

Assessment of startup period at coal-fired electric generating units

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1. Purpose

This analysis explores the time and gross load levels (electricity generation as a percentage of nameplate capacity) that may be needed for coal-fired electric generating units (EGUs) to control emissions with air pollution control devices (APCDs). The analysis uses historical electric output, heat input, and emission data from 2011 and 2012 as indicators to assess operation of APCDs at coal-fired EGUs. This information can aid in determining the end of startup and start of pollution control at coal-fired EGUs.

Abbreviations

APCD	air pollution control device(s)	mmBtu	million British thermal units (unit of energy)
CFB	circulating fluidized bed – boiler type	MW	megawatt(s) – one million watts
CO ₂	carbon dioxide	NO _x	nitrogen oxides
EGU	electric generating unit	PC	pulverized coal – boiler type
EPA	(U.S.) Environmental Protection Agency	SCR	selective catalytic reduction – NO _x control
FGD	flue gas desulfurization – SO ₂ and acid gases control	SO ₂	sulfur dioxide

Definitions

Emission rates: average mass emissions (in pounds) released per million British thermal unit (mmBtu) of heat input

Failed start: a startup event in which the EGU begins combusting fossil fuel and subsequently ceases combusting fossil fuel without generating any electricity. Failed starts may be planned or unplanned, and often occur when bringing a plant online after a maintenance outage.

Normal start: a startup event in which the EGU begins combusting fossil fuel and generates some measurable amount of electricity before ceasing fossil fuel combustion.

Startup event: initiation of fossil fuel combustion at an EGU following one or more hours of non-operation (i.e., no combustion)

- Hot start^a: A startup event in which the EGU was offline for 24 hours or less before starting to combust fossil fuels
- Warm start^a: A startup event in which the EGU was offline for 25 - 119 hours before starting to combust fossil fuels
- Cold start^a: A startup event in which the EGU was offline for 120 hours or more before starting to combust fossil fuels

^a Hot, warm, and cold starts are defined using turbine metrics presented in Lefton SA and Hilleman D, 2011. Make Your Plant Ready for Cycling Operation. *Power Magazine*. August 1. (http://www.powermag.com/issues/features/Make-Your-Plant-Ready-for-Cycling-Operations_3885.html).

2. Introduction

EPA received several comments concerning our definition of the end of startup in response to the proposed reconsideration for the Mercury and Air Toxics (MATS) Rule. Several commenters advocated that the startup period should not end when the EGU begins generating electricity or useful thermal energy as EPA proposed. Rather, commenters argued that startup should end at different times depending on whether the unit was subcritical or supercritical, and what types of controls were installed. Commenters stated that some APCDs, such as SCR, need up to 12 hours after electricity generation begins before they become operational. They also stated that CFB units become stable only after they reach approximately 40 percent load.

EPA examined available data concerning the types of EGUs on which the commenters focused: subcritical and supercritical units with FGD and SCR, and CFB units. This assessment required an hour-by-hour analysis of startup events using emissions, heat input, and electric output data from the EPA's Clean Air Markets Database¹ for the types of units identified by the commenters. Using this data, we calculated the average time, in hours, for specific types of units to achieve decile and quartile load bins (e.g., 10%, 20% and 25% of nameplate capacity) and for SO₂ and NO_x APCDs to begin reducing SO₂ and NO_x emission rates, respectively. This analysis offers insights into the startup process and the time required for SO₂ and NO_x APCDs to become effective at coal-fired EGUs. EPA believes that the removal efficacy of APCDs, as evidenced by hourly emission rates well below uncontrolled levels, may be used as an indicator of the end of the startup period for the purpose of the MATS rule.

3. Data and methodology

EPA collects the emission data analyzed in this paper under 40 CFR §75 (Part 75).² Most fossil fuel-fired EGUs report hourly emissions (e.g., SO₂, NO_x, CO₂) and operations (e.g., operating time, heat input, gross electricity generation) data on a quarterly basis.³ We used these data to identify all startup events at 414 PC EGUs with FGD and/or SCR APCDs and CFB boiler EGUs⁴ during calendar years 2011 and 2012.

The purpose of this paper is to assess commenters' claims that there are performance differences among combustion technologies and APCDs as they relate to startup events. **In light of the comments received** and to facilitate this assessment, we examined operating data by boiler type (PC supercritical, PC subcritical and CFB boilers) and control type. For SO₂ emissions, we examined PC boilers with FGD and CFB units. For NO_x emissions, we examined PC supercritical and PC subcritical boilers with SCR.

We excluded cogeneration units from this analysis because adequate steam production data were not available. In addition, because the focus of the analysis is on the performance of the APCDs, coal-fired EGUs

¹ The aggregated data set used in this analysis is included in the docket EPA-HQ-OAR-2009-0234; full data are available from the Clean Air Markets Database at <http://ampd.epa.gov/ampd>.

² Supercritical boiler type is drawn from EIA form 860 and EPA research. The analysis data set noted above includes this field. Form 860 (2011) data are available at <http://www.eia.gov/electricity/data/eia860/index.html>.

³ Sources report data at the monitor (stack) level but this study used data apportioned to the unit. For more information about Part 75, see the *Plain English Guide to the Part 75 Rule* at www.epa.gov/airmarkets/emissions/docs/plain_english_guide_part75_rule.pdf.

⁴ CFB boiler technologies are capable of controlling SO₂ by injecting limestone in the combustion bed. For purposes of this paper, a CFB boiler is considered an SO₂ APCD.

without FGD and/or SCR APCDs as of January 1, 2011, were excluded from the analysis.⁵ Finally, we excluded data during operating hours with the most conservative substitute data (i.e., maximum potential concentration, maximum potential flow)⁶ because these data may not be true representations of emissions.

For purposes of conducting this analysis, we defined a startup event as the initiation of fossil fuel combustion following one or more hours of non-operation (i.e., no combustion), which is consistent with the proposed definition of startup in the MATS reconsideration notice. For each startup event, we calculated the following values:

- Number of non-operating hours prior to the startup event (i.e., hours between previous cessation of combustion and start of combustion).
- Number of hours between start of combustion and start of electricity generation.⁷
- Gross electricity generation as a percent of nameplate capacity by hour following start of generation.
- Emission rates and heat input by hour after start of combustion and start of electricity generation.

For “normal” startup events – when an EGU begins generating electricity following the start of fossil fuel combustion – we calculated hourly emission rates, time to achieve specific gross load levels (e.g., 10%, 20% and 25% of nameplate generating capacity), and hourly emission rates after achieving specific gross load levels (e.g., 25% of nameplate capacity).

4. Results

During calendar years 2011 and 2012, there were 9,719 distinct startup events (see Table 1)⁸ – 9,467 at PC EGUs and 252 at CFB EGUs. Of these startup events, 2,147, or approximately 20%, were “failed” starts – a startup event in which an EGU begins combusting fossil fuel and subsequently ceases combusting fossil fuel without generating any electricity. Failed starts may be planned or unplanned, and often occur when bringing a plant online after a maintenance outage.

⁵ When a comparison is made between “uncontrolled” and “controlled” units, the uncontrolled data represent startup events at EGUs that did not have the relevant APCD. In other words, uncontrolled SO₂ emission rates are based on PC EGUs that have installed SCR, and therefore are a part of the data set, but have not installed an FGD APCD. For NO_x, “non-SCR” startup events are based on PC EGUs that have installed FGD but do not have an SCR. These units may, however, have other NO_x controls such as low-NO_x burners, overfired air, and/or selective non-catalytic reduction APCDs.

⁶ Part 75 requires the use of substitute data when a monitor is not working properly or has not been quality assured. See <http://www.epa.gov/airmarkets/emissions/continuous-factsheet.html>.

⁷ Reporting instructions for Part 75 allow the use of default megawatt values, typically 1 or 2, when combustion is underway but gross load is zero. For this study, we conservatively set the start of electricity generation from the hour where gross load exceeded 2.

⁸ Because startup events are grouped by boiler and control, a startup event may be counted more than once. For example, each startup event at a PC EGU with an FGD and SCR would be counted as a startup event at an FGD-equipped EGU and at an SCR-equipped EGU.

Table 1: Number of normal and failed starts by boiler and APCD types, years 2011 and 2012.

Boiler-control	Normal starts	Failed starts	Total starts
PC EGU	7,364	2,103	9,467
<i>Supercritical w/ FGD</i>	1,612	369	1,981
<i>Supercritical w/ SCR</i>	1,413	324	1,737
<i>Subcritical w/ FGD</i>	4,827	1,335	6,162
<i>Subcritical w/ SCR</i>	2,578	823	3,401
CFB EGU	208	44	252

The average EGU had between 9 and 10 startup events per year during 2011 – 2012, but data from a small number of EGUs indicated significantly more startup events, over 100 startup events in 2011 and 83 in 2012. For the 414 coal-fired EGUs in this analysis, the overall number of startup events remains reasonably consistent across both years.

4.1 Operations between start of combustion and start of generation

We analyzed emissions and operations data for each startup event from the start of fossil fuel combustion to the start of electricity generation. Specifically, we examined the length of time an EGU combusts fossil fuel before initiating electricity generation, giving consideration to the period of time the unit was offline and whether or not the unit successfully initiated electricity generation.

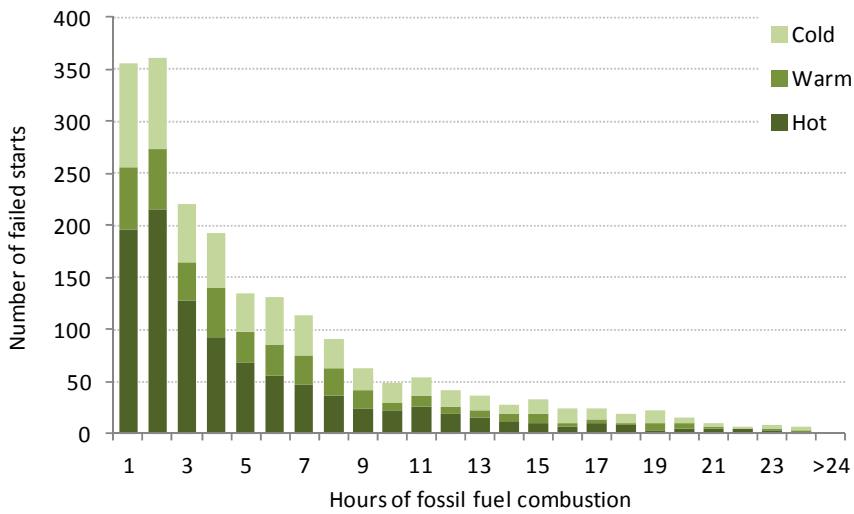
We explored these data to examine commenters’ claims that starting a coal-fired EGU is a complicated process that can take several hours to complete. Generally, during startup of a coal-fired boiler the operator slowly heats the boiler to avoid problems with boiler expansion and overheating of equipment (e.g., reheaters, superheaters).⁹ If the boiler is offline for a short time and does not experience significant temperature declines, the time between start of combustion and start of electricity generation may be very short. During a “cold start” – a startup event following an extended outage of 120 hours or more since the last instance of fuel combustion – Babcock and Wilcox¹⁰ states that larger coal-fired EGUs “may need four to six hours for startup.” Generally, natural gas or fuel oil is combusted during this time to slowly raise the temperature in the boiler. Natural gas and oil are used because of their low ignition temperature and ignition stability.

Approximately 20% of the startup events examined in this study failed to successfully generate electricity following the start of fossil fuel combustion. These failed starts can occur for a variety of safety and operating reasons. In general, these failed starts have a short duration—the average failed start combusted fossil fuel for less than 8 hours with a median of 4 hours. Figure 1 shows the distribution of hours of fossil fuel combustion during failed starts. Fossil fuel combustion during approximately 75% of the failed starts lasted 10 hours or less. The failed starts that combusted fossil fuel for more than 10 hours generally followed longer periods of downtime (e.g., extended maintenance events). The average time offline before such failed starts is approximately 360 hours.

⁹ Lefton SA and Hilleman D, 2011. Make Your Plant Ready for Cycling Operation. *Power Magazine*. August 1. (http://www.powermag.com/issues/features/Make-Your-Plant-Ready-for-Cycling-Operations_3885.html)

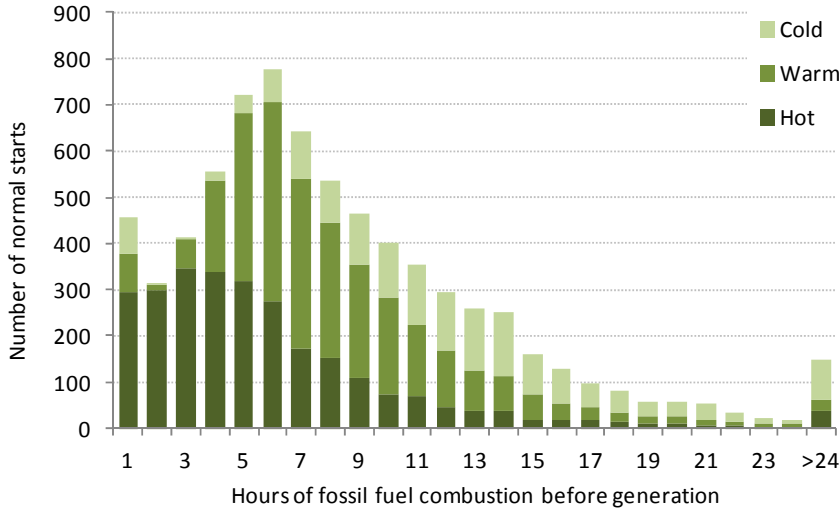
¹⁰ Kitto JB, Stultz SC, editors, 2005. *Steam: Its Generation and Use*. 41st ed. Barberton, Ohio: Babcock & Wilcox Company. P. 11-14.

Figure 1: Duration of fossil fuel combustion during failed startup events



More than 97% of the normal starts – a startup event in which an EGU begins combusting fossil fuel and subsequently generating electricity during at least one operating hour before the EGU ceases combusting fossil fuel – in this database were at PC EGUs. Following the start of fossil fuel combustion, PC EGUs began generating electricity in a relatively short period of time. On average, the time between start of fossil fuel combustion and start of generation was less than 9 hours (see Figure 2).

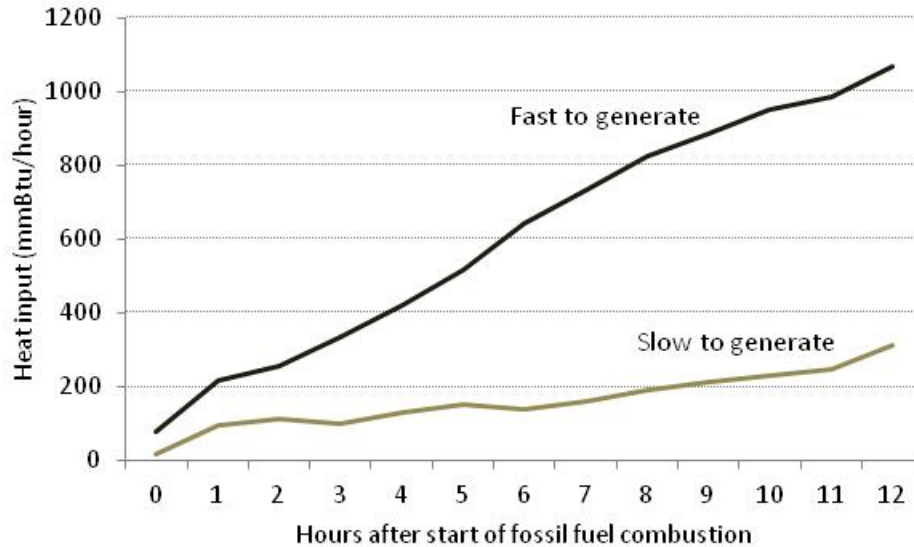
Figure 2: Duration of fossil fuel combustion prior to electricity generation during normal startup events at PC EGUs



Approximately 3% of the normal startup events in this analysis were at CFB boiler EGUs. For these startup events, the average time between start of fossil fuel combustion and start of generation was approximately 10 hours with a median of 8 hours, comparable to the study population as a whole. However, over 40% of startup events at CFB boiler EGUs had extended periods (10-75 hours) of fossil fuel combustion before electricity generation commenced. It is not evident why these CFB boiler EGUs combusted fuel for so many hours before generating electricity, but the hourly heat input during these “slow to generate” startup events (greater than 10 hours between start of fossil fuel combustion and start of electricity generation) is considerably lower than

the heat input during “fast to generate” starts (less than or equal to 10 hours between start of fossil fuel combustion and start of electricity generation) (see Figure 3).

Figure 3: Heat input per hour following start of fossil fuel combustion at CFB boiler EGUs



4.2 Operations following the start of generation

4.2.1 Pulverized coal EGUs

Following the start of generation, both supercritical and subcritical PC EGUs increased generation rapidly, achieving higher loads within the first few hours. Figure 4 shows that across startup events at supercritical PC EGUs, generation averaged approximately 30% of nameplate capacity by hour 3 and approximately 38% of nameplate capacity by hour 4. (Note: the yellow line is the average gross load as a percentage of nameplate capacity across all startup events at supercritical PC EGUs; the purple boxes and black whiskers are the quartile ranges.) Figure 5 shows that across startup events at subcritical PC EGUs, generation averaged approximately 33% of nameplate capacity by hour 2, 42% of nameplate capacity by hour 3, and 49% of nameplate capacity by hour 4.

Figure 4: Gross electricity generation as a percentage of nameplate capacity (MW) by hour following start of generation at supercritical PC EGUs

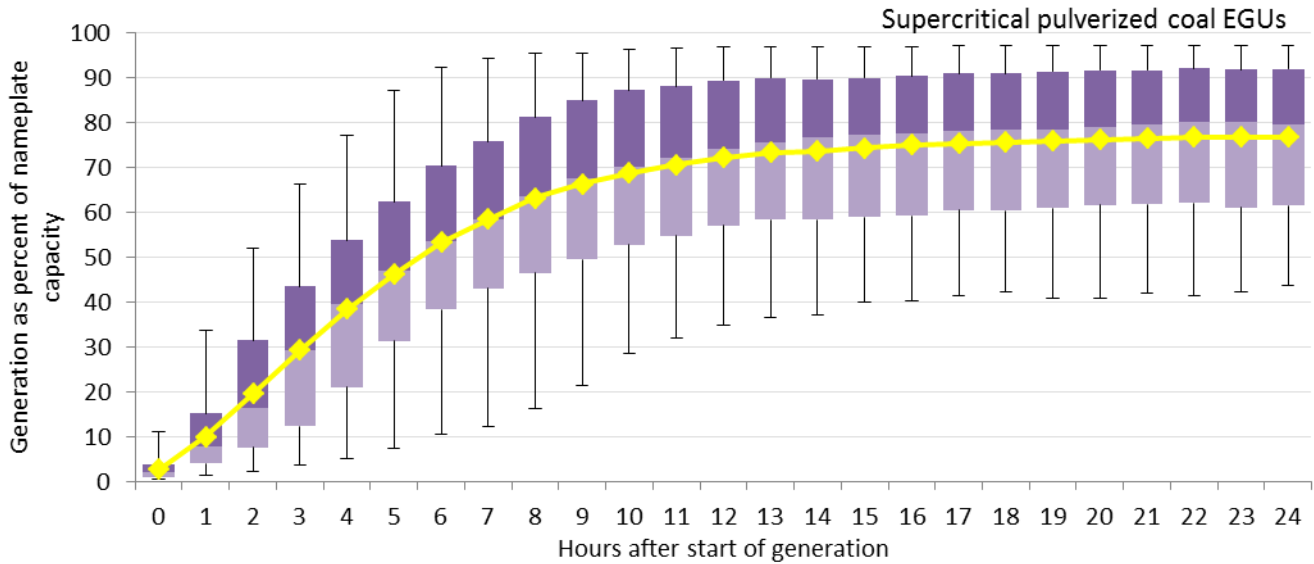
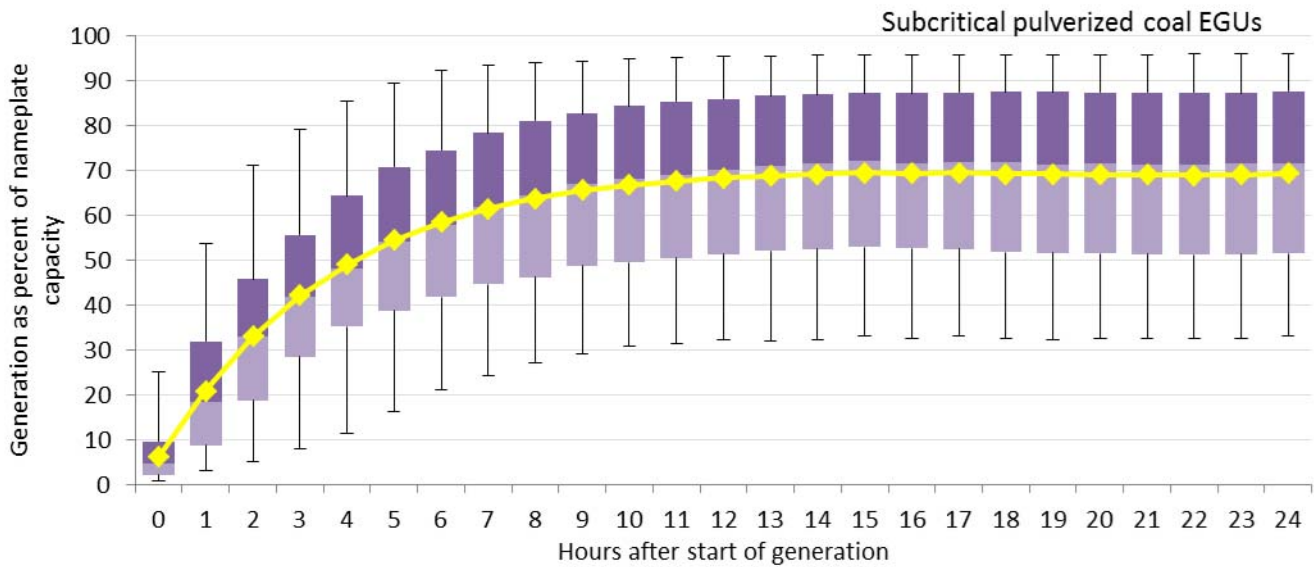


Figure 5: Gross electricity generation as a percentage of nameplate capacity (MW) by hour following start of generation at subcritical PC EGUs



During the majority of normal starts, supercritical (Figure 6) and subcritical (Figure 7) PC EGUs achieved 20% and 25% of nameplate capacity within the first few hours after the start of generation.

Figure 6: Hours after start of generation for supercritical PC EGUs to generate 20% (left) and 25% (right) of nameplate capacity

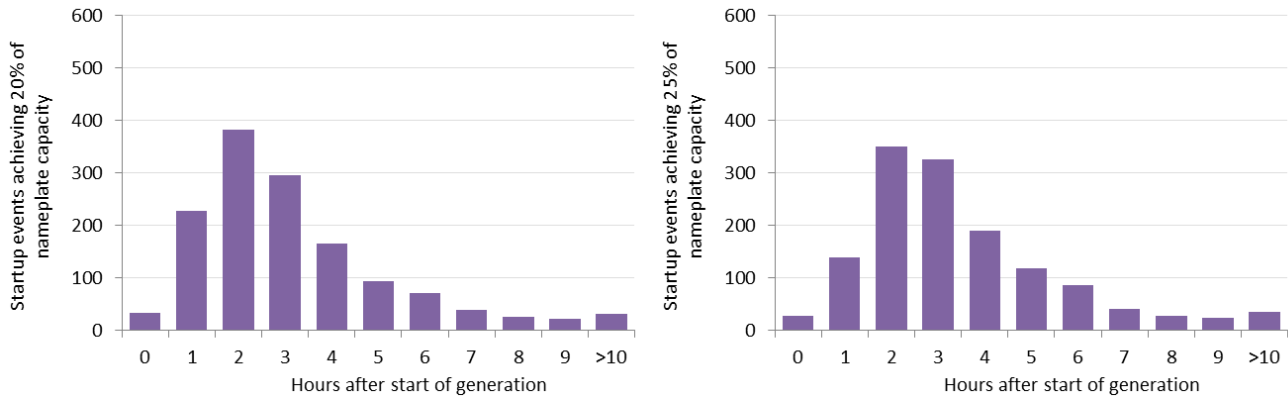
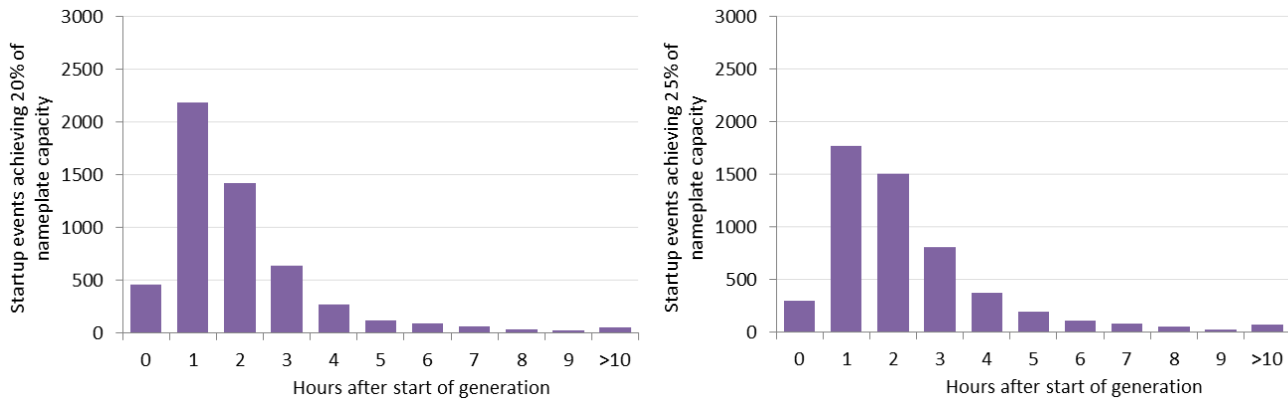


Figure 7: Hours after start of generation for subcritical PC EGUs to generate 20% (left) and 25% (right) of nameplate capacity



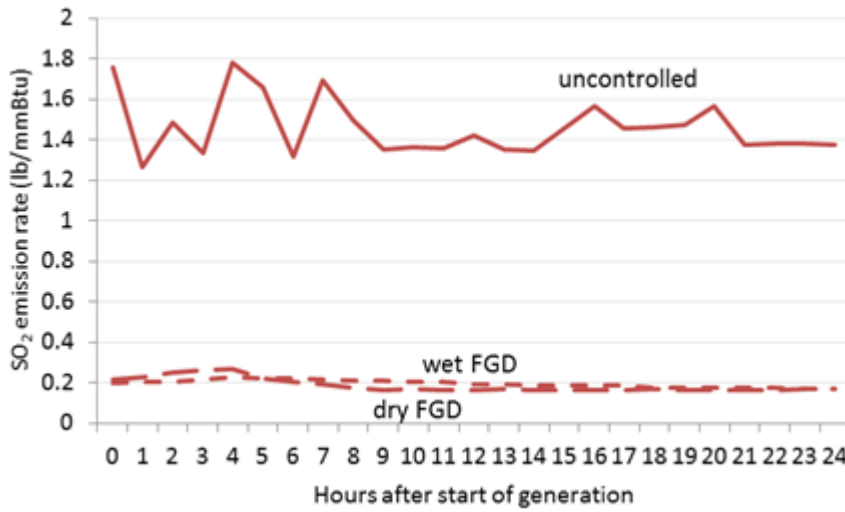
4.2.1.1 SO₂ emissions from supercritical PC EGUs with FGDs

Of the 1,802 normal startup events at supercritical PC EGUs, over 80% occurred at units with wet FGD and an additional 6% were at units with dry FGD (see Table 2). The average SO₂ emission rates for the hours following the start of generation are shown in Figure 8. The average SO₂ emission rates for normal starts at both dry FGD- and wet FGD-equipped supercritical PC EGUs are approximately 80%-90% lower across every hour (0-24) than the average SO₂ emission rates for normal starts at supercritical PC EGUs without FGDs (i.e., uncontrolled). This indicates that both wet FGD and dry FGD APCDs are able to begin capturing SO₂ emissions commensurate with the start of electricity generation.

Table 2: Number of normal starts at supercritical PC EGUs by SO₂ control type

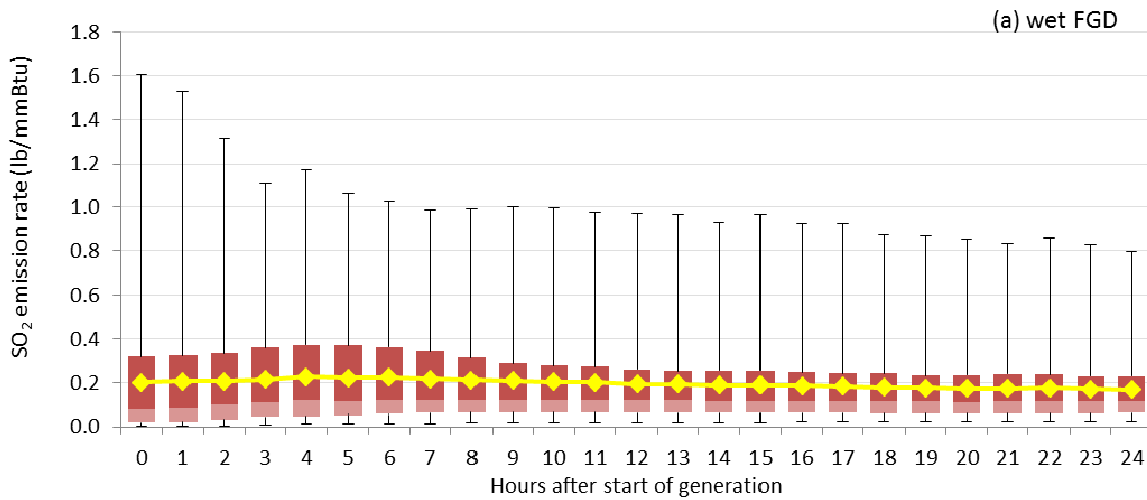
SO ₂ control type	Normal starts
Wet FGD	1,492
Dry FGD	120
Uncontrolled for SO ₂	190
Total	1,802

Figure 8: Average SO₂ emission rates following start of generation at supercritical PC EGUs by SO₂ control type



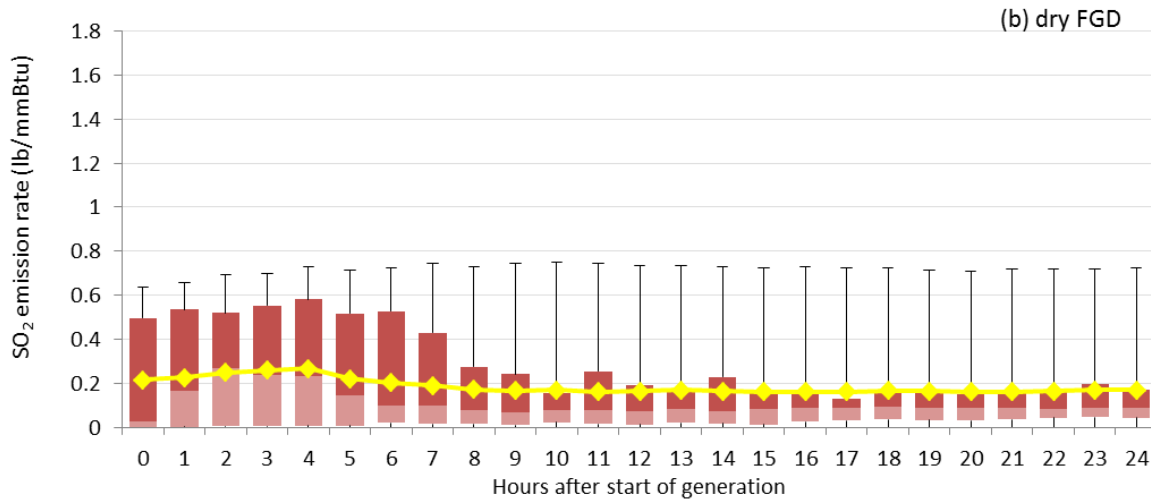
Figures 9 and 10 show the distribution of SO₂ emission rates during normal starts at supercritical PC EGUs with wet FGD (Figure 9) and dry FGD (Figure 10). (Note: the top and bottom 5% of emission rates are excluded from the chart;¹¹ the yellow line is the average emission rate across starts at supercritical PC EGUs with FGD; the red boxes and black whiskers are the quartile ranges.) The figures show that average and median SO₂ emission rates are low at the start of generation for the majority of normal starts, indicating that both wet FGD and dry FGD are likely operating at the start of generation.

Figure 9: Average SO₂ emission rates following start of generation at supercritical PC EGUs with wet FGDs



¹¹ A number of PC EGUs shut down in 2011 and 2012. Several startup events at these units had high SO₂ emissions for more than 24 hours after the start of generation indicating the FGD equipment was not in use. By excluding the top 5% of values, these outliers do not bias the analysis. For parity, we also excluded the bottom 5%.

Figure 10: Average SO₂ emission rates following start of generation at supercritical PC EGUs with dry FGDs



Following gross load levels greater than or equal to 25% of nameplate capacity, supercritical PC EGUs' SO₂ emission rates are relatively low and stable (see Figure 11 for wet FGD and Figure 12 for dry FGD). Both types of FGDs show declining average SO₂ emission rates by the third hour after reaching 25% load.

Figure 11: Average SO₂ emission rates following gross load levels greater than or equal to 25% of nameplate capacity at supercritical PC EGUs with wet FGDs

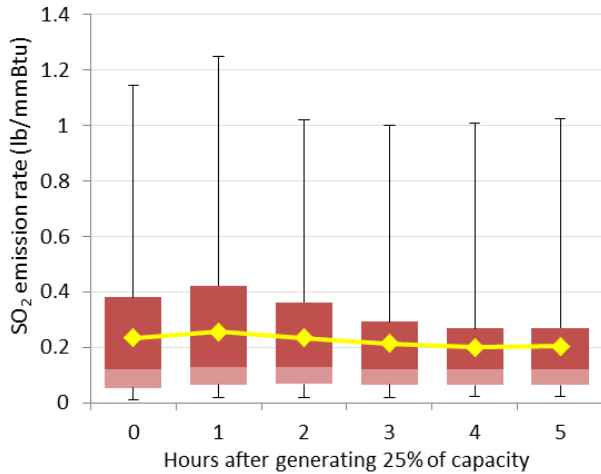
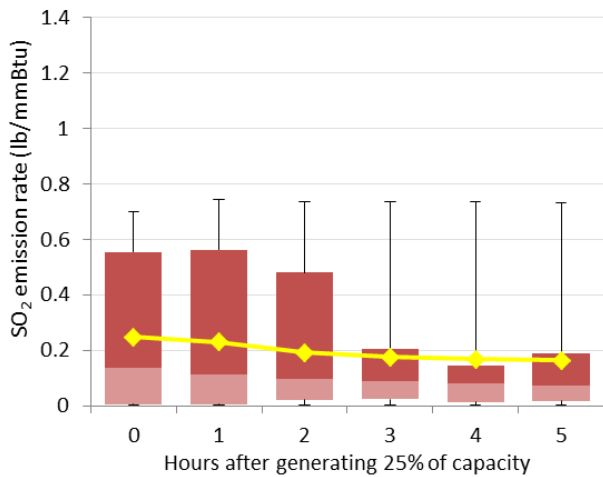


Figure 12: Average SO₂ emission rates following gross load levels greater than or equal to 25% of nameplate capacity at supercritical PC EGUs with dry FGDs



4.2.1.2 NO_x emissions from supercritical PC EGUs with SCRs

Commenters stated that SCRs need up to 12 hours following the start of generation to become operational. To evaluate this claim EPA examined hourly NO_x emissions at EGUs with and without SCR. Of the 1,802 normal startup events at supercritical PC EGUs, 78% were at supercritical PC EGUs with SCR (see Table 3). Nearly all of the remaining non-SCR supercritical PC EGUs have low-NO_x burners, over-fired air, and/or selective non-catalytic reduction installed. The average NO_x emission rates for the hours following the start of generation are shown in Figure 13. The average NO_x emission rates for SCR-equipped and non-SCR supercritical PC EGUs begin at approximately the same level but the rate for the SCR-equipped units grows slower and begins to decline by hour 5. This indicates that, on average, SCR APCDs are able to begin controlling NO_x emissions within a few hours following the start of electricity generation at supercritical PC EGUs.

Table 3: Number of normal starts at supercritical PC EGUs by NO_x control type

NO _x control type	Normal starts
SCR	1,413
non-SCR	389
Total	1,802

Figure 13: Average NO_x emission rates following start of generation at supercritical PC EGU by NO_x control type

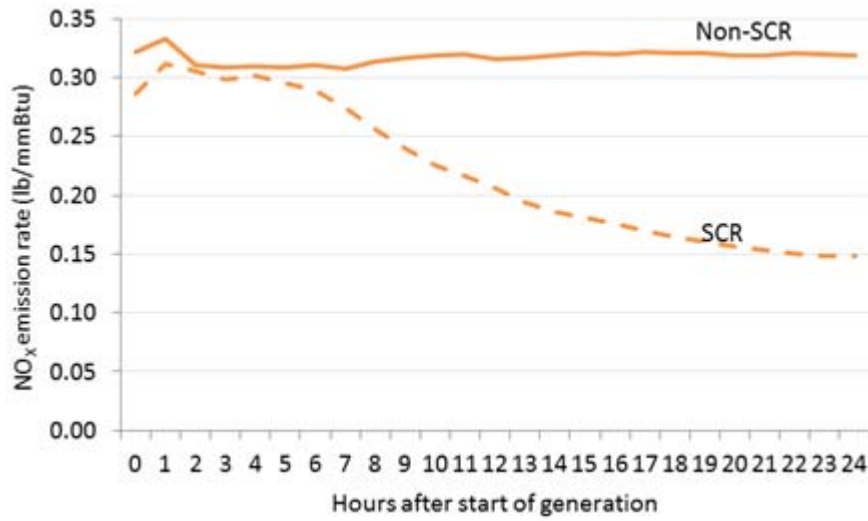


Figure 14 shows the distribution of NO_x emission rates during normal starts at supercritical PC EGU with SCR NO_x APCDs. (Note: the top and bottom 5% of emission rates are excluded from the chart; the yellow line is the average emission rate across starts at PC EGU with SCR; the orange boxes and black whiskers are the quartile ranges.) The figure shows that average and median NO_x emission rates for the full range of normal starts at SCR-equipped supercritical PC EGU begin to decline around hour 6, indicating that, on average, SCR effectively controls NO_x approximately 6 hours or less after the start of generation.

Figure 14: Average NO_x emission rates following start of generation at supercritical PC EGU

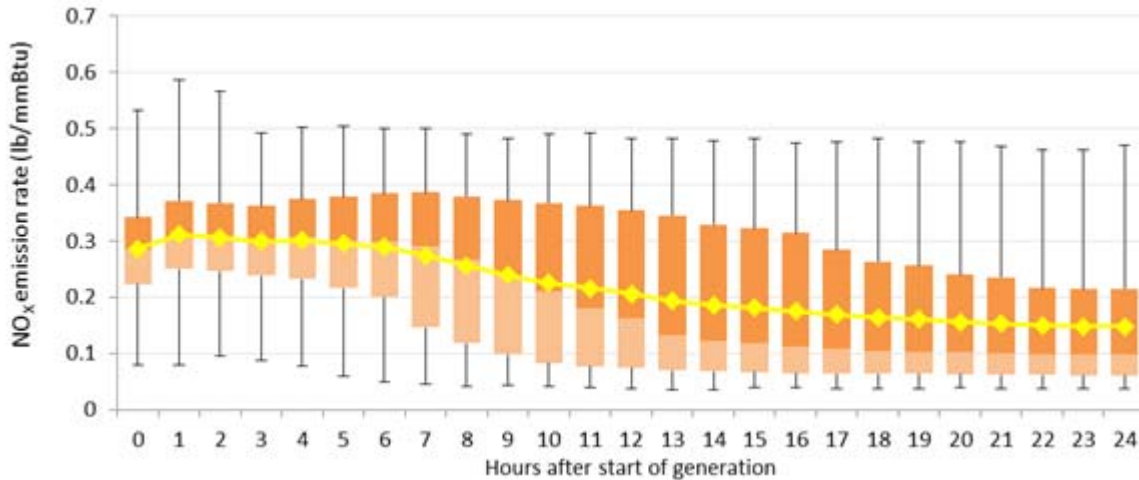
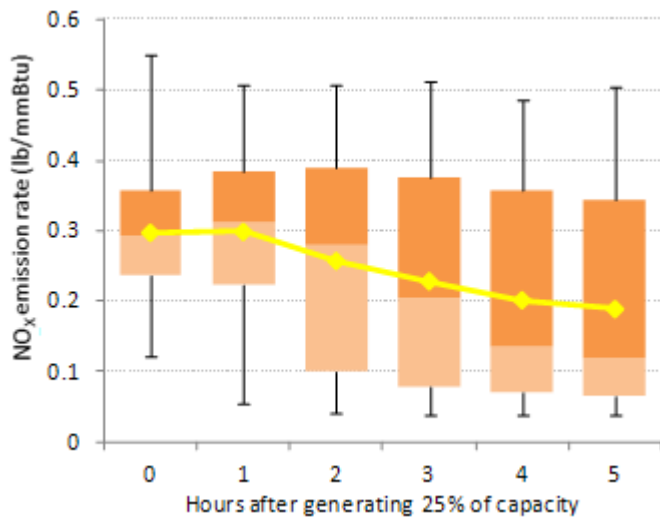


Figure 15 shows the distribution of NO_x emission rates during normal starts after achieving 25% of nameplate capacity at supercritical PC EGU with SCR NO_x APCDs. (Note: the top and bottom 5% of emission rates are excluded from the chart; the yellow line is the average emission rate across starts at supercritical PC EGU with SCR; the orange boxes and black whiskers are the quartile ranges.) The figure shows that average and median NO_x emission rates at SCR-equipped supercritical PC EGU begin to decline around 2 hours after achieving 25% of nameplate electricity generating capacity.

Figure 15: Average NO_x emission rates following gross load levels greater than or equal to 25% of nameplate capacity at supercritical PC EGUs with SCRs



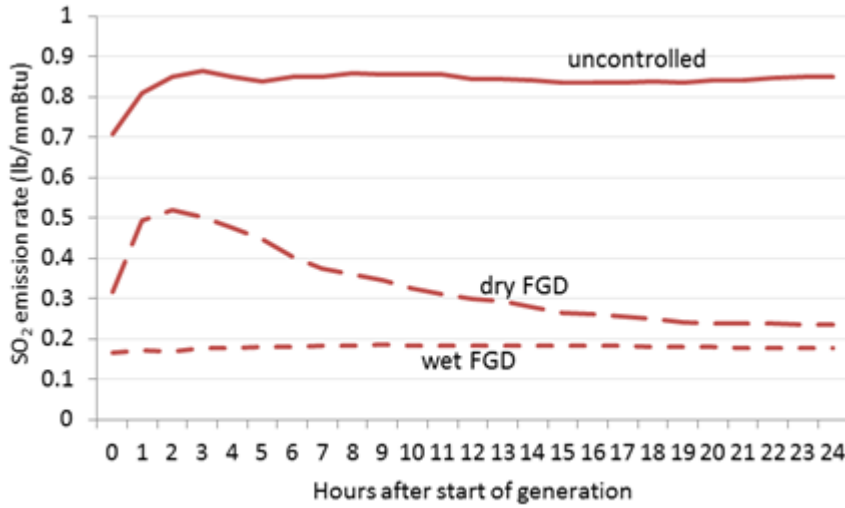
4.2.1.3 SO₂ emissions from subcritical PC EGUs with FGDs

Of the 5,770 normal startup events at subcritical PC EGUs, 70% were at subcritical PC EGUs with wet FGD and an additional 14% were at subcritical PC EGUs with dry FGD (see Table 4). The average SO₂ emission rates for the hours following the start of generation are shown in Figure 16. The average SO₂ emission rates for normal starts at wet FGD-equipped subcritical PC EGUs are approximately 75%-80% lower across every hour (0-24) than the average SO₂ emission rates for normal starts at subcritical PC EGUs without FGDs (i.e., uncontrolled). The average SO₂ emission rates for normal starts at dry FGD-equipped subcritical PC EGUs are approximately 40%-70% lower across every hour (0-24) than the average SO₂ emission rates for normal starts at subcritical PC EGUs without FGDs.

Table 4: Number of normal starts at subcritical PC EGUs by SO₂ control type

SO ₂ control type	Normal starts
Wet FGD	4,024
Dry FGD	803
Uncontrolled for SO ₂	943
Total	5,770

Figure 16: Average SO₂ emission rates following start of generation at subcritical PC EGUs by SO₂ control type



Figures 17 and 18 show the distribution of SO₂ emission rates during normal starts at subcritical PC EGUs with wet FGD (17) and dry FGD (18). (Note: the top and bottom 5% of emission rates are excluded from the chart; the yellow line is the average emission rate across starts at subcritical PC EGUs with FGD; the red boxes and black whiskers are the quartile ranges.) The figures show that average and median SO₂ emission rates are low at the start of generation for the majority of normal starts, indicating that wet FGD are likely operating at the start of electricity generation and dry FGD begin controlling emissions within the first 3 to 4 hours after the start of electricity generation.

Figure 17: Average SO₂ emission rates following start of generation at subcritical PC EGUs with wet FGDs

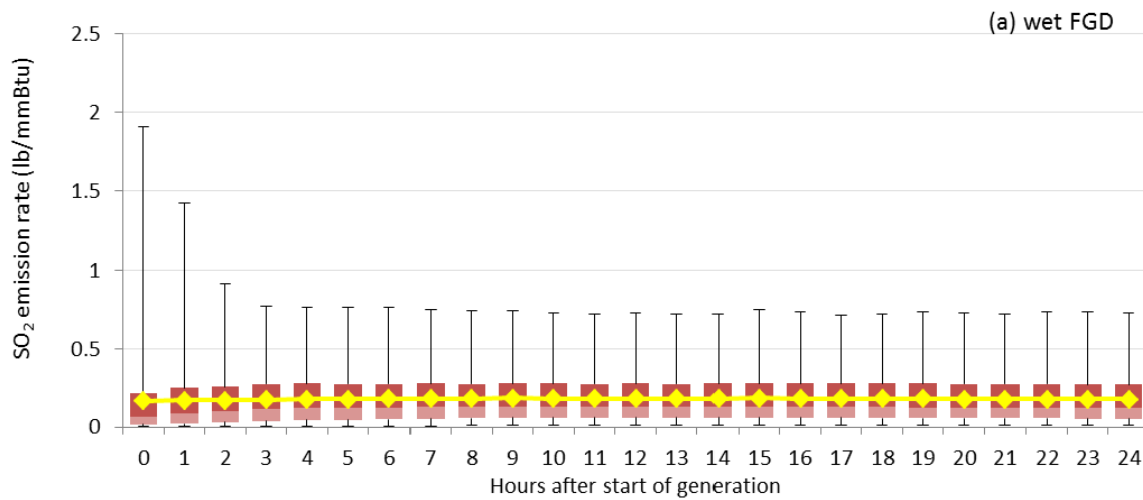
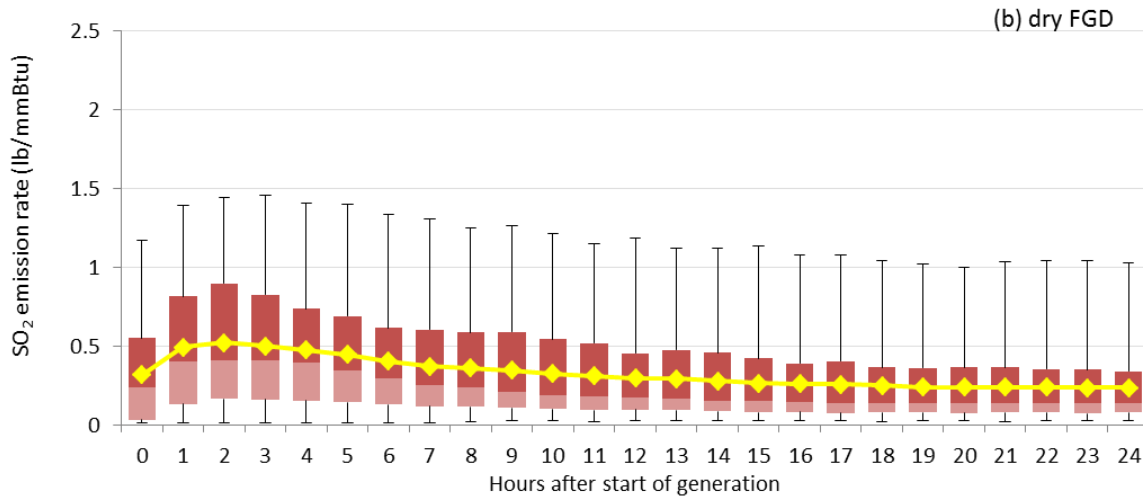


Figure 18: Average SO₂ emission rates following start of generation at subcritical PC EGUs with dry FGDs



Following gross load levels greater than or equal to 25% of nameplate capacity, subcritical PC EGUs with wet FGD have relatively low and stable average and median SO₂ emission rates (see Figure 19) while subcritical PC EGUs with dry FGD reduce average SO₂ emission rates (see Figure 20) by over 30 percent in the first 3 hours following gross load levels of 25% of nameplate capacity. Average and median SO₂ emission rates at dry FGD-equipped subcritical PC EGUs begin declining within the first hour of achieving gross load equal to or greater than 25% of nameplate capacity.

Figure 19: Average SO₂ emission rates following gross load levels greater than or equal to 25% of nameplate capacity at subcritical PC EGUs with wet FGDs

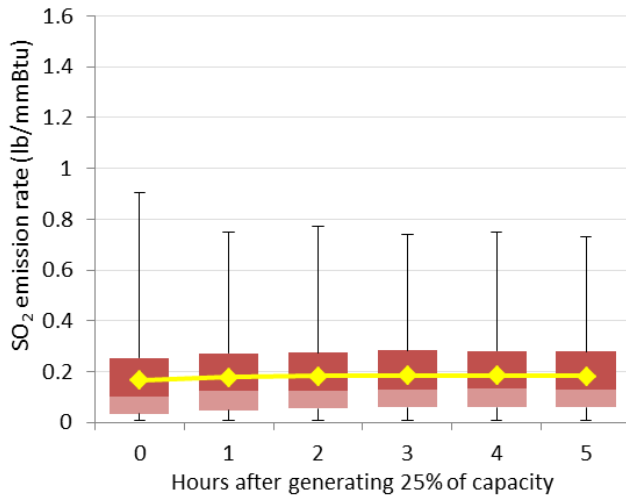
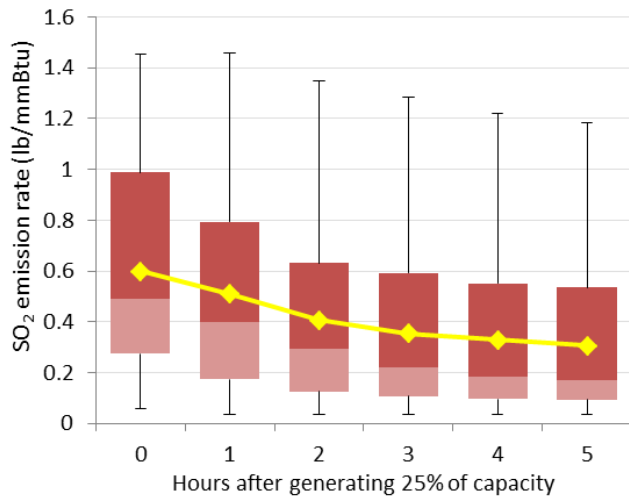


Figure 20: Average SO₂ emission rates following gross load levels greater than or equal to 25% of nameplate capacity at subcritical PC EGUs with dry FGDs



4.2.1.4 NO_x emissions from subcritical PC EGUs with SCRs

Of the 5,770 normal startup events at subcritical PC EGUs, nearly 47% were at subcritical PC EGUs with SCR (see Table 5). Nearly all of the remaining non-SCR subcritical PC EGUs have installed low-NO_x burners, over-fired air, and/or selective non-catalytic reduction. The average NO_x emission rates for the hours following the start of generation are shown in Figure 21. The average NO_x emission rates for SCR-equipped and non-SCR supercritical PC EGUs begin at approximately the same level but the rate for the SCR-equipped units begins to decline around hour 2.

Table 5: Number of normal starts at subcritical PC EGUs by NO_x control type

NO _x control type	Normal starts
SCR	2,578
non-SCR	3,192
Total	5,770

Figure 21: Average NO_x emission rates following start of generation at subcritical PC EGUs by NO_x control type

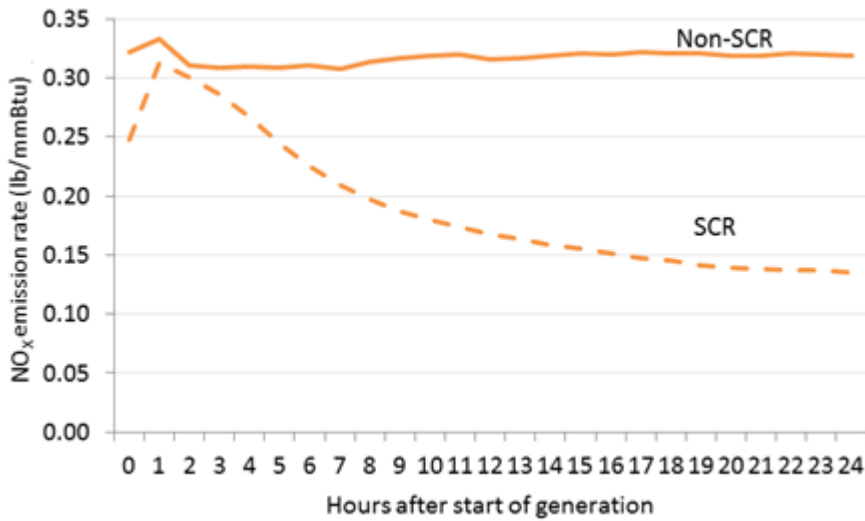
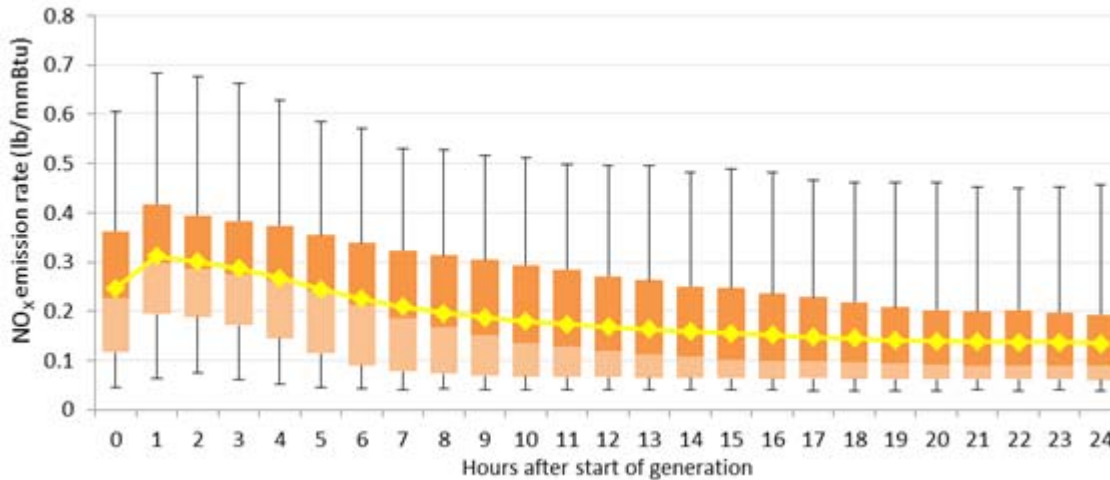


Figure 22 shows the distribution of NO_x emission rates during normal starts at subcritical PC EGUs with SCR NO_x APCDs. (Note: the top and bottom 5% of emission rates are excluded from the chart; the yellow line is the average emission rate across starts at PC EGUs with SCR; the orange boxes and black whiskers are the quartile ranges.) The figure shows that average and median NO_x emission rates for the full range of normal starts at SCR-equipped subcritical PC EGUs begin to decline around hour 2, indicating that SCR are likely starting to control NO_x 2 to 3 hours after the start of generation.

Figure 22: Average NO_x emission rates following start of generation at subcritical PC EGUs

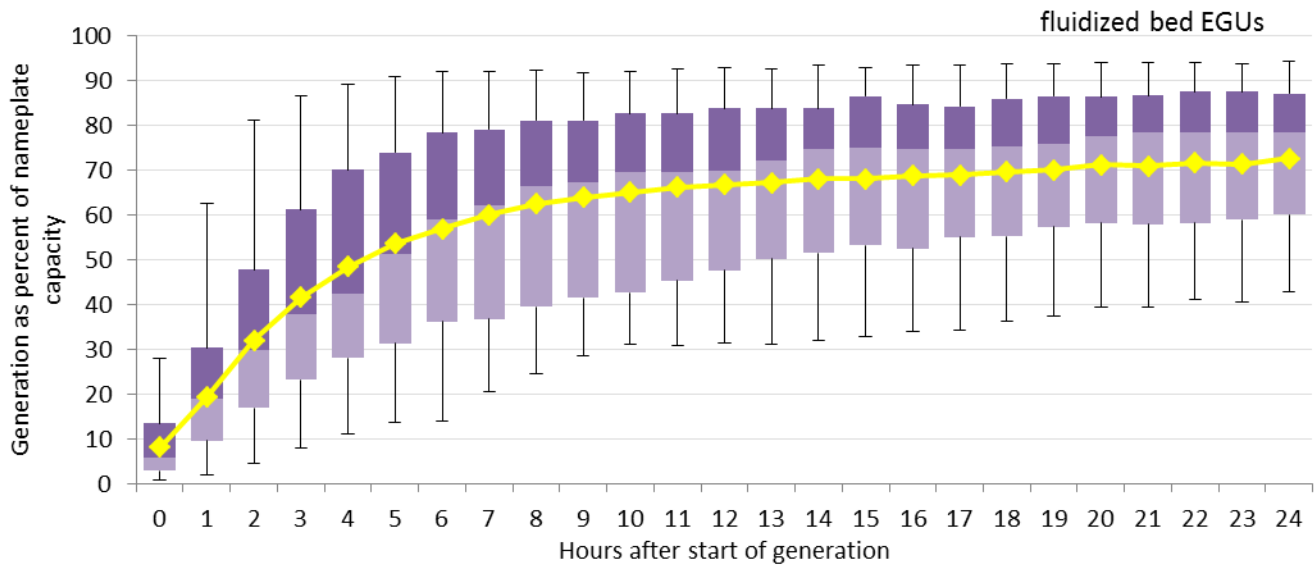


4.2.2 Circulating fluidized bed boiler EGUs

Commenters stated that CFB boiler EGUs are subject to different constraints during startup procedures and that they must achieve approximately 40% load before becoming stable. CFB boiler EGUs typically do not have post-combustion FGD APCDs installed since they achieve significant SO₂ capture by adding lime or limestone to the bed of the boiler. To address the issues raised by commenters, EPA evaluated CFB boiler EGU starts separately from PC EGUs.

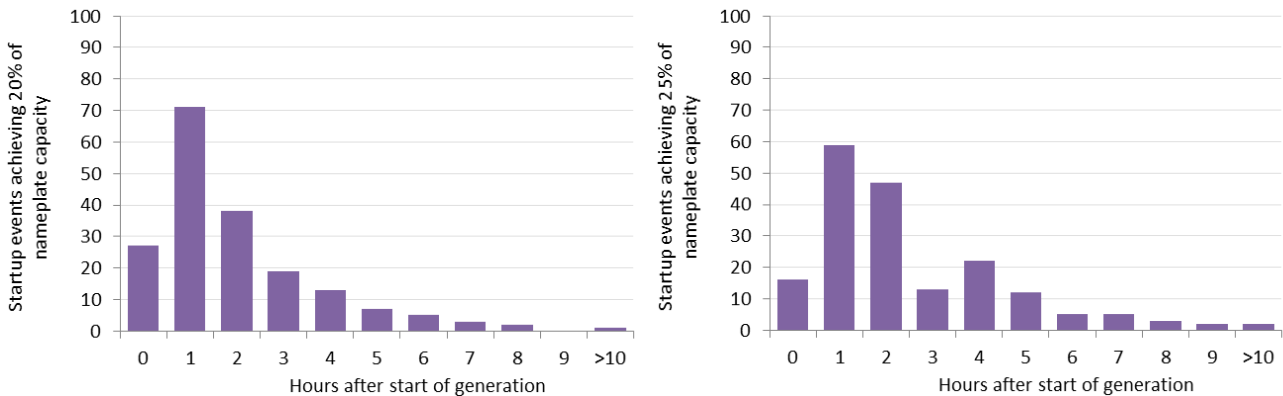
Figure 23 shows that across startup events at CFB boiler EGUs, generation averaged approximately 30% of nameplate capacity by hour 2 and 40% of nameplate capacity by hour 3. (Note: the yellow line is the average gross load as a percentage of nameplate capacity across all startup events at CFB boiler EGUs; the purple boxes and black whiskers are the quartile ranges.) We found that CFBs achieve 25% and 40% load bins, on average, as fast as subcritical and supercritical PC EGUs (see Figures 4 and 5).

Figure 23: Gross electricity generation as a percentage of nameplate capacity (MW) by hour following start of generation at CFB boiler EGUs



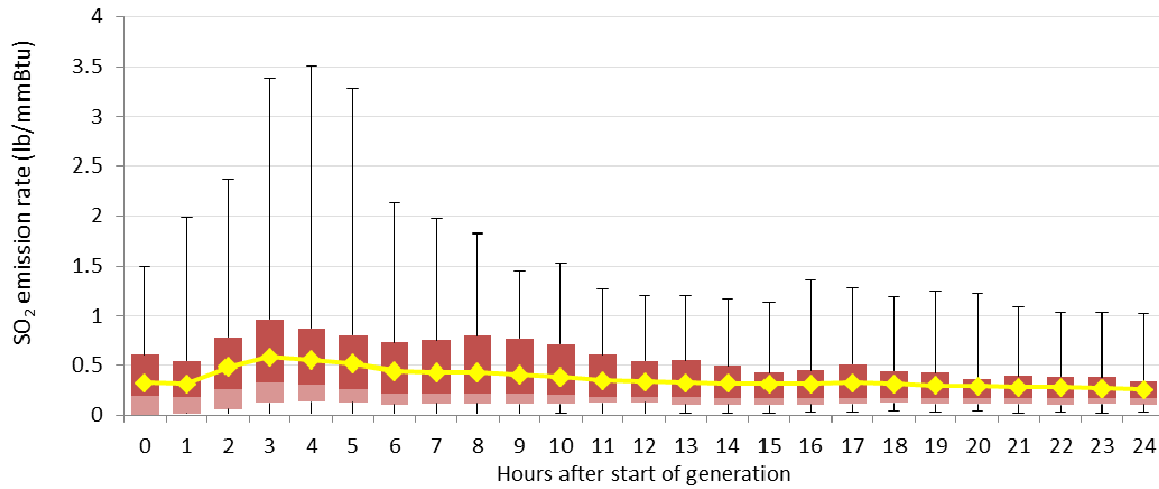
During the majority of normal startup events, CFB boiler EGUs achieved 20% and 25% of nameplate capacity within the first few hours (see Figure 24).

Figure 24: Hours after start of generation for CFB boiler EGUs to generate 20% (left) and 25% (right) of nameplate capacity



Because CFB boiler EGUs generally do not have separate FGD APCDs, there is no need to compare uncontrolled and controlled emission rates. Figure 25 shows that average and median SO₂ emission rates during startup events at CFB boiler EGUs begin to decline at hours 4 to 6 following the start of electricity generation. (Note: the top and bottom 5% of emission rates are excluded from the chart; the yellow line is the average emission rate across startup events at CFB boiler EGUs with FGD; the red boxes and black whiskers are the quartile ranges.)

Figure 25: Average SO₂ emission rates following start of generation at CFB boiler EGUs



5. Conclusion

In this analysis of supercritical and subcritical PC EGUs with FGD and/or SCR and CFB boiler EGUs, EPA examined several indicators that can aid in assessing the time required to achieve operating benchmarks. These indicators show that, on average, all types of EGUs in this study:

- can reach 25% of nameplate capacity in 3 hours or less after the start of generation;
- can begin controlling SO₂ and NO_x emissions 3 hours or less after reaching 25% of nameplate capacity or 6 hours or less following the start of electricity generation

We found no significant difference in performance related to startup events between the different boiler types and APCD technologies assessed in this analysis.