What is 21st Century Coal?

**Clean Coal Defined...**

- Use of modern, highly efficient methods and technology in the extraction and utilization of coal to produce valued products.
- Satisfying the desired global objective of economic sustainability, energy security, and environmental care.
- Wide scale deployment of clean coal technologies that enable the ultimate goal of continuous emission improvements leading to near-zero emissions.
Why Coal? World’s Fastest Growing Energy Source, Expected to Overtake Oil

Total World Primary Energy Demand by Fuel

Why Clean Coal?
To Improve Lives and Livelihoods

Affordable Electricity Enables People to Live Longer and Better

Every 10-Fold Increase in Per Capita Electricity Use Drives a 10-Year Increase in Longevity

The Economic Miracle Powered by Coal

Near Perfect Correlation Between Coal Use and GDP Growth

The Goal: Near-Zero Emissions

- Efficiency improvements at Existing Plants
- Building New Supercritical and Ultra-Supercritical Plants
- Demonstrating and Deploying IGCC and Carbon Capture, Utilization and Storage
- Advance Carbon Capture, Utilization and Storage and Btu Conversion
- Retrofitting Existing Coal-Based Generation with Carbon Capture/Storage Up to 90% Lower CO₂
- CO₂-Enhanced Oil Recovery, Producing 4 Million b/d

Technology is the Path to Achieve our Environmental Goals

20 years
Clean Coal Technologies Are Environmental Success Story

Total Emissions Have Declined While Coal Consumption Increased

% Change Since 1970


Coal-Based Power Generation
GDP per Capita (2005 $)
NOx Emissions/kWh
SOx Emissions/kWh

Source: USDA 2011, EIA 2012, NETL 2011
Advanced Technologies Build On Progress for Sustainable Future

China Houses 55% of the World’s Advanced Coal Fleet

- **Emission rates one-fifth the average of U.S. coal fleet...**

- **Every 1% efficiency gain reduces lifetime emissions by 2,000 tons of NOx and SO\(_2\) and 2.5 million tons of CO\(_2\)**

21st Century Coal Technology Achieves Near-Zero Criteria Emissions

Older Fleet

- Sulfur Dioxide: ↓89%
- Nitrogen Oxide: ↓93%
- Particulates: ↓30%
- CO₂: ↓30%

Advanced Coal

- Sulfur Dioxide: ↓99.9%
- Nitrogen Oxide: ↓99.9%
- Particulates: ↓99.9%
- CO₂: ↓99.9%
How? Higher Temperatures Increase Environmental Efficiencies

**Typical Supercritical and Ultra-Supercritical PC Control Equipment Increase Power Per Unit**

- **Low NOₓ Burners**
  - Reduces NOₓ

- **Steam Generator**
  - High efficiency boiler produces less emissions per megawatt output

- **Selective Catalytic Reduction**
  - Further reduces NOₓ and enhances mercury removal

- **Wet ESP**
  - Reduces fine particulate and sulfuric acid mist

- **Scrubber**
  - Reduces SO₂ and mercury

- **Fabric Filter**
  - Captures particulate matter and mercury

- **Cooling Tower**

- **Emission Monitoring**
  - Continuously monitors many types of emissions

- **Bottom Ash**
  - A by-product useful in concrete and other products, or stored

- **Fly Ash**
  - A by-product useful in concrete and other products, or stored

- **Gypsum**
  - A by-product useful in wallboard

- **Typical Supercritical and Ultra-Supercritical PC Control Equipment**

- **PC Boiler with Low NOₓ Combustion System**
  - SCR
  - NH₃ Injection
  - Air Heater
  - FD Fans
U.S. Advanced Coal-Fueled Generating Fleet is Still Growing

More than 11 GW of New Supercritical Technology Capacity Added

~ 40 million tons of coal annually in new operating plants

Supercritical Technology Since 2000

Operating
- Oak Creek: 1,230 MW (2009)
- Comanche: 750 MW (2010)
- Oak Grove: 1,600 MW (2009)
- Iatan 2: 850 MW (2010)
- Trimble County 2: 750 MW (2011)
- Sandy Creek: 900 MW (2013)
- Westin 4: 530 MW (2008)
- Longview: 695 MW (2011)
- Prairie State: 1,600 MW (2012)
- Cliffside: 825 MW (2012)
- Turk: 600 MW (2012)

Total: 11,120 MW
Each Investment Delivers Greater Efficiencies, Lower Emissions

Efficiency Improvement is the First CO₂ Mitigation Technology

**CO₂ Emissions vs. Net Plant Efficiency**

- Yuhuan CO₂ emissions are about 25% less than the typical U.S. coal plant
- Coal Utilization Research Council / Electric Power Research Institute R&D targets about 35% reduction in CO₂ emissions from coal combustion technologies

Source: Based on Booras and Holt (2004).
Coal’s Versatility Adds to Energy Security

_Btu Conversion Transforms Coal into Clean Electricity, Natural Gas & Transportation Fuels_

![Diagram showing the conversion of coal into various energy forms: Electricity, Industrial Gas, Pipeline SNG, Ethanol, Diesel, Jet Fuel, and Hydrogen. It also shows CO₂ Capture and Sequestration.](image-url)
Harnessing Coal’s Carbon Delivers Economic and Environmental Objectives

**Carbon Capture Utilization & Storage (CCUS) Technologies**

- **Pre-Combustion:** Operates like a “scrubber” to absorb the CO$_2$ from the boiler exhaust flue gas.

- **Post-Combustion:** Selectively absorbs and recover the CO$_2$ from the syngas. Commercially available.

- **Oxy-Combustion:** Combusts fuel in the presence of oxygen, rather than air, produces a highly pure CO$_2$ exhaust.

- **CO$_2$ Uses**
  - Deep geologic storage is beginning to be demonstrated globally.
  - Enhanced Oil Recovery (EOR) has been deployed for decades in the Permian Basin (west Texas) from natural CO$_2$ sources.
CO₂ Capture Options are Significant

Numerous Companies Advancing a Variety of Technologies
Over the next 30 years:

- 87 billion barrels in stranded oil could be recovered in the U.S. alone
- CO₂ is a necessary feedstock for EOR
- Maximum needed: 14 billion tons of CO₂
  7 billion tons of coal

Coal Provides the Best Deal for Baseload Power

No Subsidies Required for Coal to Be Cost Effective...
Yet U.S. Subsidies Highest Cost and Least Abundant Generation

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Cost per megawatt hour</th>
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<tbody>
<tr>
<td>Oil &amp; Gas</td>
<td>$0.64</td>
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<tr>
<td>Coal</td>
<td>$0.64</td>
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<tr>
<td>Hydropower</td>
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<td>Nuclear</td>
<td>$3.14</td>
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<td>Wind</td>
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<tr>
<td>Solar</td>
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Alarmingly High Methane Emissions Raise New Questions About Gas

Up to 4% of Methane Could Be Escaping, 23x More Potent GHG than CO₂

- Study of Uinta Basin: 9% of production fugitive, 2x industry est. loss rates
- Study of Denver–Julesburg Basin: Leakage rate 2x official figures
- Latest U.S. EPA studies suggest 2.4% natural gas production lost to leakage
- Princeton/EDF conclude anything greater than 3.2% adds to warming

“We were expecting to see high methane levels, but I don’t think anybody really comprehended the magnitude of what we would see.”

- Colm Sweeney, NOAA’s Earth System Research Laboratory
Advanced Coal Delivers Real “Green” Jobs and Socioeconomic Benefits

100 Gigawatts of Green Coal Technology

Cumulative Benefits During Construction

<table>
<thead>
<tr>
<th>Benefits</th>
<th>100GW</th>
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<tbody>
<tr>
<td>Jobs (million job years)</td>
<td>6.9</td>
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<tr>
<td>Output (trillions)</td>
<td>$1.1</td>
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<tr>
<td>Labor Income (billions)</td>
<td>$368</td>
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Annual Benefits During Operations

<table>
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<th>Benefits</th>
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<tbody>
<tr>
<td>Jobs (thousands)</td>
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<tr>
<td>Output (billions)</td>
<td>$58</td>
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<td>Labor Income (billions)</td>
<td>$17</td>
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</table>

In Summary, Advanced Coal Technologies Key to Economic, Environmental and Energy Security Goals

GreenGen Power Plant and Carbon Research Center; Tianjin, China