30% of all boilermakers in the utility system construction industry may be a challenge, if the Midwest is similar to the nation with only 9.8% of all boilermakers in this industry as of 2011.[33] Again, such a scale-up could be a major challenge and create a bottleneck in completing MATS deployments without substantial cost over-runs or project delays. As with the national estimates, we should note that the total supply of boilermakers in the MISO region is not a hard cap, since additional labor may be available from other regions, industries, or training.

**Figure 22**
**Projected Need for Boilermakers in the MISO Region**




*Sources and Notes:*

Boilermaker demand consistent with MATS scenarios from V.B and labor requirements from Section III.A and Appendix C. Current boilermaker employment data from BLS (2010).

[33] Industry-specific data for employment are available nationally but are not available regionally, which is why those numbers are not reported here.

## D. MISO Retrofit Outage Analysis

Figure 23 shows a projection of the total coal plant planned outages that are likely to be needed in MISO in each of the retrofit upgrade scenarios that we examine. The dark blue portion of the chart shows "typical" outages that would be needed for the coal fleet, assuming that all plants will need 23 days of planned outages per year.[34] We also evaluate the incremental outage duration that would be needed for each type of retrofit as reported in Table 3 above. For simplicity, we assume that outages can be scheduled optimally such that all outages are uniformly realized over each 90-day spring and fall outage season. This is an optimistic assumption that will generally understate the potential system impacts and difficulty in absorbing these planned outages. On the other hand, MISO will have some ability to mitigate the impacts of these outages by scheduling a portion of planned outages in other months; MISO has already begun to analyze its ability to schedule outages during other months.[35]

The figure shows that MISO will have to prepare for approximately 4 GW of additional average outages during the four MATS compliance seasons prior to the MATS deadline and 1-year extension deadline. This is approximately 40% more simultaneous coal outages than MISO would likely have to schedule if there were no coal retrofits. These 4 GW of incremental outages are a substantially greater concern in the high-retirement scenarios than in the low-retirement scenarios because the high-retirement scenarios will also have a lower reserve margin and less ability to schedule a large number of simultaneous outages. However, we note that some of these concerns could be mitigated by scheduling some of the outages outside the regular seasons for planned outages.

MISO has already begun to analyze its total system capability to absorb incremental outages during the traditional outage season, finding that it has substantial capability to schedule outages during the winter months December through February, in addition to the traditional spring and fall outage seasons. MISO's initial analysis indicates that its system has the capability of absorbing more than 27 GW of simultaneous outages at the 2012 installed reserve margin level, whether these outages are scheduled over 6 or 9 months.[36] Even after accounting for modest retirements in Scenarios 1 and 2, it appears that MISO would have no difficulty absorbing the 4 GW of incremental outages that may be needed for MATS.[37]

However, in Scenario 3 with 12 GW of retirements, MISO's ability to absorb large simultaneous outages is likely to be substantially diminished, possibly to less than 16 GW by 2015. In this case, there would be only approximately 4 GW of slack in the 6-month outage season with which to absorb non-coal planned outages and account for imperfect outage scheduling. Moving to a 9-

34 Based on the average number of planned outage days for all coal plants in the U.S. from NERC 2010 GADS data, from Ventyx (2012). Note that this is less than the average individual outage duration as identified from analyzing CEMS data in Section III.B because, as explained previously, by using CEMS data we were not able to distinguish planned outages from maintenance, forced, and economic outages.

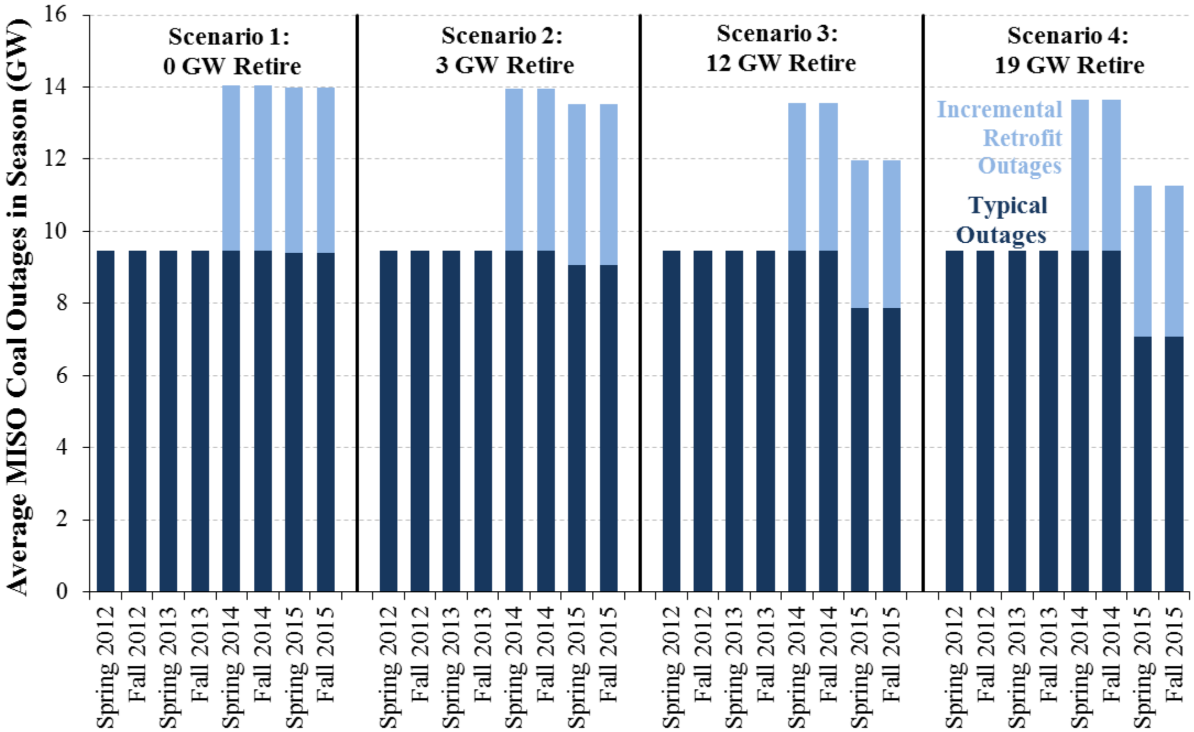
35 See MISO (2012), p. 6.

36 Average of 6 or 9 month outage season from MISO (2012), p. 6.

37 Based on a rough calculation of outage capability using the average over 6 or 9 months from 2012 and adjusting downward for projected retirements. Outages needed for coal are as displayed in Figure 23 for 6 months or the same quantity of outage days divided over 9 months.

month outage window is likely to create enough flexibility to absorb this concern.[38] Scenario 4 with 19 GW of retirements would be highly problematic, however, with only approximately 10 GW available over the 9-month outage window and a total of 7.5 GW needed for coal units alone. This would leave little room for imperfect scheduling or non-coal outages.

**Figure 23**
**Projected Average Seasonal Coal Planned Outages Needed in MISO**




*Sources and Notes:*

"Typical" outages are the average needed coal plant outages given the installed coal fleet for that season based on average NERC GADS planned outage rates.

"Incremental retrofit" outages are the additional average outages that will be needed in each season for longer outages associated with retrofit upgrades.

## VI. SUMMARY OF FINDINGS

In evaluating the feasibility of the entire coal feet to meet MATS by the compliance deadline, we found that it is very likely that the industry will run into delays and bottlenecks, while MISO may face an operational challenge in managing outage scheduling. With respect to the timeline needed for retrofits, we find that some types of upgrades can be implemented before 2015 without difficulty, including ACI and DSI, which can be implemented within approximately a year and a half. However, most projects have a longer lead time of approximately 3-4 years including wet and dry FGD, baghouse, ESP, and SCR retrofits, as well as new gas CTs and CCs.

Some of these long-lead projects will be able to come online prior to the MATS deadline, particularly as many of them are already under development. Many plant owners have already

38 A rough calculation shows that the outages needed for coal would be approximately 8 GW over 9 months, compared to approximately 16 GW available for all outages.

announced upgrade plans, although many others are likely still in the scoping phase. For the retrofit projects that need state commission approval of cost recovery to move forward, their ability to meet the MATS deadline will in part depend on the states' speed of approval when evaluating a large number of projects at once. These long lead times introduce a substantial concern for any long-lead projects that are initiated late, both due to the timing constraint and due to the potential for difficulty in obtaining the necessary engineering and construction support during a period of very high demand.

To evaluate the scale of the supply chain demands from MATS, we compared projected retrofit and new build demands against the historical maximum for the industry in the U.S. and nationally. We separately looked at retrofits and new builds on a Wet FGD-equivalent basis, converting the MW of upgraded or built capacity into one equivalent unit based on capital costs. This approach reflects our assumption that capital costs are a reasonable indicator of the demands that a particular retrofit will impose on labor and equipment supply chains. We find that MATS will require retrofit and new build activities that exceed the historical industry maximum in the Midwest by 51%-162% based on MISO's projected retrofit requirements and individual plant owner announcements. For the nationwide retrofits, the needs imposed by MATS could be substantially below historical maximums if the EPA's projections are correct, or up to 93% above historical maximums if industry estimates are more accurate. We believe that the EPA estimates may be optimistic while industry estimates may be pessimistic, especially in the highest retrofit cases.

It appears that MATS will require a ramp up in labor, engineering, equipment, and construction that is likely to introduce substantial bottlenecks locally or nationally. These bottlenecks are likely to introduce delays or cost escalation, for example, if certain craft labor categories or qualified EPC firms are in short supply. The competitive marketplace will find opportunities to mitigate such concerns (*e.g.*, by increasing labor supply with training, relocation, and overtime) but such measures are costly and time-consuming.

We evaluated the potential for craft labor to become a bottleneck that could introduce project delays. Based on our estimates of typical craft labor requirements for retrofits and new construction, we projected a time profile of craft labor required for MATS compliance. Comparing projected labor needs against the current labor supply for each craft revealed that boilermakers are the most likely bottleneck. As many as 7,590 boilermakers (or 40% of boilermakers currently employed nationally) could be needed to complete the projected retrofits and new generation construction by 2015. This potential demand is more than four times the number of boilermakers (1,850) currently employed in the Utility System Construction Industry.[39] Therefore, meeting the projected demand for boilermakers will likely require a combination of adjustments on the supply side, including training new labor, relocation, extending work hours, and attracting craft labor from other industries.

Finally, we examined the potential impacts of MATS on MISO's outage scheduling process by examining the length of planned outages that coal units need in typical years compared with the duration of outages associated with plant retrofits. Based on our interviews with project

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39 According to the Bureau of Labor Statistics definitions, the Utility System Construction Industry includes utility construction activities in power, communication, oil, gas, water and sewer sectors, see U.S. Census Bureau (2012).

developers and electric utilities, we understand that most of the construction and installation associated with retrofits can be completed while the plant is operating, although final tie-in to major plant systems can only be done during a plant outage. These tie-ins will usually be scheduled concurrently with other standard maintenance during a planned outage but will require a longer than typical outage for completion. Based on an analysis of historical plant operations for coal plants, we estimate that some upgrades such as Dry FGD, DSI, SNCR, and ACI require that the outage duration need only be extended a few days or a week, although some types of upgrades impose much longer outages. Wet FGD, baghouse, and SCR retrofits are likely to require outages be extended by approximately three weeks.

Considering the fleet-wide impacts of these outages, it appears that MISO may have to schedule approximately 45% more MW of coal outages per season for MATS compliance by Fall 2015 (which assumes many plants will gain a 1-year compliance extension). The impact of these additional outages is further exacerbated by the fact that a substantial fraction of coal plants are likely to retire rather than comply with MATS, hence reducing the system's ability to absorb additional outages. Based on MISO's initial analysis of the fleet's ability to absorb outages, it appears that the total quantity of outages for MATS could be easily absorbed and scheduled in its low retirement scenarios. However, in MISO's 12 GW retirement scenario, it appears that MISO may only be able to absorb these outages by extending its typical 6-month (fall and spring) outage season to a 9-month (fall, winter, and spring) season. In MISO's even higher 19 GW retirement scenario, it appears likely that the RTO would not be able to schedule all of the needed outages even in a 9-month window without facing reliability concerns or gaining an additional 1-year reliability extension to 2017.

Overall, meeting MATS will be a major challenge for the industry, states, and MISO for a number of reasons. The industry will need to install retrofits at a pace and scale that exceeds the historical demonstrated capability, while the system operator is likely to experience a substantial operational challenge in the transition.

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## LIST OF ACRONYMS

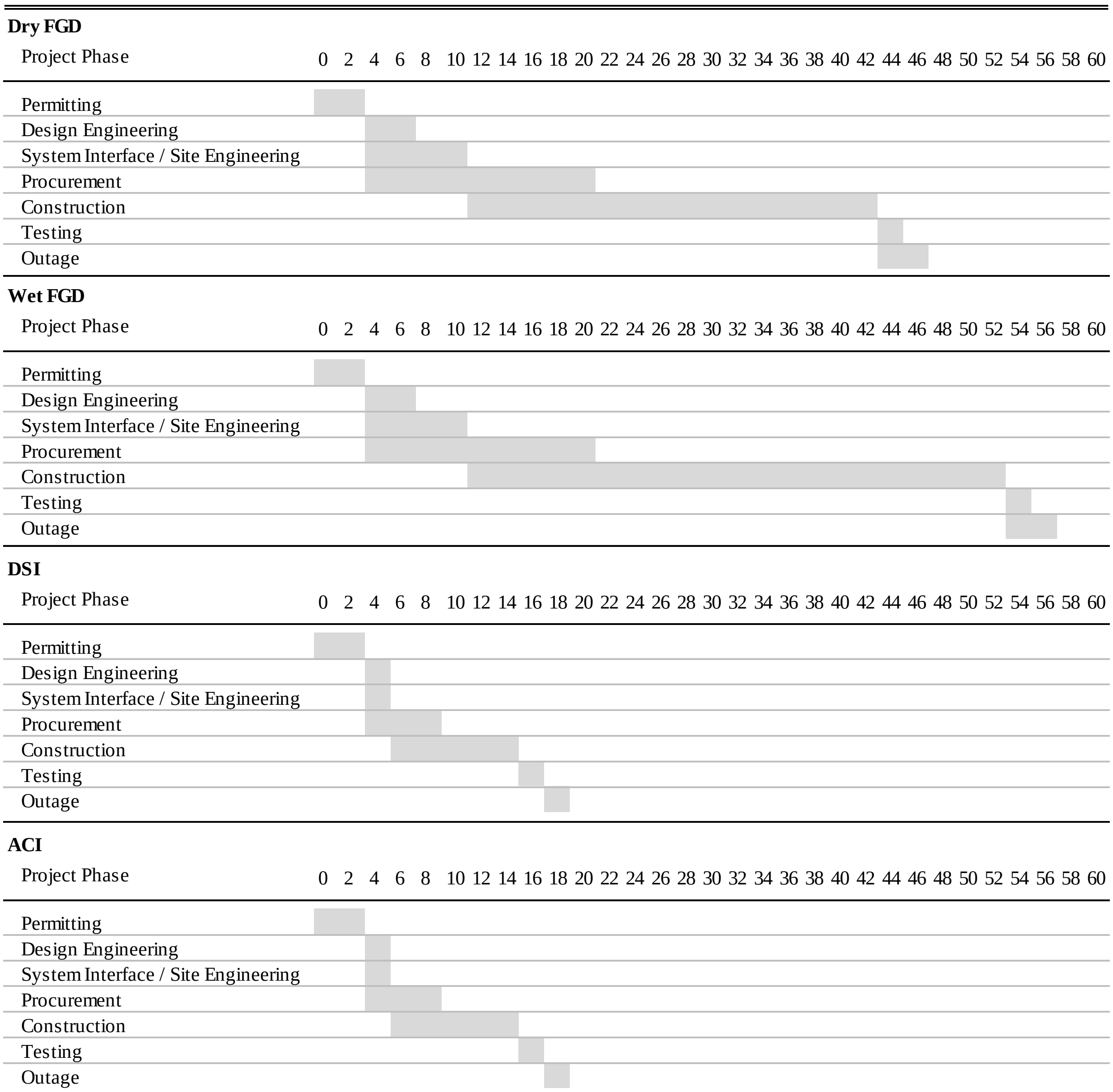
| | |
|---|---|
| ACI | Activated Carbon Injection |
| BLS | Bureau of Labor Statistics |
| CAIR | Clean Air Interstate Rule |
| CC | Combined Cycle |
| CT | Combustion Turbine |
| CSAPR | Cross-State Air Pollution Rule |
| DOE | Department of Energy |
| DSI | Dry Sorbent Injection |
| EEI | Edison Electric Institute |
| EIA | Energy Information Administration |
| EPA | Environmental Protection Agency |
| EPRI | Electric Power Research Institute |
| ESP | Electrostatic Precipitator |
| FGD | Flue Gas Desulfurization |
| GADS | Generating Availability Data System |
| ICAC | Institute of Clean Air Companies |
| ICAP | Installed Capacity |
| ICF | ICF International |
| IEc | Industrial Economics, Incorporated |
| MATS | Mercury and Air Toxics Standards |
| MISO | Midwest Independent Transmission System Operator |
| NERC | North American Electric Reliability Corporation |
| RPS | Renewable Portfolio Standard |
| SCR | Selective Catalytic Reduction |
| SNCR | Selective Non-catalytic Reduction |
| UARG | Utility Air Regulatory Group |
| URS | URS Corporation |

**APPENDICES**

## APPENDIX A. TIMELINES FOR TYPICAL ENVIRONMENTAL RETROFIT PROJECTS

This appendix contains Figure 24 and Figure 25 showing our estimated timelines for various environmental retrofit projects.

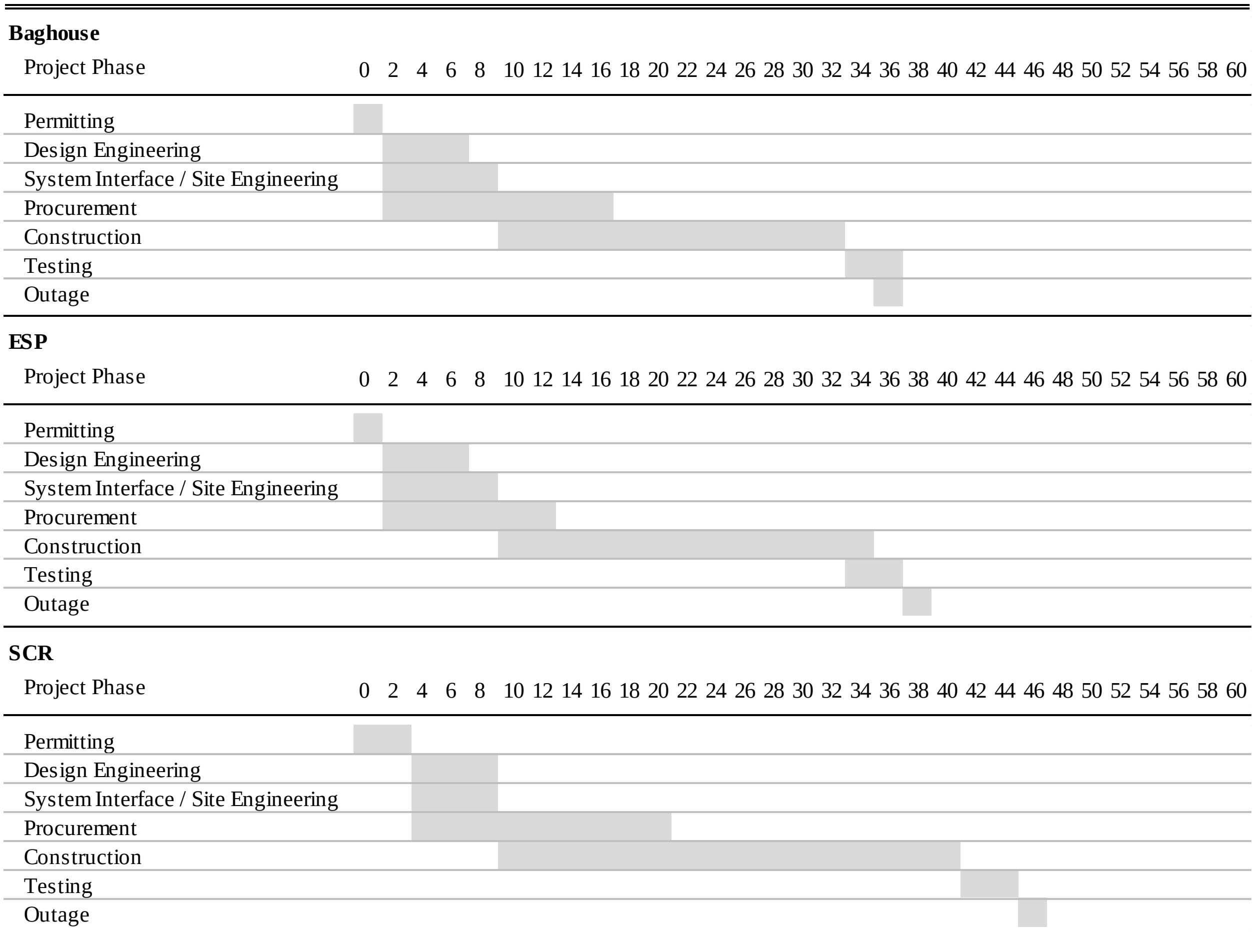
**Figure 24**
**Typical Timelines for Dry FGD, Wet FGD, DSI and ACI Retrofit Projects**




*Sources and Notes:*

Based on interviews with electric utilities (AEP, Dairyland Power Cooperative, Detroit Edison, Dominion, Duke, First Energy, Indianapolis Power & Light, TVA, Tucson Electric Power, and Wisconsin Electric) and equipment manufacturing and construction companies (Babcock and Wilcox, Bechtel, Washington Group, Alstom, IHI Corporation, and Foster Wheeler).

**Figure 25**
**Typical Timelines for Baghouse, ESP, and SCR Retrofit Projects**




*Sources and Notes:*

Based on interviews with electric utilities (AEP, Dairyland Power Cooperative, Detroit Edison, Dominion, Duke, First Energy, Indianapolis Power & Light, TVA, Tucson Electric Power, and Wisconsin Electric) and equipment manufacturing and construction companies (Babcock and Wilcox, Bechtel, Washington Group, Alstom, IHI Corporation, and Foster Wheeler).

## APPENDIX B. PROJECTED RETROFITS AND NEW GENERATION PLANTS IN MISO

To supplement our summary of MISO's estimated new build, retirement, and coal retrofit projections from Section I.B, we provide a more detailed breakdown in the following table.

**Table 9**
**Estimated New Builds and Coal Retrofits in the MISO Region by 2015**

| | Scenario 1: EPA | | Scenario 2: 3k Retire | | Scenario 3: 12k Retire | | Scenario 4: 23k Retire | |
|---|---|---|---|---|---|---|---|---|
| | MW | Count | MW | Count | MW | Count | MW | Count |
| **New Builds** | | | | | | | | |
| Gas - CC | 300 | 1 | 300 | 1 | 2,400 | 1 | 4,800 | 1 |
| Gas - CT | 0 | 0 | 0 | 0 | 7,200 | 0 | 16,800 | 0 |
| Coal | 2,299 | 4 | 2,299 | 4 | 2,299 | 4 | 2,299 | 4 |
| Wind | 1,943 | 28 | 1,943 | 28 | 1,943 | 28 | 1,943 | 28 |
| Other | 68 | 4 | 68 | 4 | 68 | 4 | 68 | 4 |
| **Total** | **4,610** | -- | **4,610** | -- | **13,910** | -- | **25,910** | -- |
| **Coal Retirements** | **520** | **10** | **3,214** | **51** | **12,305** | **151** | **18,625** | **196** |
| **Coal Retrofit Upgrade** | | | | | | | | |
| **No Need for Upgrade** | **7,650** | **59** | **7,492** | **49** | **6,967** | **27** | **3,329** | **9** |
| **One Control Only** | **25,676** | **69** | **25,448** | **67** | **24,237** | **59** | **17,200** | **34** |
| SCR | 0 | 0 | 0 | 0 | 0 | 0 | 3,532 | 6 |
| Dry FGD | 1,525 | 5 | 1,525 | 5 | 1,037 | 3 | 698 | 2 |
| Wet FGD | 670 | 2 | 670 | 2 | 670 | 2 | 670 | 2 |
| DSI | 167 | 2 | 167 | 2 | 79 | 1 | 0 | 0 |
| Baghouse | 23,315 | 60 | 23,087 | 58 | 22,452 | 53 | 12,300 | 24 |
| **Two Controls Only** | **23,911** | **71** | **23,559** | **67** | **20,520** | **47** | **14,518** | **33** |
| SCR + Dry FGD | 460 | 1 | 460 | 1 | 460 | 1 | 799 | 2 |
| SCR + Baghouse | 0 | 0 | 0 | 0 | 0 | 0 | 8,147 | 19 |
| SNCR + ACI | 374 | 1 | 374 | 1 | 374 | 1 | 0 | 0 |
| Dry FGD + Baghouse | 17,672 | 41 | 17,672 | 41 | 16,980 | 38 | 3,435 | 7 |
| Wet FGD + Baghouse | 2,489 | 4 | 2,489 | 4 | 2,489 | 4 | 1,694 | 3 |
| DSI + Baghouse | 1,490 | 11 | 1,314 | 9 | 101 | 1 | 0 | 0 |
| DSI + ACI | 1,426 | 13 | 1,250 | 11 | 116 | 2 | 69 | 1 |
| **Three Controls Only** | **13,266** | **103** | **11,310** | **78** | **6,994** | **28** | **16,789** | **39** |
| SCR + Wet FGD + ESP | 1,650 | 2 | 1,650 | 2 | 1,650 | 2 | 1,650 | 2 |
| SCR + Dry FGD + B | 783 | 2 | 783 | 2 | 783 | 2 | 11,316 | 23 |
| SCR + Wet FGD + B | 1,646 | 5 | 1,646 | 5 | 1,646 | 5 | 2,913 | 7 |
| SNCR + Wet FGD + B | 547 | 2 | 547 | 2 | 547 | 2 | 75 | 1 |
| SCR + DSI + B | 0 | 0 | 0 | 0 | 0 | 0 | 101 | 1 |
| Dry FGD + B + ACI | 563 | 1 | 563 | 1 | 563 | 1 | 0 | 0 |
| DSI + B + ACI | 7,677 | 90 | 5,721 | 65 | 1,405 | 15 | 218 | 2 |
| SCR + Dry FGD + ACI | 400 | 1 | 400 | 1 | 400 | 1 | 400 | 1 |
| SCR + DSI + ACI | 0 | 0 | 0 | 0 | 0 | 0 | 116 | 2 |
| **Four Controls** | **342** | **3** | **342** | **3** | **342** | **3** | **905** | **4** |
| SCR + Dry FGD + B + ACI | 0 | 0 | 0 | 0 | 0 | 0 | 563 | 1 |
| SNCR + Dry FGD + B + ACI | 99 | 1 | 99 | 1 | 99 | 1 | 99 | 1 |
| SNCR + DSI + B + ACI | 243 | 2 | 243 | 2 | 243 | 2 | 243 | 2 |
| **Any Control** | **63,196** | **246** | **60,659** | **215** | **52,094** | **137** | **49,412** | **110** |
| **Wet FGD Equivalent** | **58,725** | -- | **57,259** | -- | **52,017** | -- | **53,802** | -- |

*Sources and Notes:*
Data from MISO (2011) and Ventyx (2012); new generation includes plants under and MISO-projections.

## APPENDIX C. ESTIMATED LABOR REQUIREMENTS FOR RETROFIT PROJECTS

As explained in the earlier Section III.A, along with labor estimates for a dry FGD project, we developed estimates of the total person-months of labor that would be required to install various types of retrofit labor. We present here detailed tables of labor requirements for wet FGD, baghouse, ESP, SCR, DSI, and ACI retrofit projects.

**Table 10**
**Typical Labor Needs for Wet Scrubber Retrofit Projects (Person-Months)**

| Labor Type | Permitting | Design Engineering | System Interface / Site Engineering | Procurement | Construction | Testing | Outage | Total Project |
|---|---|---|---|---|---|---|---|---|
| Design Engineers | 3 | 31 | 16 | 37 | 114 | 0 | 0 | 201 |
| Construction / Site Engineers | 0 | 8 | 136 | 25 | 715 | 13 | 5 | 902 |
| Licensing Engineers | 14 | 5 | 11 | 25 | 57 | 0 | 0 | 112 |
| Procurement Engineers | 0 | 14 | 0 | 61 | 143 | 0 | 0 | 218 |
| Project Managers | 5 | 5 | 0 | 25 | 57 | 1 | 1 | 95 |
| Construction Managers | 0 | 5 | 0 | 0 | 86 | 2 | 0 | 93 |
| First Line Supervisors | 0 | 0 | 0 | 0 | 229 | 0 | 0 | 229 |
| Plumbers, Pipefitters and Steam Fitters | 0 | 0 | 0 | 0 | 1,001 | 0 | 0 | 1,001 |
| Boilermakers | 0 | 0 | 0 | 0 | 686 | 0 | 0 | 686 |
| Electronic and Control Systems Specialists | 0 | 0 | 0 | 0 | 372 | 0 | 0 | 372 |
| Pipe Layers | 0 | 0 | 0 | 0 | 629 | 0 | 0 | 629 |
| Electrician - In-House Systems | 0 | 0 | 0 | 0 | 229 | 0 | 0 | 229 |
| Electrician - Power Line Installers | 0 | 0 | 0 | 0 | 229 | 0 | 0 | 229 |
| Iron/steel Workers | 0 | 0 | 0 | 0 | 429 | 0 | 0 | 429 |
| Brickmasons and Blockmasons | 0 | 0 | 0 | 0 | 629 | 0 | 0 | 629 |
| Concrete Finishers | 0 | 0 | 0 | 0 | 200 | 0 | 0 | 200 |
| Operator Pile Drivers | 0 | 0 | 0 | 0 | 114 | 0 | 0 | 114 |
| Carpenters | 0 | 0 | 0 | 0 | 543 | 0 | 0 | 543 |
| General Construction Labor | 0 | 0 | 0 | 0 | 1,602 | 0 | 0 | 1,602 |
| Insulation Workers | 0 | 0 | 0 | 0 | 229 | 0 | 0 | 229 |
| Reinforcing Iron and Rebar Workers | 0 | 0 | 0 | 0 | 229 | 0 | 0 | 229 |
| Welders, Solderer | 0 | 0 | 0 | 0 | 372 | 0 | 0 | 372 |
| Construction Equipment Operators | 0 | 0 | 0 | 0 | 286 | 0 | 0 | 286 |
| Power Plant Operators | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 7 |

*Sources and Notes:*

Based on interviews with electric utilities (AEP, Dairyland Power Cooperative, Detroit Edison, Dominion, Duke, First Energy, Indianapolis Power & Light, TVA, Tucson Electric Power, and Wisconsin Electric) and equipment manufacturing and construction companies (Babcock and Wilcox, Bechtel, Washington Group, Alstom, IHI Corporation, and Foster Wheeler).

## Table 11
## Typical Labor Needs for Baghouse Retrofit Projects (Person-Months)

| Labor Type | Permitting | Design Engineering | System Interface / Site Engineering | Procurement | Construction | Testing | Outage | Total Project |
|---|---|---|---|---|---|---|---|---|
| Design Engineers | 4 | 64 | 17 | 34 | 69 | 0 | 0 | 189 |
| Construction / Site Engineers | 0 | 13 | 143 | 23 | 18 | 54 | 5 | 255 |
| Licensing Engineers | 5 | 9 | 11 | 23 | 34 | 0 | 0 | 82 |
| Procurement Engineers | 0 | 21 | 0 | 57 | 0 | 0 | 0 | 79 |
| Project Managers | 2 | 9 | 0 | 23 | 34 | 4 | 1 | 73 |
| Construction Managers | 0 | 9 | 0 | 0 | 51 | 9 | 0 | 69 |
| First Line Supervisors | 0 | 0 | 0 | 0 | 206 | 0 | 0 | 206 |
| Plumbers, Pipefitters and Steam Fitters | 0 | 0 | 0 | 0 | 600 | 0 | 0 | 600 |
| Boilermakers | 0 | 0 | 0 | 0 | 411 | 0 | 0 | 411 |
| Electronic and Control Systems Specialists | 0 | 0 | 0 | 0 | 137 | 0 | 0 | 137 |
| Pipe Layers | 0 | 0 | 0 | 0 | 257 | 0 | 0 | 257 |
| Electrician - In-House Systems | 0 | 0 | 0 | 0 | 206 | 0 | 0 | 206 |
| Electrician - Power Line Installers | 0 | 0 | 0 | 0 | 206 | 0 | 0 | 206 |
| Iron/steel Workers | 0 | 0 | 0 | 0 | 617 | 0 | 0 | 617 |
| Brickmasons and Blockmasons | 0 | 0 | 0 | 0 | 428 | 0 | 0 | 428 |
| Concrete Finishers | 0 | 0 | 0 | 0 | 206 | 0 | 0 | 206 |
| Operator Pile Drivers | 0 | 0 | 0 | 0 | 206 | 0 | 0 | 206 |
| Carpenters | 0 | 0 | 0 | 0 | 566 | 0 | 0 | 566 |
| General Construction Labor | 0 | 0 | 0 | 0 | 1,251 | 0 | 0 | 1,251 |
| Insulation Workers | 0 | 0 | 0 | 0 | 274 | 0 | 0 | 274 |
| Reinforcing Iron and Rebar Workers | 0 | 0 | 0 | 0 | 771 | 0 | 0 | 771 |
| Welders, Solderer | 0 | 0 | 0 | 0 | 617 | 0 | 0 | 617 |
| Construction Equipment Operators | 0 | 0 | 0 | 0 | 377 | 0 | 0 | 377 |
| Power Plant Operators | 0 | 0 | 0 | 0 | 0 | 17 | 0 | 17 |

*Sources and Notes:*

Based on interviews with electric utilities (AEP, Dairyland Power Cooperative, Detroit Edison, Dominion, Duke, First Energy, Indianapolis Power & Light, TVA, Tucson Electric Power, and Wisconsin Electric) and equipment manufacturing and construction companies (Babcock and Wilcox, Bechtel, Washington Group, Alstom, IHI Corporation, and Foster Wheeler).

## Table 12
## Typical Labor Needs for ESP Retrofit Projects (Person-Months)

| Labor Type | Permitting | Design Engineering | System Interface / Site Engineering | Procurement | Construction | Testing | Outage | Total Project |
|---|---|---|---|---|---|---|---|---|
| Design Engineers | 2 | 9 | 14 | 19 | 59 | 0 | 0 | 104 |
| Construction / Site Engineers | 0 | 2 | 118 | 13 | 369 | 44 | 4 | 551 |
| Licensing Engineers | 3 | 1 | 9 | 13 | 30 | 0 | 0 | 56 |
| Procurement Engineers | 0 | 3 | 0 | 32 | 0 | 0 | 0 | 35 |
| Project Managers | 1 | 1 | 0 | 13 | 30 | 4 | 1 | 49 |
| Construction Managers | 0 | 1 | 0 | 0 | 44 | 7 | 0 | 53 |
| First Line Supervisors | 0 | 0 | 0 | 0 | 177 | 0 | 0 | 177 |
| Plumbers, Pipefitters and Steam Fitters | 0 | 0 | 0 | 0 | 517 | 0 | 0 | 517 |
| Boilermakers | 0 | 0 | 0 | 0 | 355 | 0 | 0 | 355 |
| Electronic and Control Systems Specialists | 0 | 0 | 0 | 0 | 207 | 0 | 0 | 207 |
| Pipe Layers | 0 | 0 | 0 | 0 | 207 | 0 | 0 | 207 |
| Electrician - In-House Systems | 0 | 0 | 0 | 0 | 355 | 0 | 0 | 355 |
| Electrician - Power Line Installers | 0 | 0 | 0 | 0 | 295 | 0 | 0 | 295 |
| Iron/steel Workers | 0 | 0 | 0 | 0 | 665 | 0 | 0 | 665 |
| Brickmasons and Blockmasons | 0 | 0 | 0 | 0 | 310 | 0 | 0 | 310 |
| Concrete Finishers | 0 | 0 | 0 | 0 | 207 | 0 | 0 | 207 |
| Operator Pile Drivers | 0 | 0 | 0 | 0 | 207 | 0 | 0 | 207 |
| Carpenters | 0 | 0 | 0 | 0 | 207 | 0 | 0 | 207 |
| General Construction Labor | 0 | 0 | 0 | 0 | 532 | 0 | 0 | 532 |
| Insulation Workers | 0 | 0 | 0 | 0 | 177 | 0 | 0 | 177 |
| Reinforcing Iron and Rebar Workers | 0 | 0 | 0 | 0 | 650 | 0 | 0 | 650 |
| Welders, Solderer | 0 | 0 | 0 | 0 | 650 | 0 | 0 | 650 |
| Construction Equipment Operators | 0 | 0 | 0 | 0 | 517 | 0 | 0 | 517 |
| Power Plant Operators | 0 | 0 | 0 | 0 | 0 | 14 | 0 | 14 |

*Sources and Notes:*

Based on interviews with electric utilities (AEP, Dairyland Power Cooperative, Detroit Edison, Dominion, Duke, First Energy, Indianapolis Power & Light, TVA, Tucson Electric Power, and Wisconsin Electric) and equipment manufacturing and construction companies (Babcock and Wilcox, Bechtel, Washington Group, Alstom, IHI Corporation, and Foster Wheeler).

## Table 13
## Typical Labor Needs for SCR Retrofit Projects (Person-Months)

| Labor Type | Permitting | Design Engineering | System Interface / Site Engineering | Procurement | Construction | Testing | Outage | Total Project |
|---|---|---|---|---|---|---|---|---|
| Design Engineers | 12 | 12 | 14 | 42 | 100 | 0 | 0 | 180 |
| Construction / Site Engineers | 0 | 2 | 117 | 28 | 622 | 58 | 6 | 833 |
| Licensing Engineers | 16 | 2 | 9 | 28 | 50 | 0 | 0 | 104 |
| Procurement Engineers | 0 | 4 | 0 | 70 | 0 | 0 | 0 | 74 |
| Project Managers | 6 | 2 | 0 | 28 | 50 | 5 | 1 | 91 |
| Construction Managers | 0 | 2 | 0 | 0 | 75 | 9 | 0 | 86 |
| First Line Supervisors | 0 | 0 | 0 | 0 | 299 | 0 | 0 | 299 |
| Plumbers, Pipefitters and Steam Fitters | 0 | 0 | 0 | 0 | 1,120 | 0 | 0 | 1,120 |
| Boilermakers | 0 | 0 | 0 | 0 | 846 | 0 | 0 | 846 |
| Electronic and Control Systems Specialists | 0 | 0 | 0 | 0 | 373 | 0 | 0 | 373 |
| Pipe Layers | 0 | 0 | 0 | 0 | 473 | 0 | 0 | 473 |
| Electrician - In-House Systems | 0 | 0 | 0 | 0 | 448 | 0 | 0 | 448 |
| Electrician - Power Line Installers | 0 | 0 | 0 | 0 | 448 | 0 | 0 | 448 |
| Iron/steel Workers | 0 | 0 | 0 | 0 | 796 | 0 | 0 | 796 |
| Brickmasons and Blockmasons | 0 | 0 | 0 | 0 | 747 | 0 | 0 | 747 |
| Concrete Finishers | 0 | 0 | 0 | 0 | 373 | 0 | 0 | 373 |
| Operator Pile Drivers | 0 | 0 | 0 | 0 | 373 | 0 | 0 | 373 |
| Carpenters | 0 | 0 | 0 | 0 | 572 | 0 | 0 | 572 |
| General Construction Labor | 0 | 0 | 0 | 0 | 1,120 | 0 | 0 | 1,120 |
| Insulation Workers | 0 | 0 | 0 | 0 | 299 | 0 | 0 | 299 |
| Reinforcing Iron and Rebar Workers | 0 | 0 | 0 | 0 | 747 | 0 | 0 | 747 |
| Welders, Solderer | 0 | 0 | 0 | 0 | 846 | 0 | 0 | 846 |
| Construction Equipment Operators | 0 | 0 | 0 | 0 | 547 | 0 | 0 | 547 |
| Power Plant Operators | 0 | 0 | 0 | 0 | 0 | 19 | 0 | 19 |

*Sources and Notes:*

Based on interviews with electric utilities (AEP, Dairyland Power Cooperative, Detroit Edison, Dominion, Duke, First Energy, Indianapolis Power & Light, TVA, Tucson Electric Power, and Wisconsin Electric) and equipment manufacturing and construction companies (Babcock and Wilcox, Bechtel, Washington Group, Alstom, IHI Corporation, and Foster Wheeler).

## Table 14
## Typical Labor Needs for DSI Retrofit Projects (Person-Months)

| Labor Type | Permitting | Design Engineering | System Interface / Site Engineering | Procurement | Construction | Testing | Outage | Total Project |
|---|---|---|---|---|---|---|---|---|
| Design Engineers | 3 | 4 | 8 | 12 | 20 | 0 | 0 | 47 |
| Construction / Site Engineers | 0 | 2 | 10 | 12 | 50 | 75 | 7 | 156 |
| Licensing Engineers | 6 | 0 | 2 | 0 | 0 | 0 | 0 | 8 |
| Procurement Engineers | 0 | 0 | 0 | 72 | 0 | 0 | 0 | 72 |
| Project Managers | 0 | 0 | 0 | 12 | 10 | 6 | 1 | 29 |
| Construction Managers | 0 | 0 | 0 | 0 | 10 | 12 | 0 | 22 |
| First Line Supervisors | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 20 |
| Plumbers, Pipefitters and Steam Fitters | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Boilermakers | 0 | 0 | 0 | 0 | 149 | 0 | 0 | 149 |
| Electronic and Control Systems Specialists | 0 | 0 | 0 | 0 | 119 | 0 | 0 | 119 |
| Pipe Layers | 0 | 0 | 0 | 0 | 119 | 0 | 0 | 119 |
| Electrician - In-House Systems | 0 | 0 | 0 | 0 | 159 | 0 | 0 | 159 |
| Electrician - Power Line Installers | 0 | 0 | 0 | 0 | 119 | 0 | 0 | 119 |
| Iron/steel Workers | 0 | 0 | 0 | 0 | 199 | 0 | 0 | 199 |
| Brickmasons and Blockmasons | 0 | 0 | 0 | 0 | 179 | 0 | 0 | 179 |
| Concrete Finishers | 0 | 0 | 0 | 0 | 139 | 0 | 0 | 139 |
| Operator Pile Drivers | 0 | 0 | 0 | 0 | 119 | 0 | 0 | 119 |
| Carpenters | 0 | 0 | 0 | 0 | 219 | 0 | 0 | 219 |
| General Construction Labor | 0 | 0 | 0 | 0 | 348 | 0 | 0 | 348 |
| Insulation Workers | 0 | 0 | 0 | 0 | 40 | 0 | 0 | 40 |
| Reinforcing Iron and Rebar Workers | 0 | 0 | 0 | 0 | 219 | 0 | 0 | 219 |
| Welders, Solderer | 0 | 0 | 0 | 0 | 219 | 0 | 0 | 219 |
| Construction Equipment Operators | 0 | 0 | 0 | 0 | 100 | 0 | 0 | 100 |
| Power Plant Operators | 0 | 0 | 0 | 0 | 0 | 12 | 6 | 18 |

*Sources and Notes:*

Based on interviews with electric utilities (AEP, Dairyland Power Cooperative, Detroit Edison, Dominion, Duke, First Energy, Indianapolis Power & Light, TVA, Tucson Electric Power, and Wisconsin Electric) and equipment manufacturing and construction companies (Babcock and Wilcox, Bechtel, Washington Group, Alstom, IHI Corporation, and Foster Wheeler).

## Table 15
## Typical Labor Needs for ACI Retrofit Projects (Person-Months)

| Labor Type | Permitting | Design Engineering | System Interface / Site Engineering | Procurement | Construction | Testing | Outage | Total Project |
|---|---|---|---|---|---|---|---|---|
| Design Engineers | 5 | 13 | 0 | 0 | 16 | 3 | 5 | 42 |
| Construction / Site Engineers | 5 | 3 | 13 | 0 | 64 | 3 | 0 | 88 |
| Licensing Engineers | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| Procurement Engineers | 0 | 0 | 0 | 56 | 16 | 0 | 0 | 72 |
| Project Managers | 0 | 0 | 0 | 0 | 16 | 0 | 0 | 16 |
| Construction Managers | 0 | 0 | 0 | 0 | 16 | 0 | 0 | 16 |
| First Line Supervisors | 0 | 0 | 0 | 0 | 48 | 0 | 0 | 48 |
| Plumbers, Pipefitters and Steam Fitters | 0 | 0 | 0 | 0 | 96 | 0 | 0 | 96 |
| Boilermakers | 0 | 0 | 0 | 0 | 192 | 0 | 0 | 192 |
| Electronic and Control Systems Specialists | 0 | 0 | 0 | 0 | 64 | 0 | 0 | 64 |
| Pipe Layers | 0 | 0 | 0 | 0 | 64 | 0 | 0 | 64 |
| Electrician - In-House Systems | 0 | 0 | 0 | 0 | 64 | 0 | 5 | 69 |
| Electrician - Power Line Installers | 0 | 0 | 0 | 0 | 64 | 0 | 0 | 64 |
| Iron/steel Workers | 0 | 0 | 0 | 0 | 96 | 0 | 0 | 96 |
| Brickmasons and Blockmasons | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Concrete Finishers | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Operator Pile Drivers | 0 | 0 | 0 | 0 | 32 | 0 | 0 | 32 |
| Carpenters | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| General Construction Labor | 0 | 0 | 0 | 0 | 223 | 0 | 0 | 223 |
| Insulation Workers | 0 | 0 | 0 | 0 | 64 | 0 | 0 | 64 |
| Reinforcing Iron and Rebar Workers | 0 | 0 | 0 | 0 | 96 | 0 | 0 | 96 |
| Welders, Solderer | 0 | 0 | 0 | 0 | 96 | 0 | 0 | 96 |
| Construction Equipment Operators | 0 | 0 | 0 | 0 | 64 | 0 | 0 | 64 |
| Power Plant Operators | 0 | 0 | 0 | 0 | 0 | 64 | 5 | 69 |

*Sources and Notes:*

Based on interviews with electric utilities (AEP, Dairyland Power Cooperative, Detroit Edison, Dominion, Duke, First Energy, Indianapolis Power & Light, TVA, Tucson Electric Power, and Wisconsin Electric) and equipment manufacturing and construction companies (Babcock and Wilcox, Bechtel, Washington Group, Alstom, IHI Corporation, and Foster Wheeler).