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Office of Air Quality Planning and Standards

Rulemaking for Greenhouse Gas Emissions from Electric Utility Steam Generating Units

Tribal Consultation
May 2011
POC: Kevin Culligan

Purpose of the Consultation

- Hear from you, your concerns and comments
- Provide background information on the standards for GHG emissions from EGUs
- Provide summary of issues we are exploring for the proposal
- Discuss your input and comments

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Background

- On December 15, 2009 (74 FR 66496), EPA published a notice indicating that the EPA Administrator found that the current and projected atmospheric concentrations of GHGs are reasonably anticipated to endanger the public health and welfare of current and future generations (Endangerment Finding).

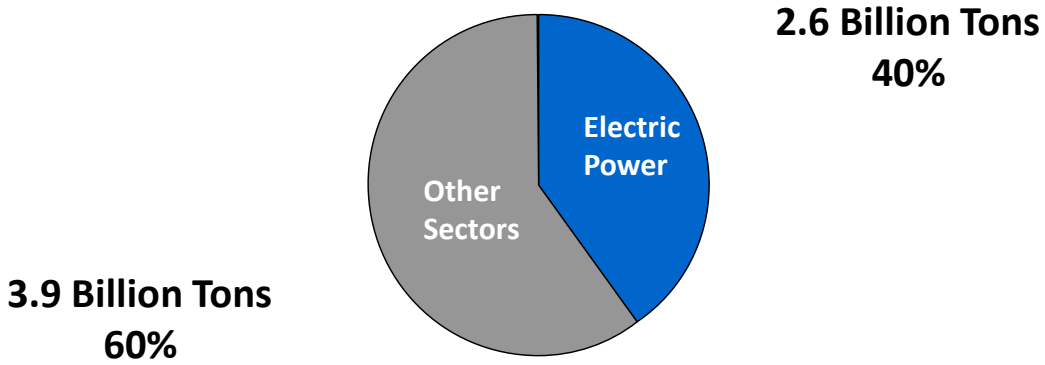
- On December 23, 2010, EPA announced that it entered into a proposed settlement agreement to issue rules that will address GHG emissions from certain fossil fuel-fired EGUs.

- Rules would establish new source performance standards (NSPS) for new and modified natural gas-, oil-, and coal-fired EGUs and emission guidelines for existing natural gas-, oil-, and coal-fired EGUs.

- Under the agreement, EPA commits to issuing proposed regulations by July 26, 2011 and final regulations by May 26, 2012.

Power Sector:
A Major Share of U.S. GHG Emissions

Carbon Dioxide (CO_2), 2008
6.5 Billion Tons



- See Appendix A for additional details

Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2008 (2010) (CO_2)
"Other" sources include transportation, other mobile sources, and industrial sources

Definition of EGU

- The regulations would apply to each EGU capable of combusting more than 250 million British thermal units per hour (MMBtu/hr) heat input of fossil fuel.

- *Electric utility steam generating unit* means any steam electric generating unit that is constructed for the purpose of supplying more than one-third of its potential electric output capacity and more than 25 megawatts electric (MWe**) output to any utility power distribution system for sale.**

- *Fossil fuel* means natural gas, petroleum, coal, and any form of solid, liquid, or gaseous fuel derived from such material for the purpose of creating useful heat.

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Section 111 Overview

- In setting the EGU GHG NSPS, there are two particularly relevant provisions under section 111 of the CAA:
  - CAA section 111(b) requires EPA to regulate new and modified sources
  - CAA section 111(d) requires EPA to establish regulations under which States will regulate existing sources.
    - Section 111(d) is only relevant when the source:
      - Emits pollutants that are **not regulated under other parts of the CAA** (i.e., pollutants regulated under NAAQS requirements or air toxics requirements) and
      - Would be subject to an NSPS if the existing source were a new source (i.e., existing sources in a source category for which NSPS under section 111(b) have been established would be subject to section 111(d) requirements).
- EPA may distinguish among classes, types, and sizes within categories of sources for the purpose of establishing standards.
- EPA bases standards on demonstrated controls and may not require use of any particular technology, except under narrow circumstances (as authorized under CAA section 111(h)).
- EPA may waive compliance for sources employing innovative technologies with the potential for equivalent or greater reductions ("innovative technology waivers").

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Section 111 Overview (cont.)

- Standards need not be established for all emitted pollutants:
  - where emissions are negligible,
  - no technology exists, or
  - not economically reasonable to control.
- Where not feasible to prescribe or enforce a standard of performance CAA section 111(h) allows for establishment of:
  - a design, equipment, work practice, or operational standard, or combination
  - which reflects the best technological system of continuous emission reduction, we determine has been adequately demonstrated.
  - taking into consideration the cost of achieving such emission reduction, and any non-air quality health and environmental impact and energy requirements
- Believe there would not be a basis for using 111(h) authority

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Section 111(b)

- NSPS implement CAA section 111(b) and are issued for categories of sources which cause, or contribute significantly to, air pollution which may reasonably be anticipated to endanger public health or welfare.
- Section 111(b) requirements apply to both new and modified sources.
  - New sources are those for which construction or modification is commenced after the publication of proposed regulations.
  - Modification is any physical change in, or change in the method of operation of, a source which increases the amount of any air pollutant emitted by the source or which results in the emission of any air pollutant not previously emitted.
    - Exempt: Routine maintenance, repair, and replacement and increased hours of operation
  - May set different standards for new and modified sources
  - May have different standards for different subcategories
- EGUs are already subject to 111(b) requirements for a number of pollutants such as SO_2, NO_X, and PM.

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Section 111(b) (cont.)

- Traditionally, these standards have been set at the unit level.
- NSPS are set at the Federal level.
- States and Tribes do not have the flexibility to approve less stringent requirements.
- NSPS reflect the degree of emission limitation achievable through application of the best system of emission reduction, taking into consideration:
  - The cost of achieving such reduction, and
  - Any non-air quality health and environmental impact, and energy requirements.
  - Level of control referred to as Best Demonstrated Technology (BDT)
- When determining Best Available Control Technology (BACT) under the New Source Review (NSR) requirements of the CAA, BACT determinations may not be less stringent than the 111(b) standards the agency has set.
- NSPS are to be reviewed at least every 8 years and revised if appropriate.

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Section 111(d)

- Emission guidelines are established under CAA section 111(d) for source categories that emit pollutants not regulated under other parts of the CAA and to which an NSPS would apply if such existing source were a new source.
- Section 111(d) requirements apply to existing sources.
- Because section 111(d) only applies to pollutants not regulated under other parts of the CAA, it has been used very infrequently.
  - Only two source categories are currently subject to section 111(d) requirements (i.e., sulfuric acid production plants and municipal solid waste landfills).
  - Solid waste incinerators have also been regulated under a very similar provision (CAA section 129) which requires the Agency to regulate those sources using the 111(d) process.
- Under section 111(d), EPA does not set explicit emission standards on individual sources, rather it develops emission guidelines.
  - While called “guidelines,” they go through notice and comment, and are binding on States.
- States must promulgate rules that are consistent with the emission guidelines.

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Section 111(d) (cont.)

- Key elements of Emission Guidelines include:
  - Description of system of emission reductions that EPA deems adequately demonstrated
  - Degree of emission limitation achievable, costs, and environmental impacts of application
  - Time required to implement
  - Other information EPA determines is necessary to facilitate formation of State Plans
- Different guidelines or compliance times (or both) may be specified for different sizes, types, and classes of designated facilities when costs, physical limitations, geographical location, or other factors make subcategorization appropriate.

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Requirements for 111(d) State Plans

- State Plans are generally due within 9 months after publication of the final emission guidelines.
  - Other timeframes may be set by EPA for specific standards.
  - States may receive exemption from plan submittal requirements by certifying no designated facilities exist.
- State Plans must contain:
  - Emission standards and compliance schedules “no less stringent than emission guidelines”
  - Allowable emission rates and possibly allowance system
  - Test methods and procedures for determining compliance
  - Enforceable increments of progress for compliance schedules longer than 12 months

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Requirements for 111(d) State Plans (cont.)

- States may adopt less stringent emission standards or longer compliance schedules than those set out in the guidelines where the States demonstrate:
  - Unreasonable cost of control due to age, location or basic process design
  - Physical impossibility of installing necessary control equipment
  - "Other factors specific to the facility or class of facility that make application of a less stringent standard or final compliance time significantly more reasonable."
- States may adopt more stringent standards or shorter compliance schedules than those contained in the guidelines.
- EPA has the authorities issue a Federal plan where the State fails to submit a satisfactory plan and to enforce the provisions of a plan in cases where the State fails to enforce them.
- In applying a standard of performance to any particular source under a State implementation plan or in promulgating a standard of performance under a plan prescribed by EPA, the remaining useful life of the existing source(s) can be considered.

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Section 111 versus Section 112

- Technology basis of standards
  - CAA section 111 standards are based on BDT
  - CAA section 112 standards are based on maximum achievable control technology (MACT) – very prescriptive
- Other considerations
  - Under CAA section 111, the cost of achieving reductions, any non-air quality health and environmental impacts, and energy requirements are considered in determining BDT
  - Under CAA section 112, costs and other impacts can only be considered when regulating beyond the minimum MACT level (the MACT floor)
- CAA section 111(d) regulations developed by EPA do not directly impact existing sources. States follow the EPA regulations developed under section 111(d) to establish implementation plans with standards of performance that apply to those sources.

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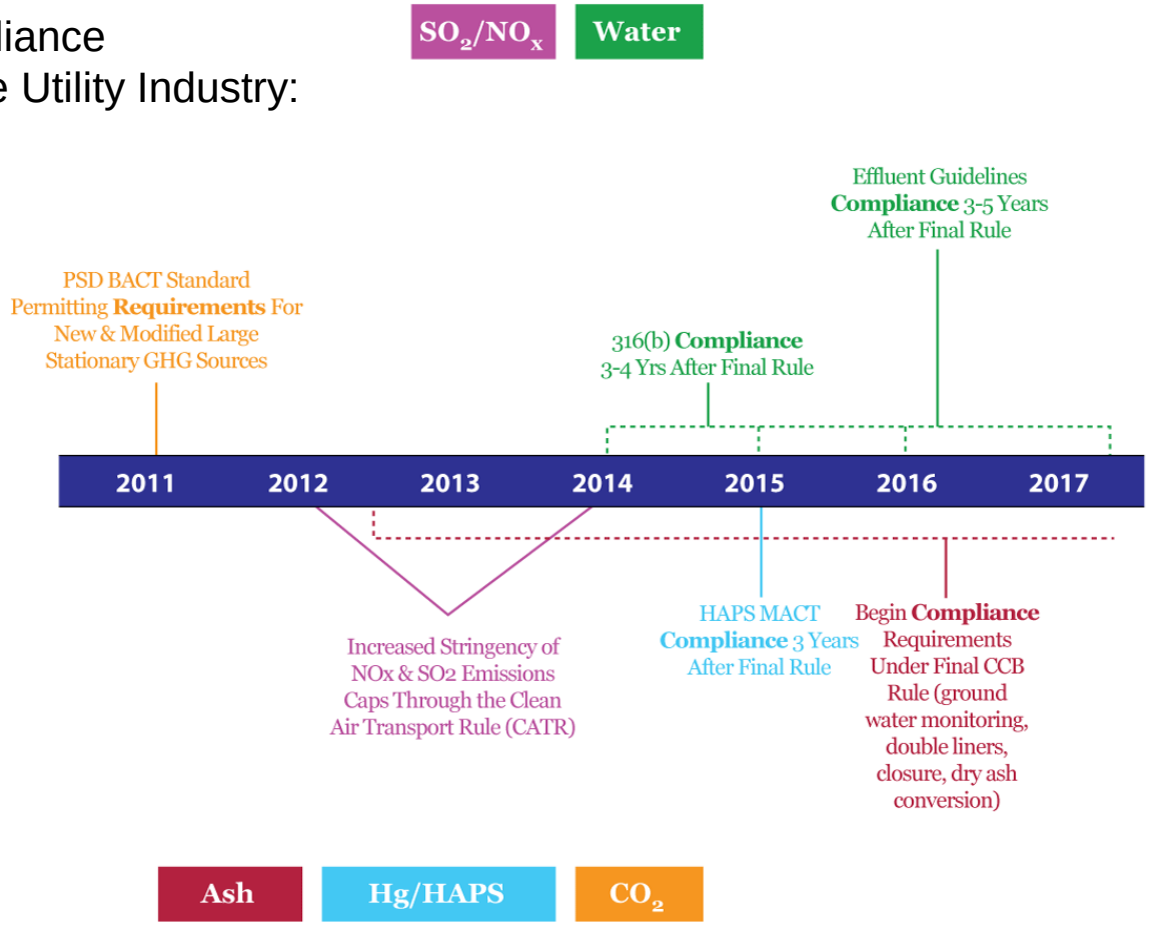
GHG Standards for Utilities are part of a set of EPA Regulations Affecting the Power Sector

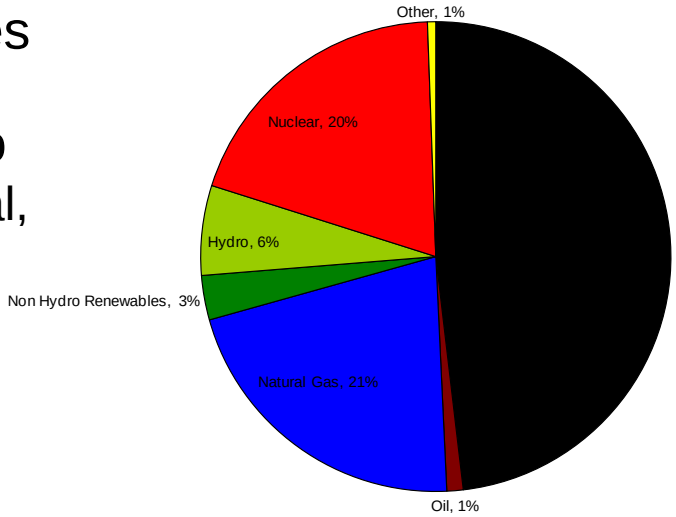
Regulatory Compliance Obligations for the Utility Industry:



Sources: WRI Analysis based on Edison Electric Institute 2010, Wegman, EPA 2003.

Affected Facilities

- Approximately 1,525 EGUs at 605 facilities
- Approximately 1,200 coal-fired boilers at 450 facilities in 44 States and Puerto Rico
  - Coal-fired EGUs include units that burn coal, coal refuse, or a synthetic gas derived from coal either exclusively, in any combination together, or in any combination with other supplemental fuels (e.g., petroleum coke, tire-derived fuels).
    - Bituminous coal ~ 50% of coal generation
    - Subbituminous ~45% of coal generation
    - Lignite ~ 5% of coal generation
  - Approximately 48 percent of nationwide net generation
- Approximately 150 oil-fired boilers at 75 facilities, mostly in Northeast, Midwest, California, Florida, and Hawaii
  - Approximately 1 percent of nationwide net generation



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Affected Facilities (cont.)

- Approximately 175 gas-fired boilers at 80 facilities, mostly in Midwest, California, Louisiana, and Texas
  - Approximately 21 percent of nationwide net generation
  - Are not subject to the NESHAP for EGUs
- The regulations would apply to integrated gasification combined cycle (IGCC, i.e, “coal gasification”) EGUs.
  - Coal is “gasified” in a high-pressure, high-temperature gasifier with a limited supply of either oxygen or air to produce synthetic gas (syngas).
  - The syngas is cooled, cleaned, and fired in a gas (combustion) turbine.
  - The hot exhaust from the combustion turbine passes through a heat recovery steam generator (HRSG, i.e., boiler) where it produces steam that drives a steam turbine.
  - Electric power is produced from both the combustion and steam turbine-generators.
  - There are two IGCC plants currently operating in the U.S.
    - Duke Energy Wabash River Power Station in Indiana (operation began in 1995)
    - Tampa Electric Company Polk Power Station in Florida (operation began in 1996)

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Affected Facilities (cont.)

- In a combined cycle gas turbine plant, a gas turbine generates electricity and the waste heat is used to make steam to generate additional electricity via a steam turbine.
  - More efficient method of generating electricity
  - Used by most new gas power plants in North America and Europe
- In a simple cycle gas turbine plant, there is no heat recovery.
  - Have the ability to be turned on and off within minutes
  - Usually used as peaking power plants because they are less efficient

- Industry includes investor- owned, publicly-owned and rural cooperative EGUs.

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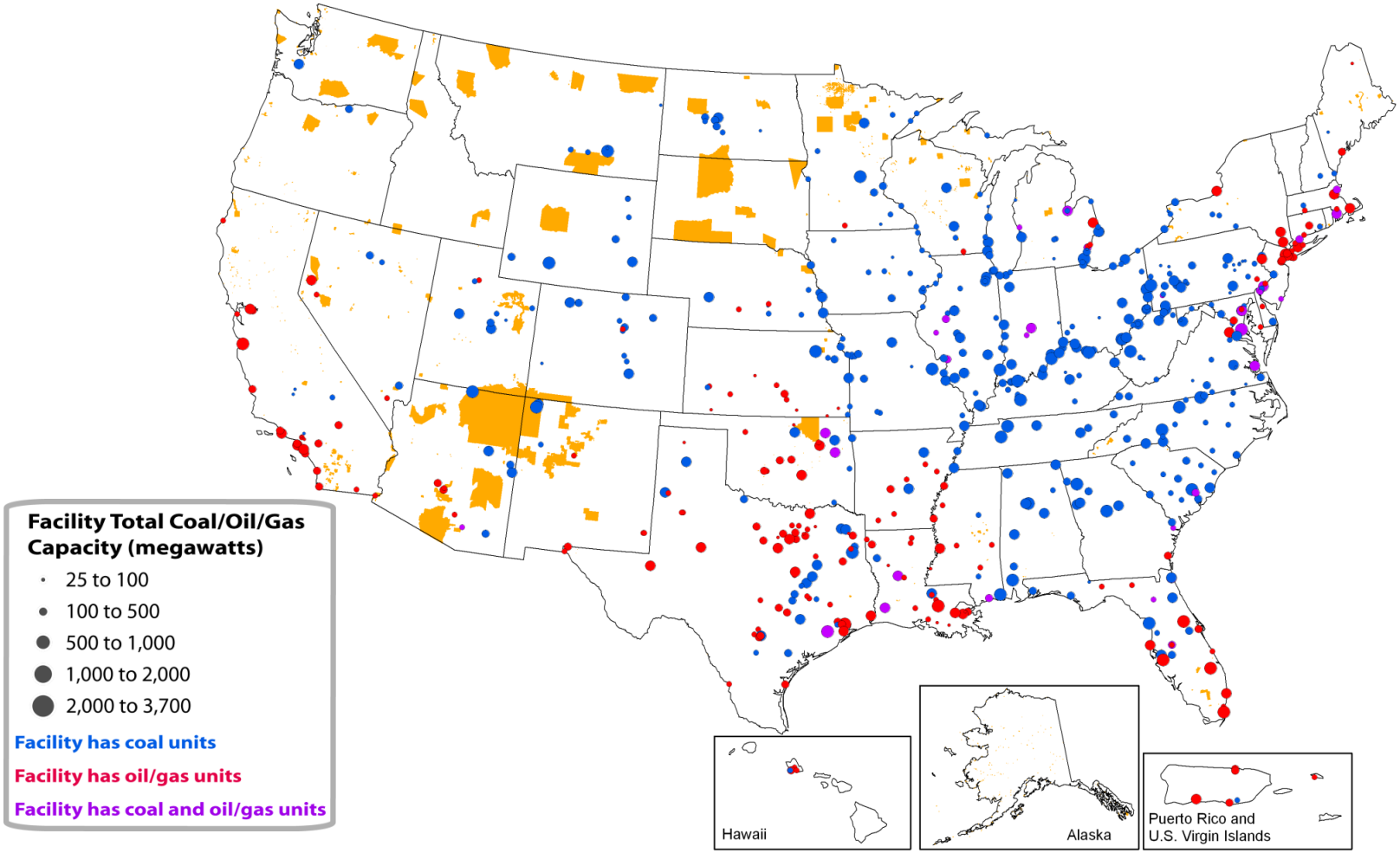
Power Plants Likely Covered by the EGU GHG Rule



Source: National Electric Energy Data System (NEEDS 4.10) (EPA, December 2010)
Note: This map displays facilities that are included in the NEEDS 4.10 data base and that contain at least one coal, oil or gas-fired steam generating unit that generates more than 25 megawatts of power. This includes coal-fired units that burn petroleum coke and that turn coal into gas before burning (using integrated gasification combined cycle or IGCC). NEEDS reflects available capacity on-line by the end of 2011; this includes committed new builds and committed retirements of old units. Only steam boilers are covered by this rule. In areas with a dense concentration of facilities, the facilities on the map may overlap and some may be impossible to see. American Indian Reservations / Federally Recognized Tribal Entities shown were provided by the US DOI, BIA, and GDSC; they are not a legal representation of reservation boundaries.

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CO_2 Emissions Control Technologies

- General types of control measures for CO_2 emissions:
  - Energy efficiency
    - Reduce the amount of fuel used by improving the efficiency of the electrical generation process
  - Post-combustion
    - Separate the CO_2 for long-term storage using carbon capture technology
  - Other measures
    - Co-firing
    - Fuel switching
    - Combined heat and power

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Efficiency Improvements for Existing EGUs

- Potential efficiency improvement technologies for existing EGUs:
  - Replace/upgrade burners – up to ~5%
  - Improve combustion - ~0.5% to 3%
  - Recover heat – up to ~6%
  - Reduce air leakage - ~1.5% to 3%
  - Capture energy from boiler blowdown - ~1% to 2%
  - Reduce slagging and fouling of heat transfer surfaces - ~1% to 3%

- Efficiency improvement technologies demonstrated on existing coal-fired EGUs:
  - Combustion control optimization – 0.15% to 0.84%
  - Cooling system heat loss recovery – 0.2% to 1%
  - Flue gas heat recovery – 0.3% to 1.5%
  - Low-rank coal drying – 0.1% to 1.7%
  - Sootblower optimization – 0.1% to 0.65%
  - Steam turbine design – 0.84% to 2.6%

- See Appendix B for additional details

Sources: EPA White Paper - Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from Industrial, Commercial, and Institutional Boilers, October 2010
EPA White Paper - Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from Coal-Fired Electric Generating Units, October 2010

Efficiency Improvements for New EGUs

- Potential efficiency improvements for new coal-fired EGUs:
  - Use of supercritical boilers
    - National Energy Technology Laboratory (NETL) analysis shows that supercritical boilers are approximately 2.3% more efficient than subcritical boilers
  - Use of ultra-supercritical boilers
    - Can potentially operate at efficiencies approaching 50%
  - Use of IGCC technology
    - NETL analysis of three coal gasification processes shows net efficiencies of 38.2% to 41.1%
  - Coal drying
    - Reported net gains in overall efficiency of 2% to 4%
  - Boiler feedwater heating
    - Increases the output of the steam cycle and potentially lowers GHG emissions

- See Appendix B for additional details

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Source: EPA White Paper - Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from Coal-Fired Electric Generating Units, October 2010

Potential Impacts of Efficiency Improvements

- Costs are very site-specific
- Potential impacts associated with efficiency improvement technologies for existing 250-MW pulverized coal plant with heat rate of 9,930 But/kWh

Efficiency Improvement Technology	Heat Reduction, Btu/kWh	Capital Cost, $
Installation of Neural Network process controls	25	0.5 million
Installation of new air heaters	92	2.0 million
Steam turbine upgrade	255	10.2 million
Improve steam turbine seals	15	0.3 million
Overhaul/upgrade of boiler feed pump	37	0.3 million
Total	**424** **~4% from base heat rate**	**13.3 million**

- Potential impacts for new coal-fired boilers
  - New coal-fired supercritical plant with net power output of 800 MWe
    - Capital costs of ~$2.7 billion
    - Annual cost of ~$0.5 billion/year
  - New IGCC plant with net power output of 800 MWe
    - Capital costs of ~$3.5 billion
    - Annual cost of ~$0.6 billion/year

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Sources: Sargent & Lundy Final Report – Coal-Fired Power Plant Heat Rate Reductions, January 2009; EPA White Paper – Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from Coal-Fired Electric Generating Units, October 2010

Carbon Capture & Storage

- There are no insurmountable technological, legal, institutional, or other barriers that prevent carbon capture and storage (CCS) from playing a role in reducing GHG emissions.
  - Current technologies could be used to capture CO_2 from new and existing fossil energy power plants; however they are not ready for widespread implementation primarily because they have not been demonstrated at the scale necessary to establish confidence for power plant application.
  - CCS retrofits could face challenges at some existing plants due to space and configurational limitations or proximity to a CO_2 pipeline or geologic storage.
- Existing Federal programs are being used to deploy at least five to ten large-scale integrated CCS projects expected to be online by 2016.
- Federal research, development and demonstration efforts are focused on reducing costs of CCS to facilitate widespread cost-effective deployment after 2020.
  - Approximately 70–90% of CCS cost is associated with capture and compression.
  - The cost and performance of CCS technologies will evolve with longer-term testing.

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Source: Report of the Interagency Task Force on Carbon Capture and Storage, August 2010

Compliance & Monitoring

- Considering a lb/MW-hr based standard
- Considering use of emission averaging
- Believe that Part 75 requirements provide a good framework
  - CO_2 monitoring
  - Output monitoring
  - Data management
- Does currently reported data have any limitations for this purpose?
  - Quality of output data
  - Use of data for annual reporting requirement to support shorter term compliance requirement
  - Potential for averaging across units

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Key Questions

- What should emission limits for new sources be based on?
- What should emission limits for modified sources be based on?
- What should emission limits for existing sources be based on?
- What regulatory mechanisms should be used to get reductions?
- How should State equivalency with guidelines be addressed?

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Summary of Listening Sessions

- EPA held four listening sessions to obtain stakeholder views on the design of section 111 performance standards to reduce GHG emissions from power plants.
- Electric Power Industry
  - Allow for fleet wide averaging
  - Give credit for replacement of older less efficient generation
- Coalition Groups
  - Allow for State programs to be deemed equivalent
  - Provide market-based flexibility
  - Recognize early action
- State and Tribal Representatives
  - Allow for State programs to be deemed equivalent
  - Reward the very best possible systems available
  - Take a multi-pollutant approach
- Environmental and Environmental Justice
  - Allow for State programs to be deemed equivalent
  - Recognize environmental benefit of non-emitting technologies
  - No special considerations for biomass
  - Aggressive GHG approach will reduce other pollutants as well

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Options Suggested at Listening Sessions

- EPA received a wide range of constructive suggestions and is evaluating the full range of options as the proposed EGU standards are being developed.
  - Stakeholders offered multiple suggestions on how standards could be set for new and existing units and, for existing standards, suggested a number of mechanisms.
  - These are not the only options that the Agency will consider and we are open to suggestions of additional options.
  - Note that there was broad support for the format of the standards being output based (e.g., pounds of GHG per KW produced).

- New Source Standards – Potential Options
  - Option 1: Fuel and technology specific efficiency standards based on existing technologies
    - Standard would likely look at coal-based technologies currently being built such as ultra-supercritical plants and IGCC plants.
    - While EPA has issued NSPS that are technology and fuel specific, in recent power sector NSPS actions the Agency has been moving more towards fuel neutral standards.

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Options Suggested at Listening Sessions (cont.)

- Option 2: Standards more aggressive than those based on highly efficient coal-powered units
  - Standards could consider technologies such as CCS and/or co-firing of lower CO_2 fuels
  - Standards could potentially include emission rate averaging with certain other categories of sources. For instance, offsets could be obtained from:
    - existing units that perform better than the existing source standard or
    - units that generate electricity but are not subject to the EGU NSPS (for instance industrial units with on-site generation and co-generation)
  - Previous NSPS rulemakings have been based on technologies demonstrated in the field (e.g., in the past when both scrubbers and SCRs were not nearly as prevalent on the coal-fired fleet, NSPS limits were based on the performance of such technologies).
- Option 3: Fuel neutral standards
  - Rather than setting limits based purely on technology, set standards based on use of lower GHG fuels – for instance, gas-fired boilers.
  - Recent power sector NSPS actions have moved more towards fuel neutral approaches.
- Option 4: Phased approach
  - Set a standard based on option #1 that applies immediately and also require a tighter standard based on option #2 or #3 after several years.

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Options Suggested at Listening Sessions (cont.)

- Existing Source Guidelines – Potential Options
  - Option 1: Base guidelines on efficiency improvements of the existing fleet
    - Approach would likely involve reductions on the order of 5%, based on the performance of best units within sub-classes of boiler types (see: *Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from Coal-Fired Electric Generating Units*, USEPA, October 2010 (http://www.epa.gov/nsr/ghgdocs/electricgeneration.pdf) and *Improving the Efficiency of Coal-fired Power Plants for Near Term Greenhouse Gas Emission Reductions*, NETL, April 16, 2010 (http://www.circleofblue.org/waternews/wp-content/uploads/2011/03/DOE-NETL-Coal-fired-energy-efficiency.pdf).
    - Approach of basing standards on best performing technology is consistent with the way many NSPS have been set.
  - Option 2: Set more aggressive guidelines that would include not only efficiency improvements, but also replacement of some older generation
    - Could be based on remaining useful life considerations (e.g. when a unit reached a certain age such as 50 years, it would be required to meet tighter standards such as the new source standards).
    - Could be based on some form of a system wide generation performance standard that would gradually decrease as there was fleet turnover.
      - Both the municipal waste combustor NSPS and the Clean Air Mercury Rule (CAMR) incorporated flexibility mechanisms that allowed averaging across facilities for compliance. While CAMR was overturned by the DC Circuit, the court never ruled on this specific issue.

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Options Suggested at Listening Sessions (cont.)

- Option 3: Phased approach
  - Establish guidelines based on option #1 at the beginning of the program and then require a tighter standard based on option #2 after several years.
  - A phased approach was used in CAMR and the court never ruled on this issue.

- Implementation Mechanisms
  - Different implementation mechanisms may be used in order to achieve the limits.
  - Many listening session participants suggested that States should have flexibility to use a wide range of mechanisms to achieve reductions.
  - EPA is considering both the legal and policy implications of allowing States to use mechanisms to meet the section 111(d) standards that differ from the mechanism(s) considered in the guidelines.
  - Approach would require that EPA set forth criteria (e.g., an emission rate target or a comparison of projected emissions under an approach laid out in the emission guidelines and the emissions under an alternative approach being considered by the State).

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Options Suggested at Listening Sessions (cont.)

- Implementation mechanism options suggested by stakeholders:
  - Averaging with tradable credits – Units would be given emission rate targets
    - If they emit below the targets, they would generate credits for each MWh generated.
    - If they emit above the targets, they would still be able to comply if they obtained credits to offset emissions above the target.
    - Such an approach would only include units covered by the EGU NSPS.
    - As noted above, averaging type approaches have been used in both the municipal waste combustor NSPS and CAMR.
  - Generation performance standard – similar to "Averaging with tradable credits" approach above, but would include all generating sources (e.g., renewables, nuclear, etc.).
  - Recognition of regional programs such as RGGI.
    - CAMR allowed the use of regional programs.
  - Intrastate programs with GHG limitations.
  - Other programs that impact a State's generation mix and could lead to reductions in emissions from covered sources such as renewable portfolio standards or clean energy standards.

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What is a modified source?

- Under the modified source provisions of the NSPS, an EGU is considered modified if it's maximum hourly emissions of a regulated pollutant increase.
  - Increase in hourly emissions ("hourly emissions test") must result from a "physical or operational change."
  - Hourly emissions test is pollutant specific.
  - Hourly emissions test looks back 5 years for the highest hourly rate "achievable."
  - The following are not, by themselves, considered modifications:
    - Maintenance, repair, and replacement which the Administrator determines to be routine.
    - An increase in production rate of an existing facility, if that increase can be accomplished without a capital expenditure on that facility.
    - An increase in the hours of operation.
    - Use of an alternative fuel or raw material if, prior to the date the standards become applicable to that source, the existing facility was designed to accommodate that alternative use.

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What is a modified source? (cont.)

- We anticipate two types of scenarios in which the modified source provisions can be triggered:
  - Modifications to the boiler significant enough to increase the amount of fuel that can be combusted
  - Addition of control equipment that generates CO_2 emissions

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Options for Boiler Modifications

- Modifications to boilers significant enough to trigger the NSPS modification provision for criteria pollutants are rare.
- Options for treatment of such modifications include:
  - Efficiency improvements (because the action that triggered it would usually be related to a fairly significant over-haul, more aggressive efficiency improvements may be cost effective)
  - Standards similar to the new source standards

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Options for Modifications Due to Emission Control Installations

- Most emission controls do not chemically create GHGs.
  - Particulate control devices such as baghouses and ESPs, and mercury control devices such as activated carbon injection do not result in chemically created greenhouse gases.
- Some sorbents used in SO_2 removal devices do result in chemically created GHGs.
  - Sorbents such as lime (used in dry scrubbing applications and some sorbent injection applications) do not result in chemical creation of GHGs.
  - Sorbents such as limestone (used in some wet scrubbing applications) and trona (used in some dry sorbent injection applications) do result in the chemical creation of greenhouse gases).

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Options for Treatment of Emission Control Projects that Result in GHG Increases

- Treating like all other modifications
- Treating as a separate subcategory of modification
  - Because such modifications often do not involve any modifications to the boiler or turbine, it might be appropriate to consider less aggressive efficiency measures
- Treating as an existing source
  - Some stakeholders have suggested this option
  - EPA is still evaluating the legal justification
- Using a different size threshold to define applicability for certain types of projects

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Questions?

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Appendix A

What are Greenhouse Gases?

- GHGs are chemical compounds found in the Earth's atmosphere
  - They allow sunlight to enter the atmosphere freely.
  - When sunlight strikes the Earth's surface, some of it is re-radiated back towards space as heat (infrared radiation).
  - GHGs absorb the infrared radiation and trap the heat in the atmosphere.
  - Over time, if atmospheric concentrations of GHGs remain relatively stable, the amount of energy sent from the sun to the Earth's surface should be about the same as the amount of energy radiated back into space, leaving the temperature of the Earth's surface roughly constant.
  - Some GHGs occur naturally and are emitted to the atmosphere through natural processes and human activities (e.g., carbon dioxide, methane, and nitrous oxide).
  - Other GHGs are created and emitted solely through human activities (e.g., fluorinated gases).

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What are Greenhouse Gases? (cont.)

- Principal GHGs that enter the atmosphere due to human activities:
  - Carbon Dioxide (CO2)
    - Burning of fossil fuels (oil, natural gas, and coal), solid waste, trees and wood products
    - Chemical reactions (e.g., manufacture of cement, steel, aluminum)
  - Methane (CH4)
    - Production and transport of coal, natural gas, and oil
    - Livestock and other agricultural practices
    - Decay of organic waste in municipal solid waste landfills
  - Nitrous Oxide (N2O)
    - Combustion of fossil fuels and solid waste
    - Agricultural and industrial activities
  - Fluorinated Gases
    - Hydrofluorocarbon (HFC), perfluorocarbon (PFC), and sulfur hexafluoride (SF6)
    - Typically emitted in smaller quantities, but are potent GHGs
    - Synthetic GHGs emitted from a variety of industrial processes
    - Sometimes used as substitutes for ozone-depleting substances
      - Chlorofluorocarbons (CFCs) - used as refrigerants, solvents, and foam blowing agents
      - Hydrochlorofluorocarbons (HCFCs) - used to replace CFCs due to lower ozone depleting potential
      - Halons - used as fire extinguishing agent

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GHG Emissions Across Sectors

GHG Emissions in U.S.

(million metric tons of CO_2 equivalent)

Gas/Source Type	1990	2000	2009
CO_2	**5100.2**	**5976.2**	**5508.1**
Fossil Fuel Combustion	4741.2	5597.7	5212.0
Non-Energy Use of Fuels	116.2	142.5	122.1
Iron and Steel Production & Metallurgical Coke Production	99.5	85.9	42.6
Natural Gas Systems	37.6	29.9	32.2
Cement Production	33.3	41.2	29.4
Incineration of Waste	8	11.1	12.3
Amonia Production and Urea Consumption	16.8	16.4	11.8
Lime Production	11.5	14.1	11.2
Cropland remaining Cropland	7.1	7.5	7.8
Limestone and Dolomite Use	5.1	5.1	7.6
Soda Ash Production and Consumption	4.1	4.2	4.3
Aluminum Production	6.8	6.1	3.0
Petrochemical Production	3.3	4.5	2.7
Carbon Dioxide Consumption	1.4	1.4	1.8
Ferroalloy Production	2.2	1.9	1.6
Titanium Dioxide Production	1.2	1.8	1.5
Wetlands remaining Wetlands	1	1.2	1.1
Phosphoric Acid Production	1.5	1.4	1

Source: Table ES-2 of EPA's Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2009, February 15, 2011

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GHG Emissions Across Sectors (cont.)

GHG Emissions in U.S. (cont.)

(million metric tons of CO_2 equivalent)

Gas/Source Type	1990	2000	2009
CH_4	**674.9**	**659.9**	**686.5**
Natural Gas Systems	189.8	209.3	221.2
Enteric Fermentation	132.1	136.5	139.8
Landfills	147.4	111.7	117.5
Coal Mining	84.1	60.4	71.0
Manure Management	31.7	42.4	49.5
Petroleum Systems	35.4	31.5	30.9
Wastewater Treatment	23.5	25.2	24.5
Forest Land remaining Forest Land	3.2	14.3	7.8
Rice Cultivation	7.1	7.5	7.3
Stationary Combustion	7.4	6.6	6.2
Abandoned Underground Coal Mines	6.0	7.4	5.5
Mobile Combustion	4.7	3.4	2.2
Iron and Steel Production & Metallurgical Coke Production	1.0	0.9	0.4

Source: Table ES-2 of EPA's Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2009, February 15, 2011

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GHG Emissions Across Sectors (cont.)

GHG Emissions in U.S. (cont.)

(million metric tons of CO_2 equivalent)

Gas/Source Type	1990	2000	2009
N_2O	**315.2**	**341.0**	**299.5**
Agricultural Soil Management	197.8	206.8	204.6
Mobile Combustion	43.9	53.2	27.8
Manure Management	14.5	17.1	17.9
Nitric Acid Production	17.7	19.4	14.6
Stationary Combustion	12.8	14.6	12.8
Forest Land remaining Forest Land	2.7	12.1	6.7
Wastewater Treatment	3.7	4.5	5.0
N2O from Product Uses	4.4	4.9	4.4
Adipic Acid Production	15.8	5.5	1.9
HFCs	**36.9**	**103.2**	**125.0**
Substitution of Ozone Depleting Substances	0.3	74.3	119.3
HCFC-22 Production	36.4	28.6	5.4
Semiconductor Manufacture	0.2	0.3	0.3
PFCs	**20.8**	**13.5**	**5.6**
Semiconductor Manufacture	18.5	8.6	1.6
Aluminum Production			
SF_6	**34.4**	**20.1**	**14.8**
Electrical Transmission and Distribution	28.4	16	12.8
Magnesium Production and Processing	5.4	3.0	1.1
Semiconductor Manufacture	0.5	1.1	1.0

Source: Table ES-2 of EPA's Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2009, February 15, 2011

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GHG Emissions - Energy Sector

Energy Sector GHG Emissions

(million metric tons of CO_2 equivalent)

Gas/Source Type	1990	2000	2009
CO_2	**4903.6**	**5781.7**	**5379.0**
Fossil Fuel Combustion	4741.2	5597.7	5212.0
Electricity Generation	1820.8	2296.9	2154.0
Transportation	1485.9	1809.5	1718.9
Industrial	849.3	853.9	738.4
Residential	338.3	370.7	340.2
Commercial	219.0	230.8	218.8
U.S. Territories	27.9	35.9	41.7
Non-Energy Use of Fuels	116.2	142.5	122.1
Natural Gas Systems	37.6	29.9	32.2
Incineration of Waste	8.0	11.1	12.3
Petroleum Systems	0.6	0.5	0.5

Source: Table 2-4 of EPA's Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2009, February 15, 2011

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GHG Emissions - Energy Sector (cont.)

Energy Sector GHG Emissions (cont.)

(million metric tons of CO_2 equivalent)

Gas/Source Type	1990	2000	2009
CH_4	**327.4**	**318.6**	**337.0**
Natural Gas Systems	189.8	209.3	221.2
Coal Mining	84.1	60.4	71.0
Petroleum Systems	35.4	31.5	30.9
Stationary Combustion	7.4	6.6	6.2
Abandoned Underground Coal Mines	6.0	7.4	5.5
Mobile Combustion	4.7	3.4	2.2
Incineration of Waste	<0.05	<0.05	<0.05
N_2O	**57.2**	**68.1**	**41.0**
Mobile Combustion	43.9	53.2	27.8
Stationary Combustion	12.8	14.6	12.8
Incineration of Waste	0.5	0.4	0.4

Source: Table 2-4 of EPA's Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2009, February 15, 2011

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GHG Emissions – Electricity Generation

Electricity Generation-Related GHG Emissions

(million metric tons of CO_2 equivalent)

Gas/Source Type	1990	2000	2009
CO_2			
Fossil Fuel Combustion	1820.8	2296.9	2154
Coal	1547.6	1927.4	1747.6
Natural Gas	175.3	280.8	373.1
Petroleum	97.5	88.4	32.9
CH_4			
Stationary Combustion	0.6	0.7	0.7
N_2O			
Stationary Combustion	8.1	10.0	9.0

Source: Table 2-13 of EPA's Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2009, February 15, 2011

- CO_2 emissions from fossil fuel combustion are ~99.5% of total GHG emissions from fossil fuel combustion (2009)
- CO_2 emissions from coal-fired combustion are ~81% of total CO_2 emissions from fossil fuel combustion (2009)

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Appendix B

Efficiency Improvements for Existing EGUs

Efficiency Improvements for Existing EGUs

Efficiency Improvement Technology	Description	Efficiency Increase
Replace/Upgrade Burners	Replacement or upgrade of older, incorrectly sized, or mechanically deteriorated burners and inoperable dampers, broken registers, or clogged nozzles	Up to ~5%
Improved combustion	Tuning of combustion system to optimum settings and use/adjustment of instrumentation (e.g., temperature sensor, oxygen monitor, excess air setting, CO monitor)	~0.5 to 3%
Heat recovery	Use of heat from boiler exhaust to preheat incoming combustion air or to preheat boiler feedwater	Up to ~6%
Reduce air leakages	Maintenance of boiler system to minimize air leakage through routine maintenance procedures and monitoring of indicators of air leakage (e.g., oxygen level, fuel consumption, gas temperature)	~1.5 to 3%
Capture energy from boiler blowdown	Recovery of waste heat (low-pressure steam) from blowdown	~1 to 2%
Reduce slagging & fouling of heat transfer surfaces	Operation within boiler's design parameters (including fuel quality), use of cleaning system (soot blower - air or steam is used to periodically remove deposition on boiler walls and tubes), and/or fuel treatment (modifies ash characteristics)	1% to 3%

Source: EPA White Paper - Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from Industrial, Commercial, and Institutional Boilers, October 2010

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Efficiency Improvements for Existing EGUs (cont.)

Efficiency Improvements for Existing Coal-Fired EGUs

Efficiency Improvement Technology	Description	Reported Efficiency Increase
Combustion Control Optimization	Adjustment of coal and air flow to optimize steam production for the generator	0.15 to 0.84%
Cooling System Heat Loss Recovery	Recovery of a portion of the heat loss from cooling water exiting the steam condenser	0.2 to 1%
Flue Gas Heat Recovery	Recovery of the heat lost when flue gas is sprayed with flue gas desulfurization (FGD) reagent slurry and cools	0.3 to 1.5%
Low-rank Coal Drying	Drying of subbituminous and lignite coals using waste heat from flue gas and/or cooling water systems	0.1 to 1.7%
Sootblower Optimization	Intermittent injection of high velocity gets of steam or air to clean coal ash deposits from boiler tube surfaces to maintain adequate heat transfer	0.1 to 0.65%
Steam Turbine Design	Maintain mechanical and physical condition of steam turbine through use of efficiently designed turbine blades and steam seals	0.84 to 2.6%

Source: EPA White Paper - Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from Coal-Fired Electric Generating Units, October 2010

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Efficiency Improvements for New EGUs

- Efficiency improvements for new coal-fired EGUs
  - Use of supercritical boilers
    - Operate at higher pressures and temperatures
    - Start-up times are quicker
    - National Energy Technology Laboratory (NETL) analysis shows that supercritical boilers are approximately 2.3% more efficient than subcritical boilers
    - Application currently limited to facilities of approximately 200 MWe gross output or more due to the availability of steam turbines that are designed for supercritical steam conditions
  - Use of ultra-supercritical boilers
    - Operate at even higher pressures and temperatures
    - Can potentially operate at efficiencies approaching 50%
    - Material degradation can be an issue when firing high-sulfur coal
    - Use is prevalent in Denmark, Germany, and Japan
    - First ultra-supercritical EGU in U.S. – Southwest Electric Power Company's John W. Turk, Jr. Power Station near Texarkana, AR
      - 600 MWe pulverized coal-fired EGU
      - Will burn Powder River Basin subbituminous coal
      - Scheduled to begin operation in late 2012

Source: EPA White Paper - Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from Coal-Fired Electric Generating Units, October 2010

Efficiency Improvements for New EGUs (cont.)

- Use of IGCC technology
  - Electric output is generated by both the combustion turbine and the steam turbine
  - NETL analysis of three coal gasification processes shows net efficiencies of 38.2% to 41.1%
- Coal drying
  - Several advanced pre-combustion coal drying technologies are or nearly are commercially available
  - Reported net gains in overall efficiency of 2% to 4%
- Boiler feedwater heating
  - Use of heat sources other than the steam turbine to heat feedwater
  - Increases the output of the steam cycle and potentially lowers GHG emissions

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Source: EPA White Paper - Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from Coal-Fired Electric Generating Units, October 2010