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New Mexico's Coal and Electricity Industries

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Escalante Generating Station. *Photo courtesy of Tri-State Generating and Transmission Association.*

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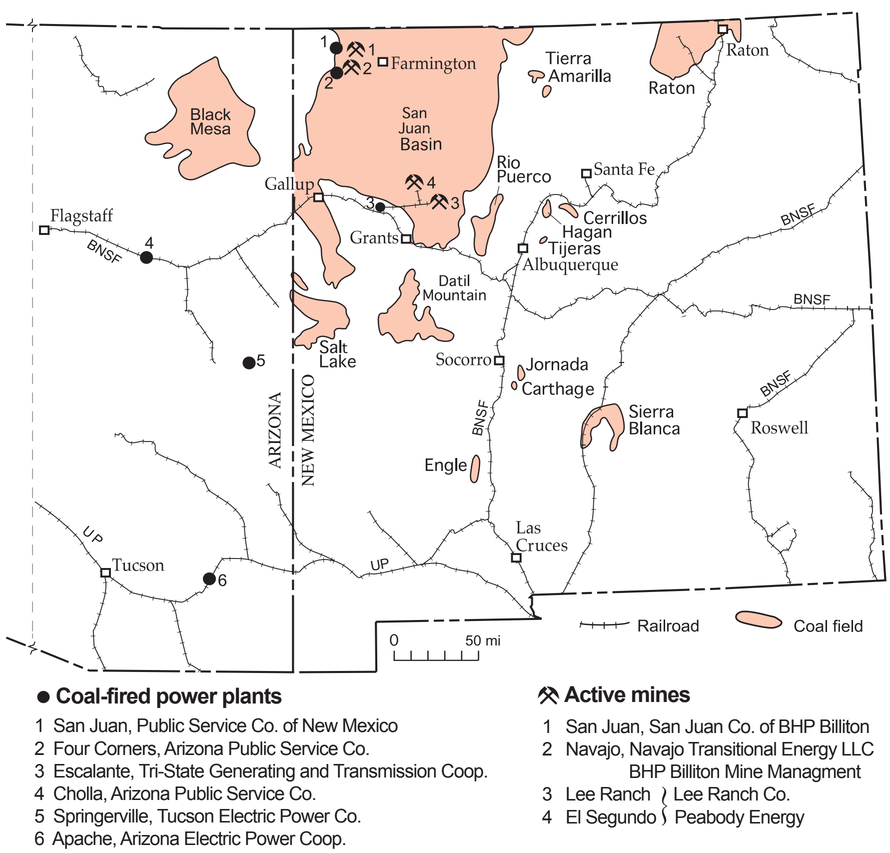
New Mexico's Coal and Electricity Industries and the Clean Air Act

Gretchen Hoffman

Editor's Note: *This issue of Lite Geology is the second in a series of three issues, all related to new technologies in the energy industries. The last issue addressed new technologies in the oil and gas industry, this issue focuses on coal and coal-fired electrical generation industries, and the third will address the renewable energy sector.*

Coal in New Mexico

Coal has played a significant role in New Mexico's history. Coal was used by the early forts and settlements, the railroads, and the smelters built in the territory after the Civil War. With the advent of electricity and the lack of large water bodies to supply hydroelectric power, coal became the fuel of choice for power generating plants in the Southwest.



Map of New Mexico coal fields and coal mines, plus coal-fired power plants in New Mexico and Arizona.

New Mexico ranked 12th in U.S. coal production during 2012. Coal mining provides an important contribution to New Mexico's state budget; it is the state's third largest source of revenues from mineral and energy production. The state also receives royalties and rentals from coal leases on state and federal lands. In 2012, the coal industry directly employed 1,770 people, and the payroll from the state's coal industry totaled $121.9 million. Along with the economic impact of coal mining in the state, 68% of the total electricity generated in New Mexico comes from coal combustion. Approximately one-third of this electricity is consumed in other states. In New Mexico, 34% of the total energy consumed comes from coal.

Generating Stations Using New Mexico Coal

New Mexico's three major coal-fired power generating stations are in the northwest part of the state (See map; Table 1, page 3). The Four Corners plant, operated by Arizona Public Service (APS), has five generating units, built between 1963 and 1970. Four Corners has one of the largest generating capacities in the area. The Navajo mine supplies coal to Four Corners; both the power plant and mine are on Navajo Nation land. North of the San Juan River, Public Service of New Mexico's (PNM) San Juan generating station has four units built between 1973 and 1982. Coal for this plant comes from the nearby San Juan mine. The Escalante Generating Station at Prewitt, New Mexico (cover photo) has one 247-megawatt unit built in 1984. Tri-State Generation and Transmission Association operates Escalante and supplies wholesale electricity to cooperatives in New Mexico. Escalante gets its coal from the Lee Ranch and El Segundo mines northwest of Grants via a rail line.

New Mexico coal is shipped by rail to generating stations in Arizona including Apache Generating Station near Cochise, Cholla near Joseph City, and Springerville Generating Station. The Springerville plant is the newest of the generating stations in Arizona fueled by New Mexico coal (Table 1, page 3).

Coal-fired power plants in the Southwest tend to be younger than those east of the Mississippi River, but 74% of coal-fired generating stations in the U.S. are at least 30 years old. The average lifespan for generating stations is 40 years. With age, the ability to retrofit these plants with emission controls to meet U.S. Environmental Protection Agency (EPA) guidelines becomes more expensive, and may affect the overall efficiency of the plant.

Generating stations using New Mexico coal

See Appendix for Descriptions of Controls
Controls apply to all units unless noted

Plant Name, State	Coal Source (Mine)	Total Generating Capacity (MW)	Year Units Built	Number of Units	Unit Retirements	NO_X Controls	SO_2 Controls	PM Controls
San Juan, NM	San Juan	1930	1973, 1976, 1979, 1982	4	Units 2 and 3 in 2017	LNB OFA	WS	ESPH, B
Four Corners, NM	Navajo	2040	1963-64 (units 1-3) 1969-70 (units 4-5)	5	Units 1-3 in 2013	LNB (2 units) LNCB (2 units)	WS	ESPH, B
Escalante, NM	Lee Ranch/ El Segundo	247	1984	1		LNC3 (3 units) OFA (1 unit) LNB	WS	B
Cholla, AZ	Lee Ranch/ El Segundo	1027	1962, 1978, 1980, 1981	4		SCR (2 units) LNC (3 units) LNB (1 unit)	WS	B (3 units) WS (1 unit)
Springerville, AZ	Lee Ranch/ El Segundo	1609	1985, 1990, 2006, 2009	4		SCR (2 units) LNC (3 units) LNB (1 unit)	DS	B
Apache, AZ	Lee Ranch/ El Segundo	350	1979	2		OFA	WS	ESPH

Data from National Electric Energy Data System (NEEDS v5.13v3) frame (EPA, 2013) with additional information EPA, 2014

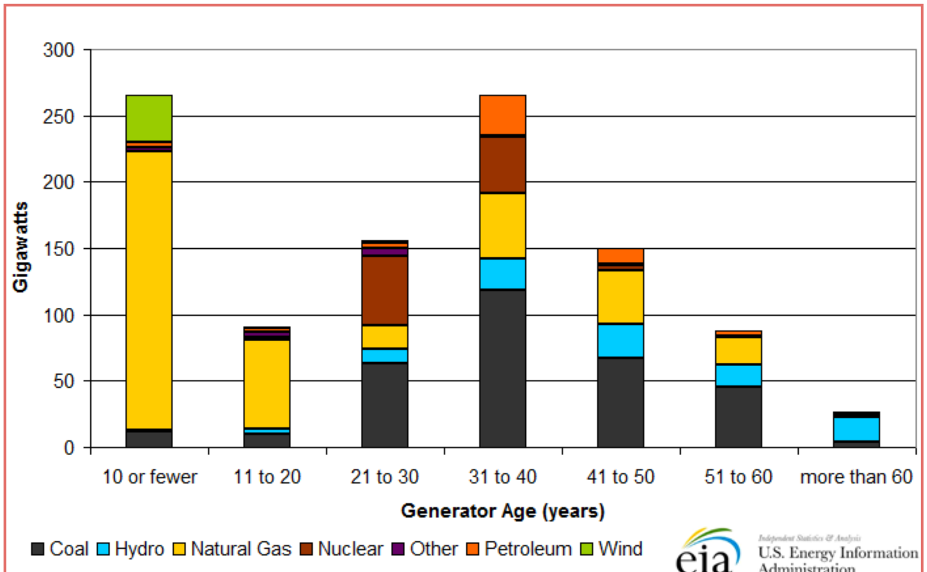
Appendix: Descriptions of nitrous oxide (NO_x), sulfur dioxide (SO_2) and particulate matter (PM) controls

NO_X Controls	Control Description
LNB	Low NO_x Burner Technology (Dry Bottom only)
LNBO	Low NO_x Burner Technology w/Overfire Air
LNC3	Low NO_x Burner Technology w/Closed-coupled/Separated OFA
LNCB	Low NO_x Cell Burner WS
OFA	Overfire Air
SCR	Selective Catalytic Reduction

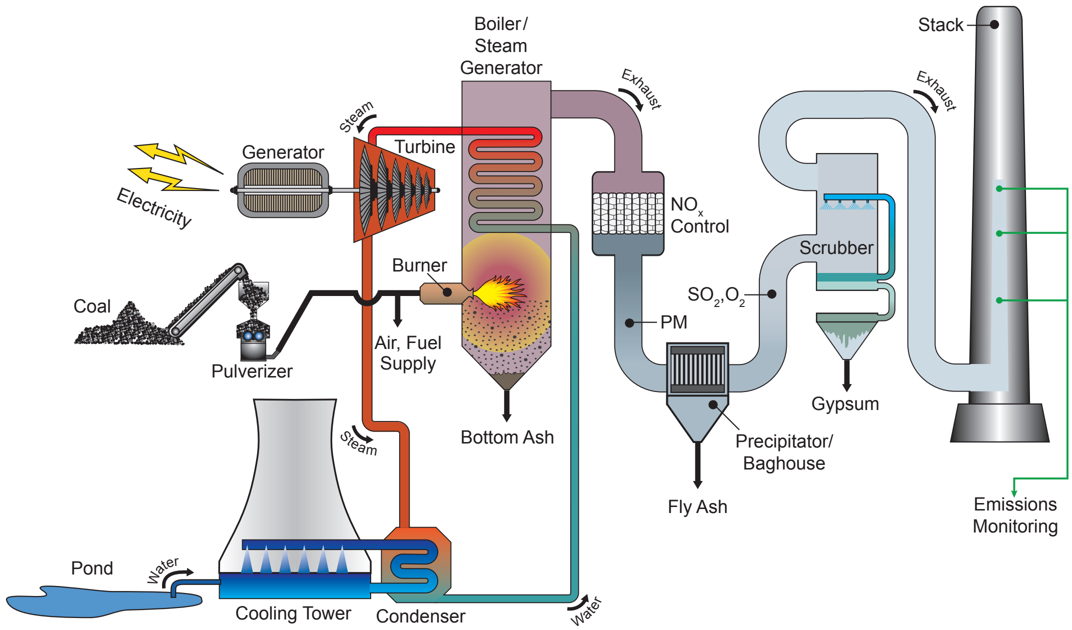
SO_2 Controls	Control Description
DS	Dry Scrubber
WS	Wet Scrubber

PM Controls (Particulate Matter)	Control Description
B	Baghouse
ESPH	Electrostatic Precipitator, Hot Side
WS	Wet Scrubber

TABLE 1—Generating stations using New Mexico coal.



Age and capacity of existing U.S. electric generating stations by fuel type as of year-end 2010. *Data from the U.S. Energy Information Agency.*



Simplified schematic diagram of a coal-fired power plant process. The terms used in the diagram are defined below. *The diagram is modified from SICK Sensor Intelligence.*

Fuel–combustion:

Coal–Most abundant fossil fuel produced in the U.S. Used to generate 39% of our nation's electricity.

Pulverizer–Grinds coal to a fine powder.

Air/Fuel Supply–An air fan dries and mixes the coal powder with hot air for efficient burning.

Burner–Nozzle device, generally in the lower boiler walls, that introduces pulverized coal and air to efficiently burn the coal. Low NO_X burners restrict the air and stage the coal combustion to limit formation of NO_X and CO_2.

Thermodynamic—electrical generation:

Boiler/Steam Generator–Large vessel with tubing for circulating water. The water is heated to steam that drives the turbine.

Turbine–Rotary mechanical device that converts the kinetic energy of the steam to mechanical energy.

Generator–Transforms the turbine's mechanical energy to electric energy.

Cooling Tower–Cools steam passing through the condenser.

Condenser–Converts steam from the turbine back to water that recirculates to the boiler.

Emissions and byproduct collection:

Bottom Ash–Coal-combustion byproduct deposited on the boiler walls that eventually falls to the bottom and is collected.

NO_X Controls–Includes low NO_X burners and selective catalytic reduction controls; these reduce NO_X and mercury emissions.

Precipitator/Baghouse–Captures particulate matter (PM) and fly ash carried out of the boiler by hot exhaust (flue) gases.

Scrubber–Removes SO_2 from the flue gas and captures some of the mercury emissions. Gypsum is a byproduct of this process.

Stack–Ventilates hot flue gases, and contains sampling devices that monitor emissions.

Clean Air Act

The Clean Air Act (CAA), adopted in the 1970s and modified by amendments since then, has regulated industry emissions to improve air quality by limiting the amount of fine particles and pollutants introduced into the air. These regulations help reduce acid rain and improve public health by dramatically reducing emissions of sulfur dioxide (SO_2) and oxides of nitrogen (NO_X). As our society has become more dependent on energy, the way we produce energy and its byproducts have become the focus of recent EPA rulings.

Sulfur Dioxide Emissions

The Clean Air Act amendment of 1990 set a goal of reducing U.S. annual SO_2 emissions by ten million tons, to achieve levels below those of 1980. Reducing SO_2 in relation to Btu (British thermal unit), or energy value, is integral in meeting emission standards. The lower sulfur/Btu standard resulted in many power plants in the Midwest switching from higher-sulfur coals mined in the eastern U.S. to low-sulfur Powder River Basin coals from Wyoming and Montana. New Mexico coal has relatively low sulfur content, so this coal market saw little change.

All of the New Mexico and Arizona power plants participating in the Acid Rain Program have SO_2 emission controls for flue gas desulfurization (Table 1 page 3). Most FGD systems use lime, limestone, quicklime, or soda ash that reacts with the SO_2, creating gypsum or calcium sulfate. Dry scrubbers capture SO_2 from the flue gas before it reaches the fly ash collectors. Fly ash is the primary particulate matter that is not combustible. In systems that use wet scrubbers, the particulate matter is captured before the SO_2. Wet or dry scrubbers can remove 90 to 98% of SO_2 from the flue gas.

Either electrostatic precipitators (ESP) or baghouses that use fabric filters capture the particulate matter from the flue gas coming from the boiler. Both ESPs and baghouses have a 99+% efficiency to comply with National Ambient Air Quality Standards established by the EPA. Particulate matter controls and flue gas desulfurization controls also capture a significant portion of the mercury emissions in the flue gas. The percent of mercury captured is dependent on the type of coal and the type of equipment used.

Nitrous Oxides Emissions

Oxides of nitrogen (NO_X) emissions are a known precursor to ozone formation and acid rain, and can react with volatile organic compounds to form photochemical smog. The Acid Rain Program set goals of reducing NO_X by two million tons from 1980 levels. NO_X forms during the combustion process when naturally occurring nitrogen in coal combines with the oxygen present in the combustion air. All the generating stations burning New Mexico coal have some form of NO_X emission controls. (Table 1 page 3)

- Frequently the controls are low NO_X burners that alter or modify the firing conditions in the boiler, typically by lowering temperatures, and help to reduce NO_X by 40 to 60%.
- Overfire Air controls divert a portion of the total combustion air away from the primary combustion zone. Overfire ports are located at the highest elevation of the burners in the furnace, reducing the oxygen available early in the combustion process. By limiting the oxygen in the primary flame zone in the boiler, less nitrogen becomes NO_X, which can reduce NO_X emissions from 30 to 70%.
- A third method to limit NO_X is by selective catalytic reduction. NO_X leaves the boiler with the exhaust gas where it passes through a large catalyst. The NO_X reacts with the catalyst and anhydrous ammonia and converts NO_X to harmless nitrogen and water. This method removes between 80 and 90% of the NO_X in the exhaust gas.

Greenhouse Gas Emissions

Greenhouse gases (GHG) trap heat from the sun and warm the planet's surface. These include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and others. Of the total amount of U.S. greenhouse gasses emitted in 2011, about 86% is energy related, and almost all of these were CO_2 emissions from combustion of fossil fuels. Electric power accounts for 39% of all U.S. energy-related CO_2 emissions. Total CO_2 emissions (including industrial, commercial, residential, and automotive) in New Mexico for 2011 were 56.5 million metric tons, 35th in the nation.

Total net electricity generated in New Mexico (2012) was 36.6 million megawatt hours with 68% from coal that produced 26.8 million metric tons of CO_2 emissions (47.6% of the total). Capturing CO_2 is the next big hurdle for coal-fired generation, and is at the forefront of new regulations from the EPA. Several pilot projects have funding from the U.S. Department of Energy to implement new technologies for CO_2 capture. None of these has reached full-scale operation (Table 2 page 6).

CO_2 Capture Technology and Transport

CO_2 capture can occur either before or after combustion of the coal. Pre-combustion involves partially oxidizing the coal in steam and oxygen or air under high temperature and pressure to form syngas. The syngas is a mixture of hydrogen (H_2), CO_2, carbon monoxide, and smaller amounts of other gases. The syngas then undergoes a reaction to convert carbon monoxide and water to H_2 and CO_2. The H_2-rich fuel is burned. The concentrated CO_2 (15 to 50% of the resultant gas) can be separated and captured, which removes 80 to 90% of CO_2 emissions. Generating stations that use this method are integrated gasification combined cycle stations (IGCC). Two current projects (Table 2, page 6) in the U.S. plan to use this method.

Post-combustion capture removes CO_2 from the flue gas stream, which is dilute (5 to 15%) compared to the syngas. By passing through a filter, usually a chemical solvent, 80 to 90% of the CO_2 in the flue gas is removed. The W.A. Parish coal plant (Table 2, page 6) will use this method. Currently CO_2 removal at natural gas power plants is by this method. After capture, the problem is compressing the CO_2 for transport, which requires a lot of energy.

Oxyfuel combustion burns the coal in pure oxygen instead of air, producing almost pure CO_2 and steam to power the turbines. The concentrated CO_2 is captured from the flue gas. The oxygen required for this method significantly increases the cost. The FutureGen site in Illinois will use this technology by retrofitting an older coal-fired plant.

Name	Location	Size MW	Feed-stock	Capture Technology	Capture/ CO_2 fate	Start	Funding: % DOE share of total cost
Texas Clean Energy Project	Penwell, TX	400	Coal	Pre-combustion, IGCC	2–3 Mt/yr, EOR Permian Basin	2015 (under construction)	26% of $1.73 billion
Kemper County	Kemper County, MS	582	Coal	Pre-combustion, IGCC	3.5 Mt/yr, EOR	2015	5% of $5.5 billion
FutureGen	Meredosia, IL	200	Coal	Retrofit, Oxy combustion	1.1 Mt/yr, Saline Aquifer	2017	60% of $1.65 billion
WA Parish	Houston, TX	250	Coal	Post-combustion, Flue gas scrubbing	1.4 Mt/yr, EOR Jackson County, TX	2016	50% of $334 million

TABLE 2—Power plant CO_2 capture and storage projects. More information can be found at the Carbon Capture & Sequestration Technologies at MIT website: **http://sequestration.mit.edu/tools/projects/index_capture.html.**

This dragline is mining coal at the Lee Ranch Mine, McKinley County, New Mexico. *Photo courtesy of Peabody Energy.*

After capturing the CO_2, the next step is transporting it for storage or use. Pipelines can transport CO_2 in a gaseous state. The CO_2 must be clean and dry so it is not corrosive. Most existing CO_2 pipelines are located in the western U.S. where naturally occurring CO_2 fields exist. The following link shows CO_2 pipelines in the U.S. **http://www.marstonlaw.com/index_files/CO2%20Pipeline%20Map.pdf**. The other method of transport is by truck as a liquid.

CO_2 Storage

There are three main categories of storage for CO_2: oil and gas replacement, coal seam storage, and deep saline aquifers. Oil and gas replacement of CO_2 for enhanced oil recovery (EOR) uses established technology that injects CO_2 into existing oil fields where it reduces the viscosity of the oil, which enhances the flow of oil from the producing formation into recovery wells. In the U.S., over 3,853 miles of pipelines transport up to 72 million tons of CO_2 per year for use in EOR. Of this total, 17 million tons are anthropogenic (generated from human activity). Most of the projects funded by the U.S. Department of Energy (Table 2, above) will use the captured CO_2 for EOR.

Another strategy is injecting CO_2 into coal seams that are too deep to mine economically. The CO_2 is adsorbed into the coal matrix, displacing methane. Coal bed methane, a form of natural gas, has become an important source of energy. Wells can extract the displaced methane, but because the CO_2 is adsorbed differently in coal than in oil-bearing formations, the economics are different from EOR.

Saline aquifers are a third type of geologic storage for CO_2. Saline aquifers are geologic formations, such as sandstone, that are porous and saturated with salt water (brine) that is unfit for agricultural use or human consumption. These aquifers need to be deep, over 800 meters (2,624 feet), and preferably have an impermeable cap rock of clay or shale to trap the CO_2. Only the FutureGen project proposes to inject captured CO_2 into a saline aquifer.

New Mexico Strategies to Meet EPA Guidelines

In February 2013, the EPA issued a proposed Best Available Retrofit Technology rule for the Regional Haze rule under the Clean Air Act. This rule addresses the need to reduce visibility impairment in national parks and wilderness areas, and applies to facilities built between 1962 and 1977. This rule affects both the Four Corners and San Juan generating stations. Both plants have decided to shut down their older units (Table 1, page 3) to comply with the EPA regulations because of the high cost of retrofitting. San Juan will retrofit the two remaining units with selective catalytic reduction technology in 2016. The loss of generating capacity will be offset by building a natural gas unit, acquiring power from Palo Verde Nuclear plant in Arizona, and by adding solar power. The Four Corners plant has already closed units 1, 2, and 3 to meet these requirements. To offset the loss of generating capacity to its customers, Arizona Public Service acquired 48% ownership of units 4 and 5 from California Edison. Both of these closures result in lower coal production from the nearby mines, significantly affecting New Mexico's coal industry. In an effort to offset some of their greenhouse emissions, Tri-State is working with Electric Power Research Institute to study potential methods of augmenting the conventional steam cycle using solar power at their Escalante plant. The goal is to have a larger output of electricity without consuming more coal and reduce their carbon footprint.

Acknowledgements—

Thanks to Leo Gabaldon and Stephanie Chavez for their work on all the graphics in this issue.

Suggested online reading

Clean Coal Technologies, Carbon Capture & Sequestration, updated May 2014, World Nuclear Association: **http://www.world-nuclear.org/info/Energy-and-Environment/-Clean-Coal--Technologies/**

Clean Coal Technology: How It Works, updated November, 2005, BBC News: **http://news.bbc.co.uk/2/hi/science/nature/4468076.stm**

Implications of Accelerated Power Plant Retirements, March 28, 2014, EIA: **http://www.eia.gov/forecasts/aeo/power_plant.cfm**

Can Kemper Become the First US Power Plant to Use 'Clean' Coal?, March 12, 2014, The Guardian: **http://www.theguardian.com/environment/2014/mar/12/kemper-us-power-plant-coal-carbon**

A Sea of Change in the Electric Grid, September 15, 2013, Albuquerque Journal: **http://www.abqjournal.com/263529/news/changing-fuel-mix-rocks-pnms-world.html**

Construction of World's Largest Carbon Capture Project Under Way, July 15, 2014, Coal Age: **http://coalage.com/news/latest/3757-construction-of-world-s-largest-carbon-capture-project-under-way.html#.U8kuC4BdXSI#UF0983**

Tri-State to host solar augmentation study at N.M. coal-based power plant, February 3, 2009, Tri-State: **http://www.tristate.coop/NewsCenter/NewsItems/EPRI-CSP-study-at-Escalante.cfm**

What is a Watt?

Power is the rate at which energy is produced or consumed. A watt (W) is a unit of power that measures the amount of electrical flow at a moment in time. For instance, a 100 W light bulb uses energy at a higher rate than a 60 W bulb and emits more light. Household appliances and other electrical devices perform "work" that requires energy in the form of electricity. A watt-hour is a unit of energy – a way to measure the amount of work performed or generated during a specific time. Power companies charge you for electrical energy by the kilowatt-hour (kWh); one kilowatt-hour =1,000 watt-hours.

- The average household in New Mexico uses 656 kWh per month.
- A 32-inch flat screen LCD television uses about 50 watts when powered on. If you watch TV for four hours a day, how many kilowatt-hours of energy are being used in a month? Answer: 50 watts x 4 hours/day x 30 days/month ÷ 1000 watts/kilowatt = 6 kWh/month.
- If we use the average price for electricity in New Mexico (11.37 cents/kWh), we can calculate how much it would cost for 6 kWh. The total cost for watching your TV four hours a day every day of the month is: 6 kWh/month x 11.37cents/kWh = $0.68/month.
- If we did the same calculation for a desktop computer and LCD monitor: [(120 watts + 40 watts) x 4 hours/day x 30 days/month] ÷1000 watts/kilowatt, the total would be 19.2 kWh/month. The cost would be: 19.2 kWh/month x11.37 cents/kWh = $2.18/month.
- You can see that using a computer, which many of us do for many hours a day, really uses a lot of energy and adds to your electric bill!

For further reading:
http://science.howstuffworks.com/environmental/energy/question501.htm

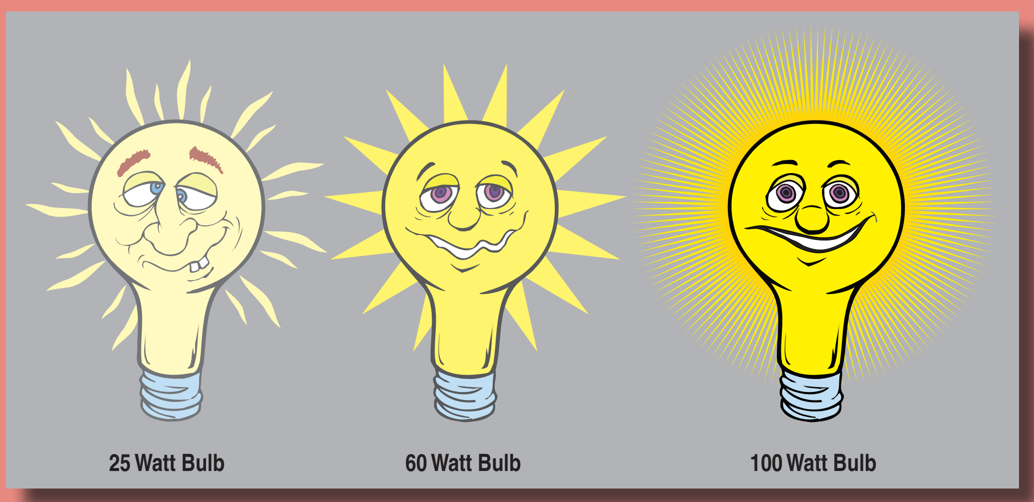


Illustration by Leo Gabaldon

Carbon Dioxide Emissions: New Guidelines and Economic Challenges

Gretchen Hoffman

On January 8, 2014, the U.S. Environmental Protection Agency (EPA) proposed standards of performance for new (those built after the ruling is finalized) generating units using natural gas or coal as a fuel source. The standard for coal is 1,100 pounds of carbon dioxide per megawatt-hour (lb CO_2/MWh), and the Best System Reduction will require partial carbon capture and storage, which has yet to be demonstrated on a commercial scale anywhere in the world. The typical coal-fired unit generates 2,000 lbs CO_2/MWh. The EPA contends that the proposed regulation will encourage the development of technologies to meet these standards.

On June 2, 2014, the EPA proposed standards for existing power plants nationwide to achieve CO_2 emission reductions by 2030 that would be approximately 30% of 2005 levels, with an interim target of 25% on average between 2020 and 2029.

The challenge in implementing these proposed standards is significant. To date, there have been several small pilot plant operations, but many of these have been cancelled partly due to funding constraints. Capturing CO_2 may sound simple, but is a complicated process for both pre-combustion and post-combustion processes. The concentration and compression of the captured CO_2 is energy intensive and can consume up to 25% of the generating units' electrical output. More coal would have to be burned to make up for the lost production.

Once captured, transporting the CO_2 by pipeline is a known technology. However, the existing pipeline system serves only a limited geographic area. Building new pipelines is a lengthy process involving land acquisition and environmental permitting. In addition, anthropogenic (human-generated) CO_2 has to compete with natural CO_2. There is also a need to characterize the geologic formation used for either storage or enhanced oil recovery. This is a time-consuming and costly endeavor, and the quantity of CO_2 produced over the life of the power plant, which averages 40 years, has to be part of the characterization.

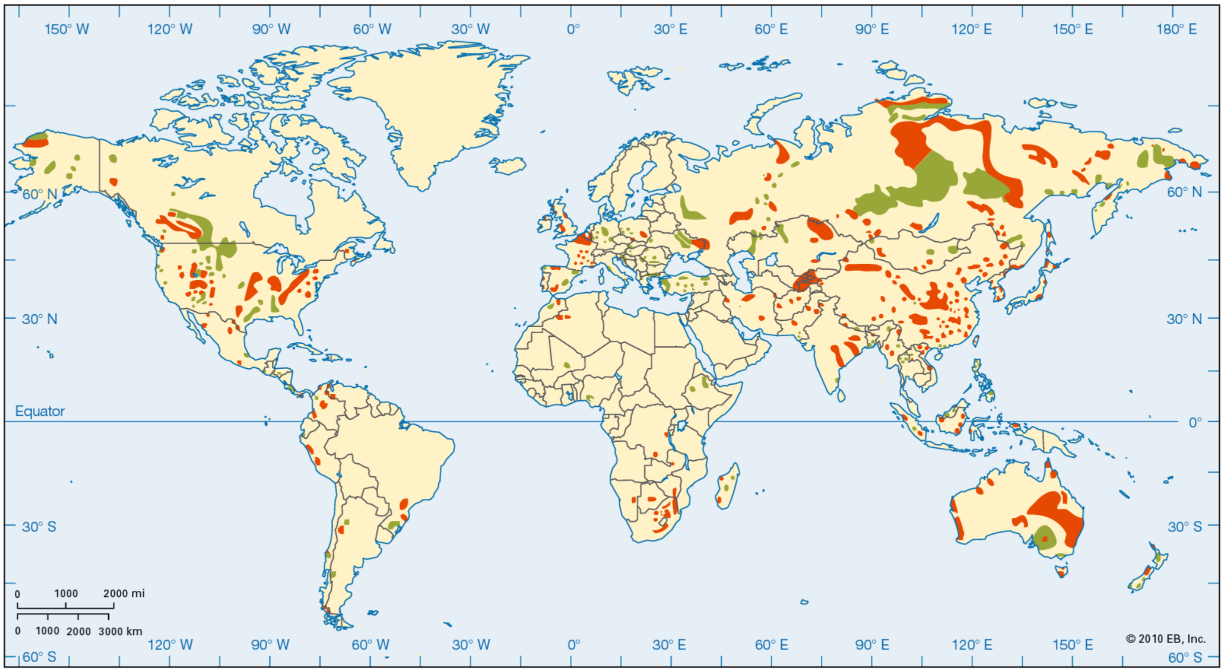
All these factors add to the cost of CO_2 capture and storage, and ultimately to the cost of electricity. Estimates by the National Energy Technology Laboratory follow:

> A new pulverized-coal plant without Carbon Capture and Storage (CCS) would cost $75/MWh. The same plant with CCS would cost $137.1/MWh.
>
> A new integrated gasification combined cycle (IGCC) plant without CCS would cost $97.8/MWh, and $141.7/MWh with CCS.

Large-scale demonstrations of CCS have yet to prove the technology. At this time, Southern Company's plant is the only large-scale, pre-combustion project in the U.S. A post-combustion project (Boundary Dam) on an existing plant in Canada is under construction. Until these or other large-scale projects have been in operation for several years, the true costs of CCS are not known.

Global Impacts of Coal Production

Maureen Wilks



Major Coal Deposits of the World

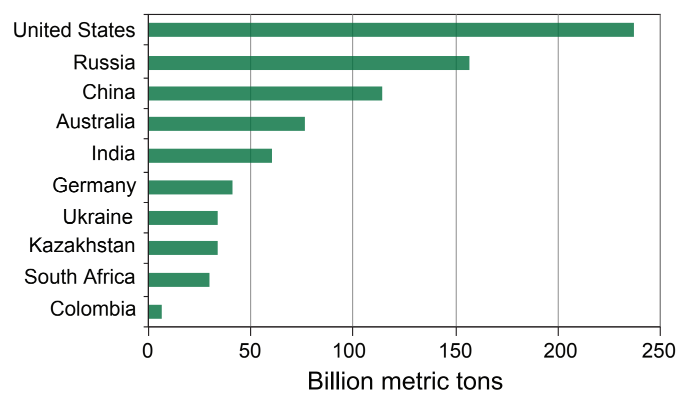
Anthracite and Bituminous Coal   Lignite

Source: http://www.britannica.com/bps/media-view/142296/1/0/0

Modern life is unimaginable without electricity. It lights houses, buildings, streets, provides domestic and industrial heat, and powers most equipment used in homes, offices, and machinery in factories. Burning coal is a primary method for generating electricity. One of the major challenges facing the world at present is that of the world's seven billion inhabitants, approximately 1.2 billion people live without any access to modern energy services. Another billion only have intermittent access to modern energy. Access to energy is a cornerstone of modern life and addressing the challenge of energy poverty is a major international priority, and a key tool in eradicating extreme poverty across the globe.

Where in the World are Coal Deposits?

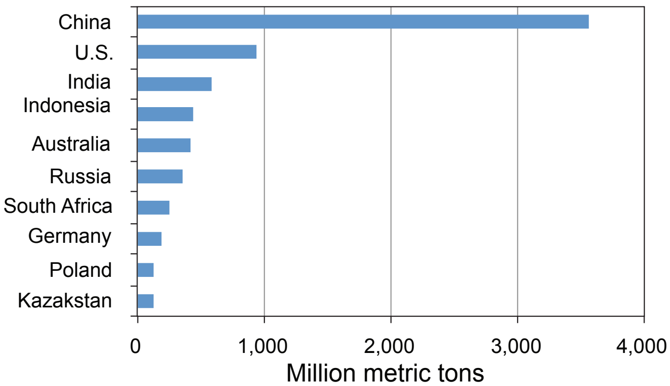
Coal deposits are found in almost every country worldwide, with recoverable reserves in about 70 countries. The biggest coal reserves are in the U.S., Russia, China, and India. After centuries of mineral exploration, the location, size, and characteristics of most countries' coal resources are quite well known. What tends to vary much more than the assessed level of the resource—i.e. the potentially accessible coal in the ground—is the amount classified as proved recoverable reserves. This is the tonnage of coal that has been proved by drilling and geologic mapping, and is economically and technically extractable. It has been estimated that there are more than 861 billion metric tons of proved coal reserves worldwide. This means that there is enough coal to last about 112 years at current rates of production.



Proved coal reserves, 2012. *Data from the World Coal Association.*

Global Consumption

Coal remains central to the global energy system. Coal provides around 30% of global primary energy needs, generates 41% of the world's electricity, and is used in the production of 70% of the world's steel. It is the world's largest source of electricity. Global consumption is expected to rise 25% by 2020, and will replace oil as the world's largest source



Top coal producers, 2012. China produces more coal than the top nine other countries combined, which has fueled its economic growth over the past thirty years. *Data from the World Coal Association.*

of primary energy. Five countries account for more than three-quarters of global coal consumption: China, the U.S., India, Russia, and Japan. China accounts for almost half of global coal consumption, and from 2000 to 2010 its coal use and emissions grew 9% each year on average. In 2010 alone, China's increase in coal-fired power generation capacity equaled Germany's total existing generating capacity.

The largest growing economies today are powered by coal and have significant coal reserves. The increase in coal consumption across the globe predominantly has been due to demand for greater electricity generation in China, India, and other non-OECD (Organization for Economic Cooperation and Development) countries, which have seen total power generation double since 2000. Well over half of this new power generation has come from coal.

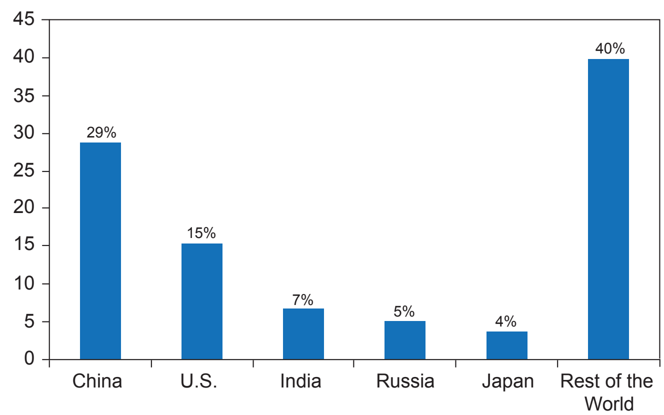
As nations like India, China, Indonesia, and African countries develop, they seek secure, reliable and affordable sources of energy to strengthen and build their economies. Coal is a logical choice in many of these countries because it is widely available, relatively safe, reliable, and relatively low cost. In India, about 300 million people still live without electricity. India's domestic coal reserves, relatively easy access to affordable imported coal, and its ability to meet the sheer scale of demand mean that much of the near future energy demand in India will be met by coal. India's coal plant capacity was relatively stagnant through 2007, but since then the government has embarked on an ambitious plan to build over 400 coal-fired power plants. In Africa, over 600 million people live without access to electricity, but compared to both China and India, individual countries in Africa are developing more slowly and are more reliant on hydroelectricity, with plans to expand using solar and wind resources. The exception is South Africa, with a population of just over 51 million people, which generates 93% of all its electricity from coal.

Global Emissions of Carbon Dioxide and the Impact on Air Quality

The largest environmental issue regarding the burning of coal, and the most difficult to address, is the generation of carbon dioxide (CO_2). Since the rise of the industrial age in the mid-19th century, countries have been releasing CO_2 into the atmosphere by burning fossil fuels, and other industrial processes like cement manufacturing. Five countries accounted for more than half the global emissions of CO_2 in 2012.

Overall, the increase in global emissions of CO_2 from fossil fuel combustion and other smaller industrial sources (two of the main causes of human-induced global warming) slowed down in 2012, increasing by 1.4% over 2011. The U.S. and the European Union saw decreases, but emissions increased in China, India, and Japan. However, the growth rate in the actual concentration of global atmospheric CO_2 was rather high at 2.4 parts per million in 2012.

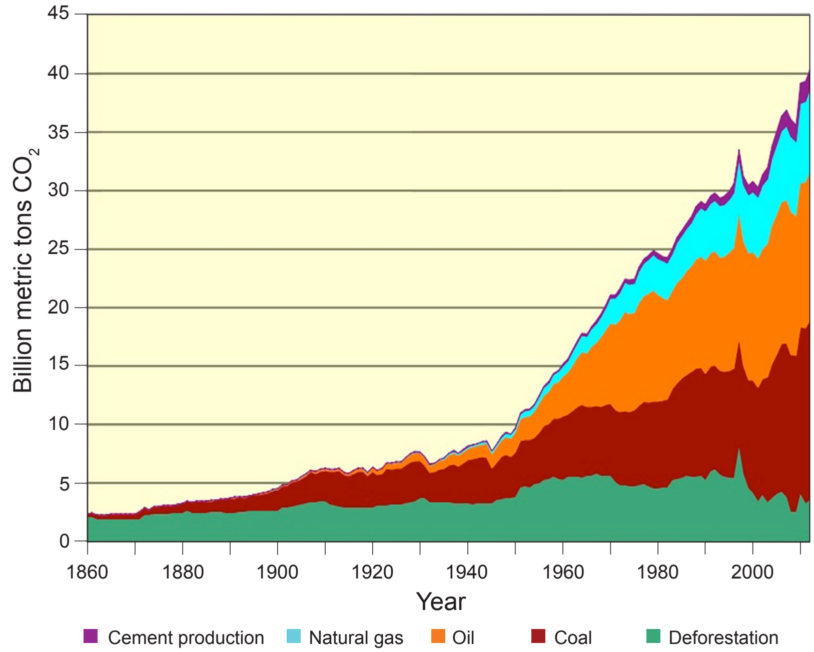
The facts behind China's coal consumption are daunting. China is the world's largest energy consumer and the leading



Global emissions of carbon dioxide, 2012. The bars show the percentage of total world carbon dioxide emissions produced by the top five countries. *Data from the Carbon Dioxide Information Analysis Center.*

emitter of greenhouse gases. In 2013, coal accounted for 65% of China's overall energy consumption, making it the most coal-dependent country among top energy consumers. The downside to this rapid growth has been the high level of air pollution in China's major cities. (However, India's state air monitoring center has admitted that pollution in Delhi is comparable to that of Beijing.) In 2013, 92% of Chinese cities failed to meet national ambient air quality standards. With these exceptionally high levels of air pollution, people in Beijing and many major Chinese cities raised public concern about air quality and created enormous pressure to change the country's heavily coal-dependent outlook. In September 2013, China's State Council, or cabinet, released an "Airborne Pollution Prevention and Control Action Plan" in which the Chinese government recognized that tackling the air pollution crisis will require significant reductions in coal consumption. The plan was accompanied by specific coal consumption targets in provincial action plans, and included reducing their overall coal consumption within four years. China is also in the process of building a state-of-the-art integrated gasification combined cycle (IGCC) coal-fueled power plant with a goal of an electricity generation efficiency of 55–60%, and more than 80% of the CO_2 being separated and reused.

No other major coal-consuming country has ever implemented such rapid changes in their coal policies. The proposed coal control measures are ambitious. As coal consumption decreases, renewable energy is increasingly meeting China's new energy demand. For the first time ever, in 2012 China's wind power production increased more than coal-fired power production. If achieved, the measures will not only fundamentally shift the coal consumption trajectory of the world's largest coal consumer, but also significantly re-shape the global CO_2 emission landscape.



Evolution of carbon dioxide emissions in the world since 1860 by source. Note that while contributions from deforestation have remained relatively constant, those from burning fossil fuels have surged in the last half century, with no end in sight. *Modified from Jean-Marc Jancovici, 2013, http://www.manicore.com/anglais/documentation_a/greenhouse/evolution.html.*

Replacement Fuels for Coal-Fired Electricity Douglas Bland

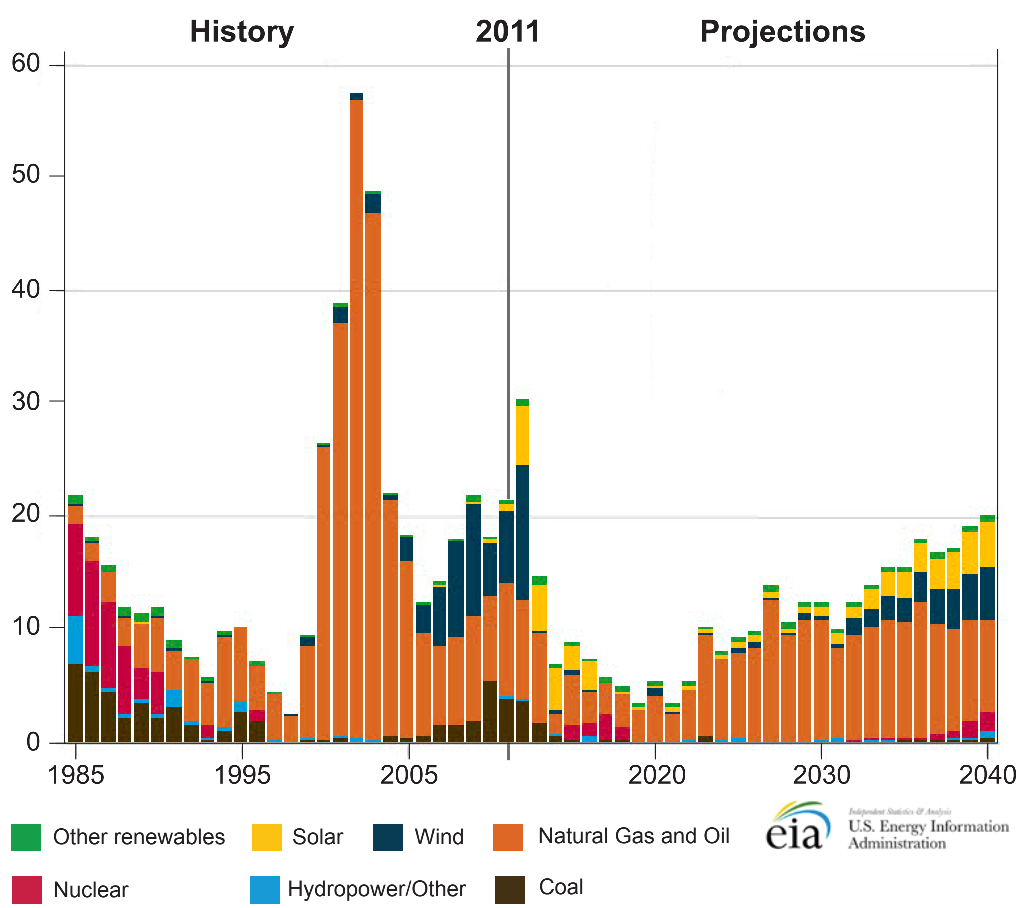
Air quality requirements and concerns over carbon dioxide emissions (the main culprit of human-caused global climate change) have spurred the electrical power industry to begin to modify its way of generating electricity. Regulations (including those proposed in 2014 to address carbon dioxide emissions) requiring that power plants meet more stringent emission limits primarily affect coal-fired plants, which have historically provided over half of the nation's power. Therefore, many older coal plants will need to either reduce emissions from their existing units or switch to new sources of energy. In addition, the overall demand for electricity in the U.S. is growing. Where will the replacement capacity and additional power come from? In the next several decades, coal is still expected to play a major role in generating electricity because many existing coal plants are likely to continue, but the projected proportions of energy sources vary drastically depending on future public policy and the availability of the various types of energy.

Electricity from renewable sources such as wind and solar is rapidly increasing, aided by advances in technology that have reduced the costs to build the infrastructure. While the cost per kilowatt/hour of electricity from renewables still exceeds the cost for coal and natural gas-fired generators, they are becoming more competitive, and regulations can be the deciding factor. Tax incentives currently in place for renewables may or may not be continued in the future.

Because carbon dioxide emissions from gas-fired power plants are about one half of those from coal plants, if significant numbers of coal-fired plants are retired and their capacity is largely replaced by gas, then carbon dioxide emissions will be reduced. Climate scientists and this administration in Washington, D.C. believe this is a necessity. Today, natural gas has become the fuel of choice. New technologies have resulted in gas from previously unproductive formations, including shale and low permeability sandstones, flowing into the U.S. supply stream. With North American production at an all-time high and further increases expected, power companies are turning to relatively cheap gas. But, what effects will this change have on future power generation, gas prices, and other non-electricity uses for natural gas, considering it is also a primary source for residential and commercial heating, and many industrial processes?

Coal is purchased under long-term contracts where prices are either fixed or subject to price controls. This results in a relatively stable price structure for electricity for the consumer. Wind and solar arrays have high initial construction costs, but once built, the costs are also relatively stable. On the other hand, natural gas is not commonly purchased under long-term, fixed-price contracts, and is therefore subject to large price fluctuations that can lead to variations in the price of electricity paid by the consumer. Gas prices are determined largely by supply and demand. Supply is affected by the amount of natural gas being produced in the U.S., the volume of gas being imported (Canada is our largest international supplier), and the amount of gas in storage facilities. Increases in supply generally result in lower prices. Natural gas demand is affected by economic growth, weather variations (cold winters and hot summers increase gas consumption for heating and cooling), and global oil and gas prices, which all affect U.S. prices. In addition, other countries are increasing their purchases of U.S. gas as a substitute for less reliable sources such as Russia, placing further demands on U.S. sources. Increasing demands on U.S. production will cause prices to fluctuate, with the long-term average likely to increase. This will affect all sectors including electricity generation, home heating, and industrial processes, which in turn will affect end-product prices.

The U.S. Energy Information Administration estimated total proven U.S. gas reserves at 349 trillion cubic feet (tcf) in 2011. With annual consumption of approximately 25 tcf, this equals about 14 years of reserves at current consumption rates. However, new reserves are being demonstrated every year (in 2011 more than 30 tcf were added), so most experts believe we have many more years before our natural gas reserves are exhausted. Coal reserves, while large, are still finite. Nuclear power has the potential to play a larger role in supplying the world's power grid, but numerous issues must be overcome before this vision can be realized. Therefore, while natural gas can be a bridge fuel as we transition away from coal-fired power plants, most experts believe renewable energy sources are the only viable long-term solution.



Annual additions to U.S. electricity generation capacity by fuel type since 1985, with projections to 2040. Note the preponderance of natural gas for new power beginning in the late 1980s and continuing for the foreseeable future, and lack of new coal-fired generation from now on. *Source: U.S. Energy Information Administration.*

WATER USE AT COAL-FIRED POWER PLANTS Shari Kelley

Thermoelectric power production needs water. Much of the water that cycles through a power plant returns to the water source. In a typical coal-fired power plant, pulverized coal is burned to generate heat to boil water, forming high-temperature, high-pressure steam. The steam expands over a turbine, spinning a generator to make electricity. The steam is condensed back to liquid form as it exits the turbine. This process is shown in the power plant diagram, (Page 4) in the first article in this publication. In many coal-fired power plants, the water is re-circulated through the steam/liquid cycle many times.

Plant efficiency is dependent on the temperature difference between the steam and the condensate; the greater the difference, the higher the efficiency of the plant. Most of the water use at a power plant is linked to maximizing this temperature difference by cooling the condensate. In a process called once-through cooling, water moves from its source through the plant and back to the source, carrying the heat from the condensate away from the plant. Waste heat returned directly to its source can have a negative impact on the source. Consequently, plants have been redesigned as closed-loop systems and the condensate is commonly cooled in a cooling tower by evaporating water. The steam clouds commonly seen above the cooling towers at power plants are caused by this evaporation.

According to a 2007 U.S. Department of Energy report, fresh water from the San Juan River enters the San Juan Generating Station near Farmington at a rate of 13,890 gallons per minute (gpm). Of that total, 12,480 gpm is diverted into the cooling towers, and 11,640 gpm of that diverted water is lost to evaporation from the cooling tower (93% of the water entering the towers; 84% of the total). Additional water losses at the San Juan Generating Station occur in the emission control (1,840 gpm) and ash handling (100 gpm) units of the system. Steam losses in the system result in water loss of 190 gpm. The remainder of the water that enters the plant is recycled through the system.

Innovative techniques to save water at power plants in the arid Southwest are currently being tested for technical merit and evaluated for economic viability. For example, air-cooled systems use no water, but the ambient air temperature on a hot summer day reduces the temperature difference between the steam and the condensate, reducing plant efficiency. Heat exchangers that incorporate desiccants that absorb water at night and allow the water to evaporate during the day are being used to improve air-cooled systems. Systems that use treated water derived from oil and gas production instead of fresh water have been tested at the San Juan Generating Station with success. Another idea involves using waste heat to drive a secondary power-generating system that contains an organic compound with a boiling point less than that of water to generate additional power. Water scarcity will continue to inspire engineers and scientists to find ways to increase power plant efficiency and decrease water use in power production.

For additional information

http://www.netl.doe.gov/File%20Library/Research/Coal/cross-cutting%20research/41906-Final.pdf

http://cornerstonemag.net/exploring-the-possibilities-the-netl-power-plant-water-program/

Earth Briefs—North Carolina Coal Ash Spill Douglas Bland

Coal is burned to generate electricity at power plants across the world. After combustion, two types of ash residue remain. Fly ash is a fine, powdery material that is collected by emissions control equipment before it can "fly" up and out of the top of the stack into the atmosphere. Bottom ash is a heavier, granular material that settles to the bottom of the boilers. In 2012, more than 50 million tons of coal ash were recycled and used in a variety of industrial products and processes, representing a significant portion of the total coal ash produced. The most common use of fly ash is as a partial replacement for cement in the manufacture of concrete. When used in this manner, it is called a pozzolan, and it makes the concrete stronger and more durable. In addition, carbon dioxide is produced in the manufacture of cement, and because less cement is required, about 10 million tons less carbon dioxide per year are released into the atmosphere. Other uses for both types of coal ash include: an ingredient in the manufacture of concrete blocks and wallboard, constructing structural fills and embankments, mine reclamation, and other agricultural and industrial applications.

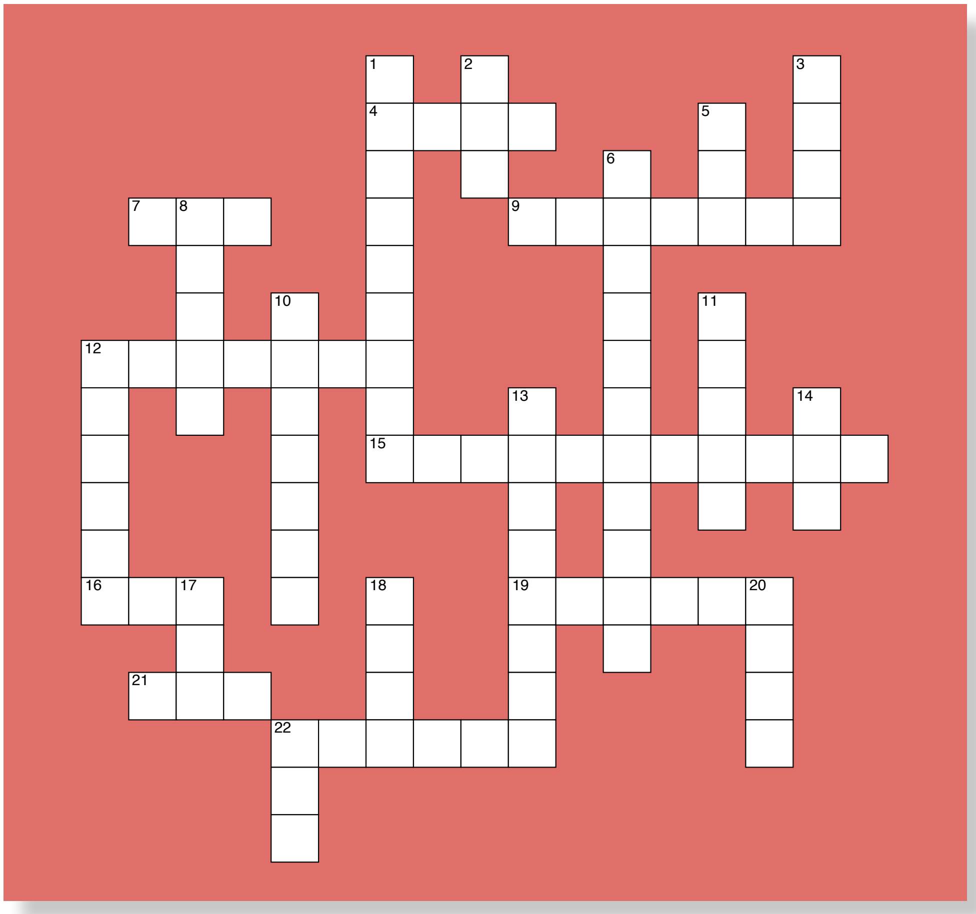
However, over half of all coal ash produced is not recycled, and some of it is stored on-site at power plants. Duke Energy operated a plant on the banks of the Dan River near Eden, North Carolina for over 50 years before closing the plant in 2012. The facility includes a 27-acre unlined pond containing a slurry of coal ash and water. On February 2, 2014 a security guard noticed that a 48-inch pipe was pouring slurry directly into the river. Over the next several days, tens of thousands of tons of coal ash and millions of gallons of contaminated water were released into the river, making it one of the largest such spills in U.S. history. The Dan River is a drinking water supply for downstream communities including Danville, Virginia.

Coal ash contains particulate matter, heavy metals, and other compounds that can be harmful to humans, fish and wildlife. River water testing downstream of the spill indicated levels of arsenic and lead that exceed U.S. Environmental Protection Agency (EPA) standards, although drinking water purified at downstream public water supply facilities meets all standards. In response to concerns raised by environmental advocates, residents, and regulators, Duke Energy and the EPA reached an agreement to clean up the spill. The action plan includes performing a comprehensive assessment, determining the location of coal ash deposits in the river, and removing deposits as deemed appropriate by EPA in consultation with the U.S. Fish and Wildlife Service. Environmental and health advocates hope this spill will spur better management of coal ash in the future.

Unused ash generated at coal-fired power plants in New Mexico is returned to the coal mine where it originated and is buried during mine reclamation. Therefore, while slurry spills, leaks, and seeps are not uncommon in the East and Midwest, they are unlikely in our state.

Coal and Electrical Generation Crossword Puzzle

Douglas Bland



ACROSS

4. NO_X contributes to formation of this

7. Oxides of nitrogen are known as this

9. Method of CO_2 disposal

12. This power plant burns San Juan Mine coal

15. In New Mexico, two thirds of this is generated from coal

16. Agency that regulates power plant pollution

19. Nozzle device

21. Abbreviation for greenhouse gases

22. New Mexico coal is low in this

DOWN

1. Power plant located at Prewitt, New Mexico

2. Major greenhouse gas

3. Used to remove SO_2 from flue gas

5. Abbreviation for Clean Air Act

6. This power plant burns Navajo Mine coal

8. NO_X contributes to formation of this

10. Converts steam to energy

11. Ventilates hot flue gases

12. Type of aquifer for CO_2 disposal

13. Captures SO_2 from flue gas

14. Unit of energy value

17. Coal combustion by-product

18. Most abundant fossil fuel in the U.S.

20. Most N.M. coal is transported by this

22. Sulfur dioxide is also known as this

The answers to the clues are located in the *New Mexico's Coal and Electricity Industries* article in this issue of *Lite Geology.* **The solution to the puzzle is found on the last page of this issue.**

New Mexico's Most WANTED MINERALS

WHEWELLITE

Virgil W. Lueth

Spectacular twinned whewellite crystal in the Freiburg Mining Academy collection, Freiburg, Germany. The specimen is from the Schlema-Hartenstein area of Germany, and is approximately three inches across; most crystals are less than one inch.

DESCRIPTION: Whewellite is a salt of an organic acid. It is colorless to pale yellow to brown when found in vitreous to pearly crystals, and has only been found as crystals. The crystals are typically equant to short prismatic, with twinning very common. They are often heart-shaped. Whewellite has one good cleavage, but usually has a conchoidal fracture and is brittle. It is insoluble in water, but dissolves in acids. It is soft, with a Mohs hardness of 2 ½ to 3, which is close to calcite.

WANTED FOR: The mineral is relatively rare, so it only has value as a mineral specimen. Large and high-quality specimens command a high price in this market. The best crystals come from Germany and other countries in Eastern Europe.

HIDEOUT: Whewellite is a rare mineral found in some low-temperature hydrothermal mineral deposits, sedimentary geodes, septarian nodules, and coal deposits. It has also been reported from some sedimentary uranium deposits. It is a common constituent of the human urinary tract where it is one of the more common kidney stones – but in this case, since it occurs in a living organism, it is not considered a mineral, only a calculus.

LAST SEEN AT LARGE: Whewellite is still at large, because it has never been described as naturally occurring in New Mexico. However, geological conditions for its formation are present here. Based on other world-wide occurrences, the mineral could be found:

- in coal deposits throughout the state, especially those affected by igneous activity near Madrid, and in the Four Corners area;
- associated with the septarian nodule fields around Cabezon where some clear to white crystals identified as barite might actually be whewellite;
- present with fluorite in some of the deposits found along the Rio Grande Rift, especially those in organic-rich limestones;
- in organic-rich sandstones associated with uranium deposits on the Colorado Plateau near Grants; and
- in hospitals and outpatient clinics (documented)

ALIASES: The mineral was given its name in 1852 for the English natural scientist William H. Whewell. It has no other names other than "kidney stones."

New Mexico's Enchanting Geology

Stacy Timmons

WHERE IS THIS?

Photo courtesy of John Fowler, Placitas, NM: Bisti view CC BY 2.0,—Bisti **http://en.wikipedia.org/wiki/Bisti/De-Na-Zin_Wilderness#mediaviewer/File:Bisti_view.jpg**

In the heart of the San Juan Basin lies the Bisti/De-Na-Zin Wilderness Area, which is managed by the U.S. Bureau of Land Management. This highly photogenic and unique region of "badlands" exposes rocks of the Fruitland and Kirtland Formations. These formations were deposited in swampy, river deltas about 65 to 70 million years ago (Upper Cretaceous age). Badlands are enchanting for geologists and non-geologists alike. These unique landforms are the result of an erosional process that highlights the varying hardnesses of different rock types, and their mineral content. Softer rock formations like mudstones erode easily. In contrast, the harder, more cemented formations such as sandstones will take longer to erode, and provide a protective layer over underlying softer materials. In order for these formations to occur there are several requirements, including highly erodible mudstones, sparse vegetation, and a semi-arid climate with periodic, intense precipitation events. Iron-oxides (basically rust) in the sediments provide additional color and beauty, in addition to coal and ash layers. The unique shapes left behind are a result of millions of years of erosion on this very old landscape, leaving behind colorful layers of sediments and bizarrely eroded shapes.

 By Susan Welch

Cupcake Core Sampling

Grade Level 4–12

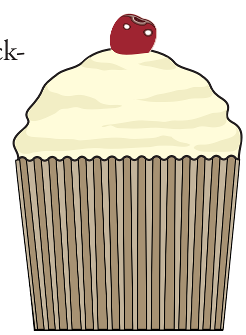
Objectives:

Students will gain understanding of how geologists determine where ore bodies are found beneath the surface of the Earth. Rather than digging up large areas of land to expose an oil field or to find a coal or mineral-bearing strata, core samples can be taken and analyzed to determine the likely composition of the Earth's interior. In this activity, students model core sampling techniques to find out what sort of layers are in a cupcake, which has been baked with hidden ore body layers.

Materials:

- White cake mix
- Food coloring or cocoa powder
- Frosting
- Foil baking cups
- Plastic transparent straws: ¼" diameter, cut approximately 4 inches tall; 4 straws per student
- Drawing paper or graph paper
- Plastic knife

Method:



Prepare cupcake batter according to package directions, but use food coloring or cocoa powder to color one third of Layer some white batter in the bottom of each muffin cup. Create the middle layer (ore body) using a random shaped blob of the colored batter that does not go all the way across the surface of the cupcake. Cover the middle layer with more white batter. Bake cupcakes according to package directions; frost when cool. Using foil baking cups and frosting will prevent the students from seeing the interior of the cupcakes, in the same way that a geologist can't see the interior of the Earth. Tell the students that the frosting layer is equivalent to the soil, which covers the layers below. Students must think like a geologist to explore what is beneath the surface of the Earth.

Procedure:

Provide each student with a cupcake, 4 straws, plastic knife, and a piece of paper. Explain that each cupcake has a hidden layer, or ore body, beneath the surface, and the exercise is to explore the interior without slicing it open. The sketches at the end of this lesson serve as the Answer Key. Provide the key after students have done the activity.

1) Have the students fold a piece of drawing paper into two sections, and in each section draw an outline, or profile, of a vertical slice through the cupcake (see sketch #1 in Answer Key).

> **a)** For the first profile sketch, students will leave it blank until they obtain exploration data.
>
> **b)** In the second profile sketch, have students draw a prediction of what they think this profile, or cross-section, of possible layers inside of the cupcake would look like.

2) Ask the students how they might get more information about the ore body inside the cupcake without peeling the foil or cutting it open with a knife. Someone may suggest using the straw to take a core sample. Explain that geologists drill multiple core samples to study not only the types of materials found in the samples, but also the depth at which they are located beneath the surface.

3) Before drilling begins, ask the students to design a drilling plan to explore the layers of the cupcake. Sketch 4 empty straws on the blank cupcake diagram and number the straws #1-4 to correspond to the locations of the 4 core samples they will drill. The straws should all be in a straight line across the cupcake (see sketch #2 on Answer Key).

4) Demonstrate how to drill and remove a core sample from the cupcake. Remember to use the straw like a drill, rotating it while slowly pressing it down through the cupcake. As each core sample is removed, have the students examine it. Be sure to keep track of the number of each core (see sketch #3 on Answer Key).

5) Draw the profile (different cake layers) of each sample in the corresponding sample location on their sketch (see sketch #4 on Answer Key).

6) Have students estimate the boundaries of the colored ore body by drawing lines connecting cake of the same color, using the data plotted from the cores. Some colors may not go all the way across the cupcake if they are not represented in all the cores. This is similar to ore bodies that are not continuous horizontally (see sketch #4 on Answer Key).

7) Next, the students should cut open the cupcakes with a knife to compare them to the drawings. The cut should be made through the places where the cores were taken. Discuss how closely the appearance of the cupcake matches the profile created from the core drill data. This profile only illustrates a two-dimensional slice through the ore body.

8) Ask the students how they could figure out what the ore body would look like in three dimensions (throughout the entire cupcake). Have them cut the cupcake again, perpendicular to the first cut. See how the layers differ from what is seen in the first cut. How would an expanded drilling program (more cores) help to more accurately outline the ore body?

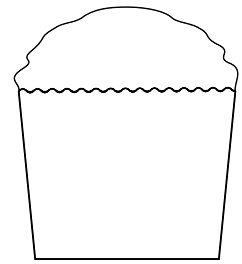
9) To expand this lesson, have students research how exploration geologists use technology and engineering practices to improve their understanding of the location and extent of an ore body hidden beneath the surface of the Earth.

This lesson is modified from an American Institute of Geology Earth Science Week activity, and adapted from Women in Mining Education Foundation Activities. Links for these lessons can be found at:

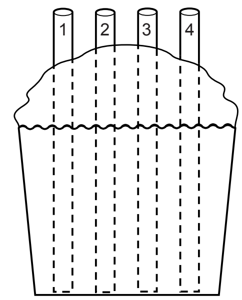
American Geological Institute, Earth Science Week activity: Cupcake Core Sampling **http://www.earthsciweek.org/forteachers/cupcakecoring_cont.html**

Women in Mining: Layer Cake Core Drilling (Advanced Version of Cupcake Core Drilling)
http://www.womeninmining.org/activities/Cake_Core_Drilling.pdf

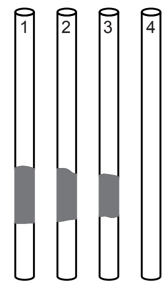
Answer Key



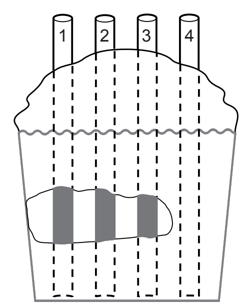
1. Sketch of blank cupcake profile



2. Sketch of core drilling plan



3. Core drilling samples showing ore body



4. Ore body data on cupcake sketch

Profile of a New Mexico Earth Science Teacher

Linda Brown lives in Tijeras, New Mexico and teaches geology and astronomy at Eldorado High School in Albuquerque. She is a National Board Certified teacher who has taught for 12 years. Linda grew up in Fort Wayne, Indiana where her excitement for geology began as a young child. A geology class in high school inspired her to major in geology at the University of New Mexico (UNM). Linda pursued her passion for volcanology as an undergraduate by doing a Senior Honors Thesis that focused on gas geochemistry of the volcanic hydrothermal systems in the Lesser Antilles, in the Caribbean. She chose a career in teaching because she wanted to inspire kids to explore their world and to develop a sense of wonder about science and natural phenomena.

School, grade level and subjects taught:

Eldorado High School, grades 10–12, Geology and Astronomy; both are separate year-long courses. I am also the Science Bowl coach. This is an after-school program to prepare students for a regional competition that involves answering questions about science and math.

Educational background:

B.S. Earth and Planetary Sciences, 2002, UNM

B.S. Anthropology, 2002, UNM

Teaching License Certification Program, 2004, UNM

Awards and recognition:

National Boards Certification, 2012

Golden Apple Scholar, 2003

Why is it important for students to learn about Earth Science?

Earth processes have a big impact on our lives and, as such, I believe it's important for students to have an understanding of them. For example, climate change and resource availability are huge factors in our world today. As students transition into adulthood, it's important for them to have a basic understanding of the science behind the topics that they will be exposed to in the news, and around which political policy is made. I also think it's important for students to learn about the forces that have shaped the world in which they live. Living in such a geologically rich place like New Mexico, students are exposed to geology just by stepping outside, so learning about this geology is personally relevant for them. Students are naturally interested in big, Earth-shaping events like volcanoes and earthquakes, and this interest can hook students and draw them in so they enjoy learning science.

Linda Brown rock climbing during Advanced Field Camp with the University of New Mexico in the Grand Canyon, Arizona. *Photo courtesy of Linda Brown.*

Advice or suggestions for other Earth Science teachers:

My advice is to take advantage of opportunities to learn more about Earth Science and about the geology of New Mexico. Teacher workshops, such as Rockin' Around New Mexico, are excellent opportunities to increase knowledge and to get out and see first-hand the wonderful geological features that abound in our state. I also suggest taking advantage of any opportunity to participate in fieldwork. One of my most rewarding experiences and best learning opportunities was doing fieldwork collecting volcanic gases in the West Indies and analyzing them to determine baseline parameters of activity.

Favorite lesson in Earth Science:

One of my favorite lessons is a computer lab by UNAVCO where students investigate the relationships between volcanoes, earthquakes, and plate boundaries in the Pacific Northwest. I like this lab because it gives students a visual representation of how volcanoes and earthquakes are related to plate boundaries, and because it gets students working with real data. It also introduces students to the concept of vectors in the form of GPS data showing plate motion. In this lab, students use UNAVCO's EarthScope Voyager Jr. website in order to observe location data for volcanoes, and location and depth data for earthquakes.

Click here for the student lab worksheet **http://geoinfo.nmt.edu/education/exercises/UNAVCO_lab.** Students have to interpret the patterns in data in order to answer questions. After working through the sections on earthquakes and volcanoes, students are asked to examine GPS vector data,

Linda with husband Brian and daughter Maya on vacation at Crater Lake National Park in Oregon. *Photo courtesy of Linda Brown.*

use the data to determine where they think plate boundaries are located, and make comparisons of the data with the locations of volcanoes and earthquakes. The link to this lab is:

http://www.unavco.org/education/resources/educational-resources/lesson/visualizing-relationships-with-data/visualizing-relationships-with-data.html

How did you fall in love with geology?

I have had an interest in geology since I was a kid, and like most kids, I liked to collect rocks. However, the biggest impact for me was when I fell in love with volcanoes. This happened when Mt. Saint Helens erupted in 1980, when I was in the 6th grade. I remember watching reports about it on the news and I was really hooked when one of my classmates brought in a jar of ash from the eruption that her relative had sent to her. I fell further in love with geology when I took a geology class during high school. That love carried over into my university studies, where I majored in geology with a focus on volcanology.

What hobbies do you have that relate to your science teaching?

I enjoy traveling and hiking in places that are geologically rich, and learning about the local geology. I am able to bring my travel experiences into the classroom and incorporate them into my lessons. I am also an avid photographer, and my students are able to see my photos that I incorporate into lectures to illustrate geological features, or that I have running as a slideshow on my computer. I find that students are often hooked into a topic by my personal experiences.

Favorite web links and resources:

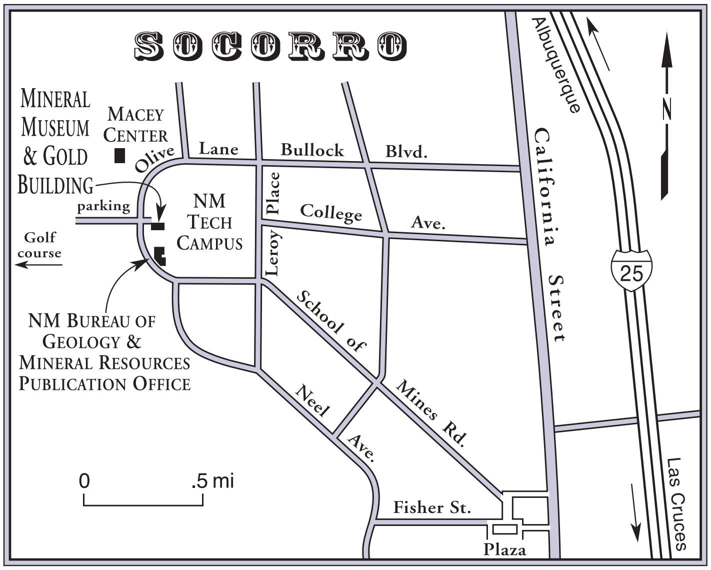
- Volcano World: **http://volcano.oregonstate.edu/** This website has good general information on volcanoes and information about current eruptions. I direct my students to this website as a good start to their research for their volcano project.
- IRIS: **http://www.iris.edu/hq/** I use this website for lessons on earthquakes and seismology.
- USGS website: **http://education.usgs.gov/** This is a good website with all sorts of Earth Science information.

Favorite geologic feature in New Mexico:

My favorite geological feature in New Mexico would have to be the whole extent of the Jemez Mountains. I love the variety of volcanic features, including: Valles Caldera, with its resurgent dome (Redondo Peak), lava domes, ring faults, and obsidian deposits; all the hydrothermal areas, like Soda Dam and Sulphur Springs where gases escape from fumaroles and bubbling springs; Kasha-Katuwe Tent Rocks National Monument with the layers of pyroclastic deposits eroded into fantastic shapes; and the massive cliffs of the Bandelier Tuff, formed by the voluminous outpouring of ash during the two largest eruptions 1.6 and 1.2 million years ago.

Linda at the 2014 Rockin' Around New Mexico session in Silver City, N.M. Linda checks out the tire on the 270-ton haul truck at Chino copper mine. *Photo courtesy of Linda Brown and printed with permission from Freeport-McMoRan Inc.*

Short Items of Interest to Teachers and the Public



THE MINERAL MUSEUM ON THE CAMPUS OF NEW MEXICO TECH IN SOCORRO, NEW MEXICO

Hours:

8 a.m. to 5 p.m., Monday through Friday

10 a.m. to 3 p.m., Saturday and Sunday

Closed on New Mexico Tech holidays

The Mineral Museum is located in the Gold Building on the campus of New Mexico Tech in Socorro. The bureau's mineralogical collection contains more than 16,000 specimens of minerals from New Mexico, the United States, and around the world, along with mining artifacts and fossils. About 2,500 minerals are on display at a time.

For teachers, students, and other groups, we offer free tours of the museum. We like to show off our home state minerals, as well as give students an idea of how minerals end up in products we use every day. Museum staff can also identify rocks or minerals for visitors. Please call ahead to ensure someone will be available. For more information on the museum, please visit our website at: **http://geoinfo.nmt.edu/museum/**

Dr. Virgil W. Lueth (575-835-5140)
Senior Mineralogist and Curator
vwlueth@nmt.edu

To Schedule a Museum Tour, Contact:

Susie Welch (575-835-5112)
Manager, Geologic Extension Service
susie@nmbg.nmt.edu

THE PUBLICATION SALES OFFICE AT THE NEW MEXICO BUREAU OF GEOLOGY AND MINERAL RESOURCES (on the campus of New Mexico Tech)

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- Topographic maps for the entire state of New Mexico
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Study Guides

Coal Study Guides:

The Office of Fossil Energy, within the U.S. Department of Energy, provides Coal Study Guides for secondary students on its website. Here are links for several study guides at various grade levels:

Coal Study Guide for elementary school students:

http://energy.gov/fe/downloads/coal-study-guide-elementary-school

Coal Study Guide for middle school students:

http://energy.gov/fe/downloads/coal-study-guide-middle-school

Coal Study Guide for high school students:

http://energy.gov/fe/downloads/coal-study-guide-high-school

Rockin' Around New Mexico 2014

The annual summer geology workshop for teachers, Rockin' Around New Mexico, was held from July 8–11, 2014 in Silver City, New Mexico. Twenty five teachers, mostly from New Mexico, attended this year to learn about the geology, mineral deposits, and seismic history and risks of the local area. On the first day, a field trip to explore geologic features began at the Mimbres Fault and proceeded along road cuts, with a final stop at the Continental mine to reveal spectacular exposures of metamorphic rocks. The next day, teachers toured the Chino mine and learned about copper ore deposits, mining methods, and ore processing. Environmental remediation projects were also explained. On the last day, teachers learned about earthquake hazards and safety practices, which included a *Drop, Cover and Hold On* safety drill.

Rockin' Around New Mexico workshop participants are dwarfed by a 270-ton ore haul truck at the Chino Mine. *Photo courtesy of Freeport-McMoRan, Inc.*

This workshop was sponsored by the New Mexico Bureau of Geology and Western New Mexico University, which supplied instructors and in-kind support. Funding for materials and travel was provided through a sub-grant with the New Mexico Department of Homeland Security and Emergency Management. The New Mexico Mining Association provided lunches for all participants. Freeport-McMoRan hosted a dinner and mine tours and also supplied samples of rocks, minerals, and ore concentrate to all the participants. The 3-day workshop is for active K–12 classroom teachers or pre-service teachers. A one-hour graduate credit is available through the Master of Science for Teachers (MST) at New Mexico Tech. Interested teachers should contact Susie Welch at 575-835-5112, or **susie@nmbg.nmt.edu**.

UPCOMING EVENTS FOR TEACHERS AND THE PUBLIC

Earth Science Week

October 12–18, 2014

Take part in Earth Science Week 2014! The 2014 Earth Science Week will promote awareness of the dynamic interactions of the planet's natural and human systems. ***Earth's Connected Systems*** is the theme of ESW 2014 with the goal of engaging young people and others in exploring the ways that geoscience illuminates natural change processes. By deepening our understanding of interactions of Earth systems —geosphere, hydrosphere, atmosphere, and biosphere—earth science helps us manage our greatest challenges and make the most of vital opportunities. For more information, or to order a classroom Earth Science Week Toolkit, visit the website at **http://www.earthsciweek.org/**.

The Great New Mexico ShakeOut!

Millions of people worldwide will practice how to *Drop, Cover, and Hold On* at **10:16 a.m. on October 16, 2014** during the Great ShakeOut Earthquake Drills. New Mexicans can join them today by registering for the 2014 ***Great New Mexico ShakeOut***. Participating is a great way for your family, school, or organization to be prepared to survive and recover quickly from big earthquakes– wherever you live, work, or travel. You can hold your ShakeOut drill any day in October if 10/16 does not work. Register at **http://www.shakeout.org/newmexico/index.html** to be included in the 2014 ShakeOut.

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