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New Mexico's Renewable Energy Industries

The High Lonesome Mesa wind farm is located south of Willard, New Mexico. It began operation in 2009. The 40 turbines are each about 425 feet tall to the top of the blades, and each blade weighs 30,000 lbs. Developed by the Edison Mission Group, Foresight Wind Energy, and Karbon Zero, the project will generate $24 million in taxes and fees over its 30-year lifetime. Wind speed increases as it rushes up the slopes of the mesa, which is capped by the Permian-age Glorieta Sandstone. *Photo by Douglas Bland.*

In This Issue...

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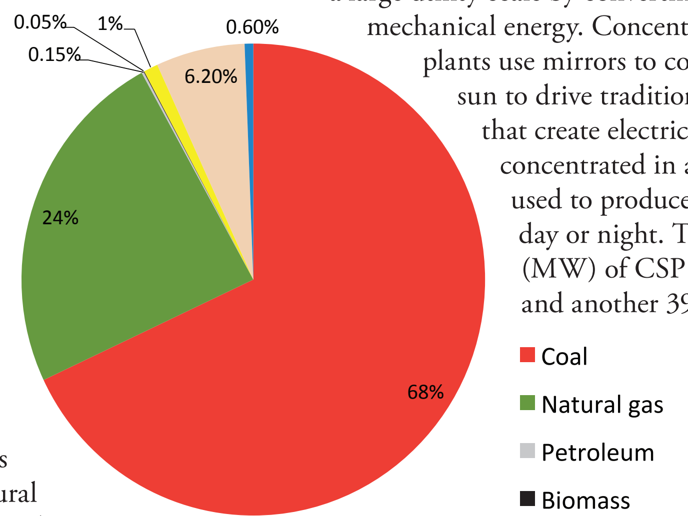
New Mexico's Renewable Energy Industries Maureen Wilks

Editor's Note: *This issue of Lite Geology is the third in a series of three issues, all related to the energy industries, including new technologies. The first two issues addressed new technologies in the petroleum and the coal/electricity industries, and this issue focuses on the renewable energy sector.*

New Mexico has a remarkable mix of energy resources including coal, natural gas, petroleum, uranium, and renewable energy. Renewable energy is energy that is generated from natural processes that are continuously replenished. Energy can be produced from sunlight, wind, geothermal heat, water, tides, and various forms of biomass and biofuels, which are used for transportation. In the previous two issues of *Lite Geology*, we looked at the more conventional energy sources for New Mexico, specifically oil, natural gas, and coal, and the impact of new technology in both finding and producing new reserves, and reducing greenhouse gas emissions (**geoinfo.nmt.edu/publications/periodicals/litegeology/backissues**). In this issue we focus on New Mexico's solar, wind, water, geothermal, and biomass energy resources, which currently account for less than 10% of our electric power generation.



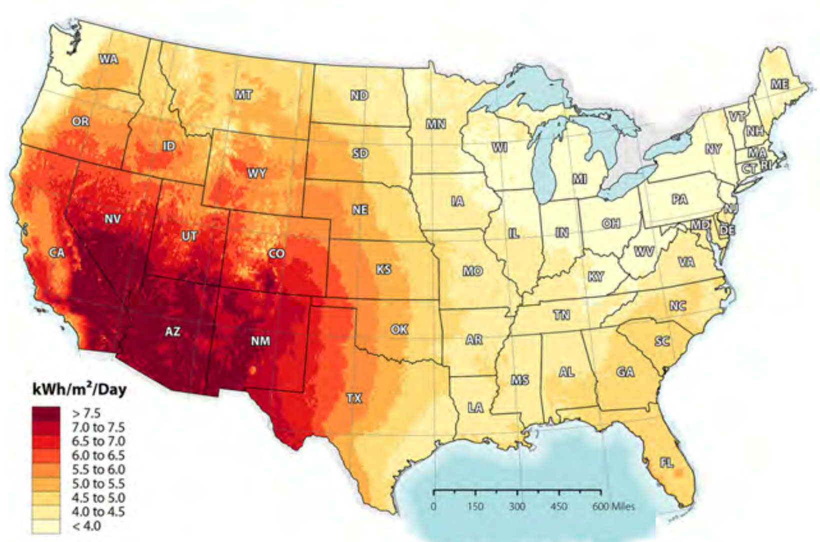
Electric power generation in New Mexico in 2012. *Source: U.S. Energy Information Administration.*

SOLAR ENERGY

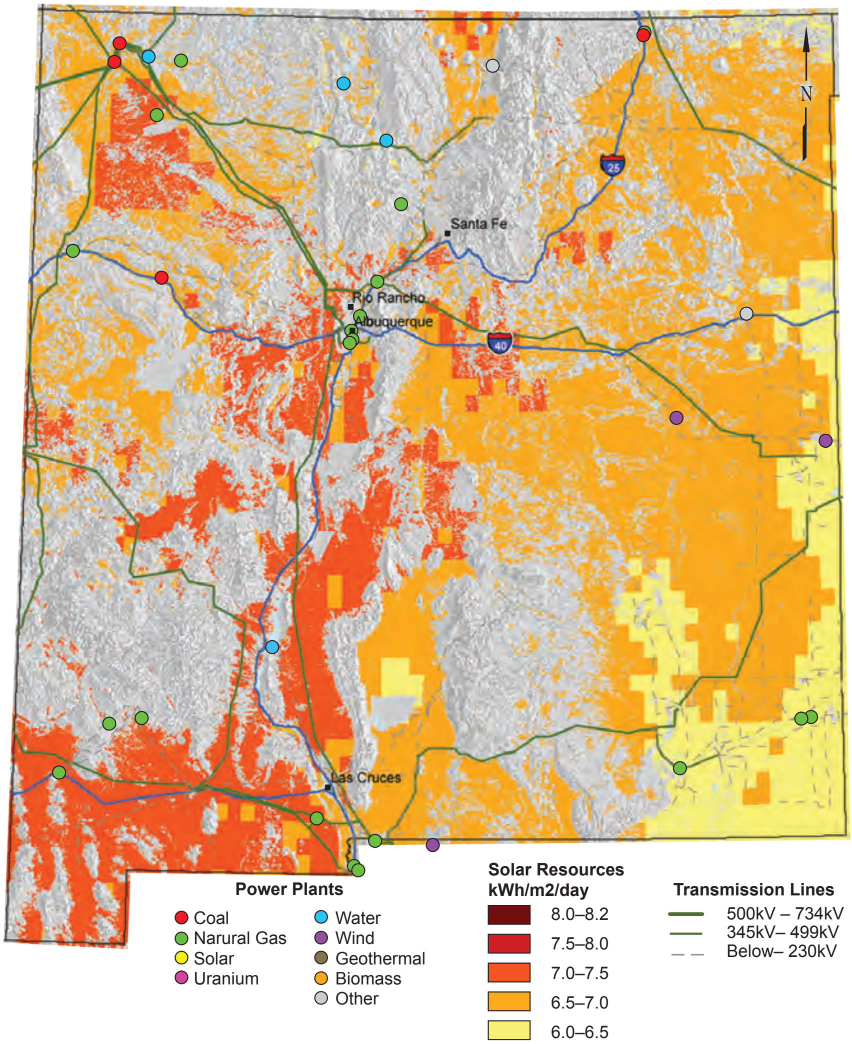
Solar energy is radiant energy that is produced by the sun. Heating with solar energy is not as easy as you might think. Capturing sunlight and putting it to work is difficult because the solar energy that reaches the Earth is spread out over a large area. The energy from sunlight that falls on White Sands Missile Range is nearly equivalent to that used by the entire United States! Specifically, the sunlight falling on an area of roughly 60 miles by 60 miles in New Mexico is equivalent to approximately 100 quads of energy (a quad is 10^{15} British thermal units, or BTUs). This is the estimated total energy used by the U.S. each year. Energy from the sun can be categorized in two forms: (1) heat, or thermal energy, and (2) light energy.

Solar thermal technologies use the sun's heat energy to heat substances (such as water or air) for applications including space heating, pool heating, and water heating for homes and businesses. There is a variety of products on the market that utilize thermal energy. Often the products used for this application are called solar thermal collectors, and can be mounted on the roof of a building or in some other sunny location.

The sun's heat can also be used to produce electricity on a large utility-scale by converting the sun's heat energy into mechanical energy. Concentrating solar power (CSP) plants use mirrors to concentrate the energy from the sun to drive traditional steam turbines or engines that create electricity. The thermal energy concentrated in a CSP plant can be stored and used to produce electricity when it is needed, day or night. Today, over 1,400 megawatts (MW) of CSP plants operate in the U.S., and another 390 MW will be placed in service in 2015. The Ivanpah Solar Concentrated Plant in the Mohave Desert has the capacity to generate 370 MW. In 2012, the Bureau of Land Management made available 97,921,069 acres of public land in the southwestern U.S. for solar projects. This amount of space can provide between 10,000 and 20,000 gigawatts (GW) of power. The U.S. currently requires close to 1,000 GW of electricity capacity to power the entire country. See the article in our last issue of *Lite Geology*, "What is a Watt?" (**geoinfo.nmt.edu/publications/periodicals/litegeology/backissues**).



Map of solar energy resources in the U.S. *Source: U.S. National Renewable Energy Laboratory.*



Map of concentrating solar power prospects in New Mexico. *Source: U.S. National Renewable Energy Laboratory.*

Photovoltaics (photo=light, voltaic=electricity) are semiconductor-based technologies similar to the microchip, which converts light energy directly into an electric current that can either be used immediately or stored, such as in a battery, for later use. Photovoltaics (PV) are often confused with solar thermal technologies, and are in fact what many people mean when they refer to "solar energy." PV panels and modules are very versatile and can be mounted in a variety of sizes and applications, such as on the roof or awning of a building, on roadside emergency phones, or as very large arrays consisting of multiple modules. Currently they are being integrated into building materials including PV shingles, which can replace conventional roofing shingles. New Mexico ranks third nationally for solar energy potential, behind only Nevada and Arizona.

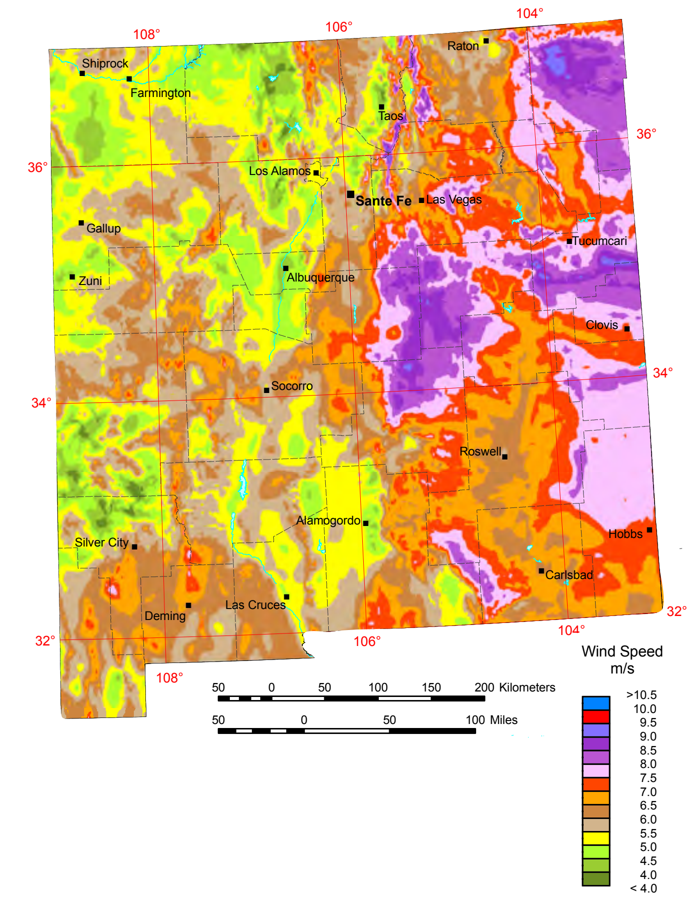
Senator Martin Heinrich, left, inspects the Cimarron Solar Plant in Colfax County, northeastern New Mexico. Photo courtesy of the Office of Martin Heinrich. Other photos and additional information about Senator Heinrich's visit to this facility can be found at: *http://www.heinrich.senate.gov/photos/tour-of-cimarron-solar-facility.*

Solar Facts for New Mexico

- In 2013, New Mexico installed 45 MW of new solar electric capacity, ranking it 13th nationally for capacity installed that year.
- The 312 MW of solar energy in New Mexico ranks the state 9th in the country in installed solar capacity. There are enough solar energy facilities in the state to power 71,200 homes.
- Cimarron Solar Facility was completed in 2010 by the developer First Solar, a leading manufacturer of thin-film PV solar modules. This photovoltaic project has the capacity to generate 30 MW of electricity – enough to power over 6,100 New Mexico homes. Locally sourced materials were used to the greatest extent possible at Cimarron. There is no use of water during normal operation, and the plant is virtually silent.
- At 50 MW, the Macho Springs Solar Project in Deming is among the largest solar installations in New Mexico. Completed in 2014 by First Solar, this photovoltaic project has enough electric capacity to power more than 10,200 homes.
- The price of photovoltaic solar cells has dropped 80% since 2008. According to a phenomenon known as Swanson's Law, the price of cells will continue to drop 20% with each doubling of cumulative shipped volume.

WIND ENERGY

Since early recorded history, people have been harnessing the energy of the wind. Wind energy propelled boats along the Nile River in Africa as early as 5,000 B.C. By 200 B.C., simple windmills in China were pumping water, while vertical-axis windmills with woven reed sails were grinding grain in Persia and the Middle East.



Map of the annual average wind speed at 260 feet (80 meters) above ground level in New Mexico. *Source: U.S. National Renewable Energy Laboratory.*

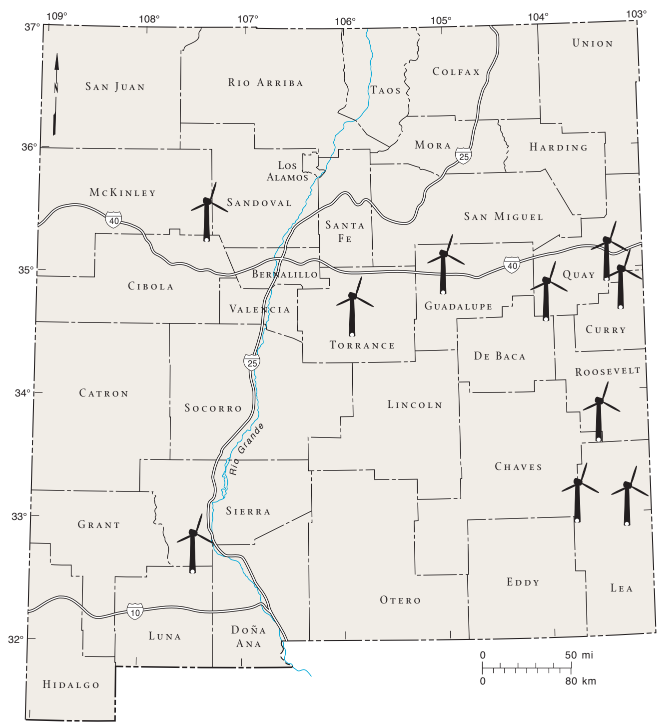
How Wind Energy Works

Wind is a form of solar energy and is a result of the uneven heating of the atmosphere by the sun, the irregularities of the Earth's surface, and the rotation of the Earth. Wind flow patterns and speeds vary greatly across the U.S. and are modified by bodies of water, vegetation, and differences in terrain. The current estimate of wind energy potential is ten times the amount of electricity consumption for the entire country. By the end of 2013, the U.S. had over 46,000 operating wind turbines across 39 states representing 61,110 MW of power.

Today's wind turbine is a highly evolved version of a windmill. Modern wind turbines harness the wind's kinetic energy and convert it into electricity. Most wind turbines have three blades and sit atop a steel tubular tower, and they range in size from 80-foot-tall turbines that can power a single home, to utility-scale turbines that can be well over 260 feet tall and power hundreds of homes. With the hub (the middle of the blades) at 260 feet (80 meters) or more above ground level, they can take advantage of the faster and less turbulent wind at this altitude.

New Mexico ranks 11th in the nation in the potential for generating power from wind. According to data from the National Renewable Energy Laboratory (NREL), New Mexico's onshore wind potential at 80 meters hub height is 492,083 MW. This means that wind power is capable of meeting more than 73 times the state's current electricity needs. Around 6.1% of New Mexico's electricity is currently generated from wind, which is equivalent to powering over 275,000 average New Mexican homes.

The eastern half of the state (Southern High Plains) has the strongest wind energy potential. On any day, odds are that the wind will be blowing. The landscape is characterized by flat to gently rolling terrain, a remnant of a vast plain that originally extended from the Rocky Mountains through northern and central New Mexico eastward beyond the Missouri River. It is the windiest region of the state because



Map of the locations of New Mexico wind farms. The base of the wind turbine represents the location of the wind farm. Additional information about the location of wind and solar facilities in New Mexico can be found at: *www.emnrd.state.nm.us/ECMD/CleanEnergyTaxIncentives/documents/PTCMapFebruary2015.pdf.*

frictional forces that reduce wind speed in other regions of greater topographic relief are less active in this relatively flat and smooth countryside. Winds generally predominate from the southeast in summer and from the west in winter, but local surface wind directions vary greatly because of local topography, and mountain and valley breezes. Most of New Mexico's wind farms are located in this region. New Mexico has 797 MW of installed wind capacity, with 587 wind turbines, and ranks 18th in the nation for total MW installed. An additional 318 MW is under construction as of early 2015.

BIOMASS ENERGY

Biomass energy is considered to be one of the key renewable resources of the future at both small- and large-scale levels. It already supplies 14% of the world's primary energy consumption, primarily in the form of burning wood and other plant material.

Extracting energy from biomass is an ancient practice, dating back to when people first burned wood to provide heat and light. Burning biomass is not the only way to release its energy. Biomass can be converted to other useable forms of energy like methane gas, or transportation fuels including ethanol and biodiesel. Methane gas is the main ingredient of natural gas. Garbage, as well as agricultural and human waste, release methane gas, which is also called *landfill gas* or *biogas*. Crops like corn and sugar cane can be fermented to produce ethanol. Biodiesel, another transportation fuel, can be produced from vegetable oils and animal fats.

Biomass is considered a renewable energy source because we can always grow trees and crops, which produce waste. One ton (2,000 lbs) of garbage contains about as much heat energy as 500 pounds of coal. Power plants that burn garbage for energy are called waste-to-energy plants. New Mexico is the 7th largest milk producer in the country, and dairy cows produce over 1.15 million tons of manure annually. The state of New Mexico is working with the U.S. Department of Energy and Dairy Producers of New Mexico, a local dairy trade organization, to develop a project involving the use of a bioreactor to produce methane from the animal waste.

The waste stream biomass energy resource in New Mexico has the potential to produce over 35 trillion Btu per year (**www.emnrd.state.nm.us/ECMD/RenewableEnergy/biomass.html**), although a large share of this resource is allocated for other uses such as particleboard manufacturing. The largest sources in this sector are saw mill and wood product waste, and municipal solid waste.

Albuquerque and Las Cruces are already using the anaerobic digestion of municipal wastewater sludge to generate methane gas. The gas then fuels the production of electricity and heat to power the wastewater facilities. Los Alamos, Roswell, and Carlsbad are using the resulting methane to heat the digesting process, water, or both.

Near Columbus, New Mexico, Sapphire Energy has the world's first commercial algae-to-energy facility. When completed, the facility will produce 1.5 million gallons per year of crude oil and consist of approximately 300 acres of algae cultivation ponds and processing facilities. Microalgae are remarkable and efficient biological factories capable of taking a waste (zero-energy) form of carbon (carbon dioxide, or CO_2) and converting it into a high-density liquid form of energy (natural oil).

The U.S. Forest Service is working with the New Mexico State Forestry Division on two wood chip-fueled power systems. One system is at Jemez Mountain schools and the other is a steam boiler at Fort Bayard Veterans Hospital. Both use lumber mill residues and forest thinnings for fuel. Several saw mills burn waste wood to provide heat for wood drying kilns.

HYDROELECTRIC ENERGY

Flowing water contains energy that can be captured and turned into electricity. This is called hydroelectric power or hydropower. Hydroelectric power generates about 10% of the nation's energy. Hydropower has been used for thousands of years. Ancient Romans built watermills that used a water wheel to drive mechanical processes such as milling (grinding), rolling, or hammering.

The most common type of hydroelectric power plant uses a dam on a river to store water in a reservoir. Water released from the reservoir flows through a turbine, spinning it, which in turn activates a generator to produce electricity. Electricity can also be generated by moving water between reservoirs located at different heights. This method, called pumped storage, is useful for supplying electricity on occasions of high peak demands. When the demand is high, water is released from a higher to a lower reservoir, which runs a turbine, and in times of low demand water from lower reservoirs is pumped up into higher reservoirs. In coastal areas, power plants can harness tidal power, which is the daily rise and fall of sea level caused by the combined effects of gravitational forces exerted by the moon, sun, and rotation of the Earth.

HYDROPOWER PLANTS IN NEW MEXICO

Plant	Capacity (MW)	Owner
Navajo Reservoir	30	City of Farmington
Elephant Butte	24.3	U.S. Bureau of Reclamation
Abiquiu	15	County of Los Alamos
El Vado	8.8	County of Los Alamos
Farmington	0.2	City of Farmington

Source: www.renewableenergyworld.com/rea/tech/hydropower.

Hydropower plants in New Mexico have the capacity to provide 78 MW of electricity, which is not a large portion of the state's total generating capacity. There is not a great deal more potential because of the state's arid climate and because greater development would involve substantial environmental concerns to aquatic ecosystems and surrounding habitats. Significant evaporative water losses occur from hydropower projects that include storage reservoirs. Drought has an adverse impact on water levels and hydro plant output.

Undeveloped small hydropower sites do exist in New Mexico, including river sites and existing dams, but numerous constraints limit the potential. These constraints include financing, multiple-use issues, regulatory barriers, economic issues, and environmental impacts.

Geothermal Energy

Geothermal energy is heat energy that is generated and stored in the Earth. In New Mexico, geothermal energy has been used to produce electricity, heat homes, greenhouses, and fish farms, and dry agricultural products. In December 2013, the Dale Burgett Geothermal Plant in the Animas Valley of southwest New Mexico started delivering up to two MW of electricity to the Public Service Company of New Mexico. Development of an expansion called Lightning Dock No. 2 is underway with an additional 6 MW of generation planned. For a more in-depth look at geothermal resources, check out Geothermal Energy at **geoinfo.nmt.edu/publications/periodicals/litegeology/28/lite_geo_28fall10.pdf** in *Lite Geology*.

Looking to the Future: New Technologies

New technologies for all areas of renewable energy are being developed. Engineers are increasing the size of wind turbine blades and making the towers taller, allowing turbines to capture more wind, especially at low speeds. For example, arrays of sensors have been paired with better algorithms for operating and monitoring the turbine, which let it keep spinning when earlier generations of wind turbines would have shut down.

Regarding solar power, scientists at Stanford University are working on photon-enhanced thermionic emission (PETE), which uses a special semiconductor chip consisting of two layers. One is optimized to absorb sunlight and create long-lived free electrons, while the other is designed to emit those electrons from the device so they can be collected as an electrical current. The efficiency of thermionic emission improves dramatically at higher temperatures, so adding PETE to utility-scale concentrating solar power plants may increase electrical output by 50%.

At New Mexico Tech, scientists are developing a process to extract electricity from brackish water produced by the oil and gas industry using a process called retarded osmosis (**www.nmt.edu/news/all-news/522-2014/5168-tech-team-extracting-power-from-dirty-water**). In addition, new technologies now drive the electric grid, which evolved from the first central power plant located on Pearl Street in New York in the early 1880s, and grew as technology advanced through the 20th century. Digital technology allows for two-way communication between electric utilities and their customers, and provides for sensing along the transmission lines to make the grid smart. It also provides more efficient transmission of electricity, and increased integration of large-scale renewable energy systems like solar, wind, and geothermal facilities.

What Minerals Supply Renewable Energy Needs? Maureen Wilks

In the debate about renewable energy, have you ever wondered what raw materials these technologies require? It is important to recognize that while the source of energy is renewable, the mechanisms by which we harness solar, wind, and water energy requires the use of an incredible amount of minerals and raw materials, which have to be either mined or recycled, and are not limitless.

A wide range of materials is used in wind turbines. The foundation alone for one wind turbine may contain over a thousand tons of concrete and rebar, and one blade can weigh 15 tons. A large turbine requires steel (iron ore, molybdenum), aluminum (bauxite), cement (clay, shale, gypsum, limestone, silica sand), concrete (aggregates, crushed stone), and wiring (copper).

Another critical component in the generation of wind energy is the rare earth elements (REEs), which include the 15 lanthanide elements (atomic numbers 57-71), plus yttrium and scandium. They share many similar properties, which is why they occur together in geological deposits. They are referred to as ‘rare’ because it is not common to find them in commercially viable concentrations. The rare earths are important because of their influence on the strong but unruly magnetic properties of iron, including the ability to give up or accept electrons, a property critical for the magnets in the turbines used to generate electricity from wind.

Currently China produces 95% of the world’s rare earth elements, which are found in placer deposits, residual deposits formed from weathering of igneous rocks, pegmatites, iron-oxide copper and gold deposits, and marine phosphates. They can be found throughout New Mexico, although most deposits are small or low-grade. As early as the 1940s, New Mexico mines were producing REEs from pegmatite deposits found in San Miguel, Rio Arriba, and Taos Counties in northern New Mexico, and in Grant County in the southwest corner of the state. New Mexico deposits are being re-examined for their potential REE, thorium, and uranium content. Veins are found in the Gallinas, Caballo, Capitan, and Cornudas Mountains, and the Laughlin Peak-Chico Hills. The abundant REE mineralogy in the Cornudas

Mountains suggests that the area has potential for undiscovered deposits of REEs, including niobium and zirconium.

The main component of photovoltaic solar panels is silicon combined with thin films made of cadmium, tellurium, copper, indium, gallium, selenium, arsenic, and other elements. Tellurium, indium, and gallium are rare elements whose electrical properties make them excellent choices in the synthesis of semi-conductors like copper indium gallium selenite (CIGS), and cadmium-tellurium (CdTe) for use in thin-film photovoltaic solar cells. The Cimarron Solar facility in Colfax County uses approximately 500,000 two feet by four feet CdTe photovoltaic modules. Tellurium makes up a scant 0.0000001% of the Earth's crust, which is three times more rare than gold. In 2013, around 105 metric tons were produced as a by-product from copper and gold mining. Both indium and gallium occur as trace amounts in zinc and bauxite ores, and can be extracted during processing of these ores.

Wind turbine at the High Lonesome Wind Farm in Torrance County, New Mexico. *Photo courtesy of Douglas Bland.*

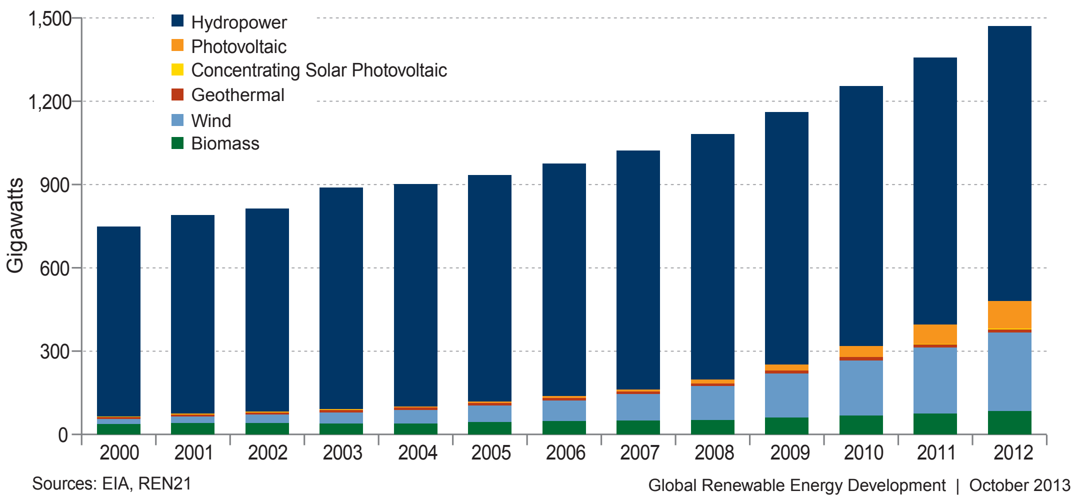
The materials used to build a concentrated solar power plant can be found and manufactured in the United States. The reflective layer is a highly reflective thin metal film, usually made of either silver or aluminum, but occasionally other metals. Because of sensitivity to abrasion and corrosion, the metal layer is usually protected by a glass (silica sand) layer on top. Although glass is brittle, it is a good material for this purpose because it is highly transparent (low optical losses), resistant to ultraviolet light, fairly hard (abrasion resistant), chemically inert, and fairly easy to clean.

An important part of the chain in renewable energy is the ability to store energy, as there are times when solar and wind output does not match the demand. Technologies like pumped storage or large battery systems can be paired with solar and wind to capture and store whatever power they generate and release it later, providing grid operators with confidence that power will be available when they need it to meet demand. Lithium is a key component of high-performance batteries used to store energy. Economic concentrations of lithium are found in brines, minerals, and clays in various parts of the world. Brines and high-grade lithium ores are the present source for all commercial lithium production. The largest known deposits of lithium are in Bolivia and Chile.

Lithium also can be recovered from hard rock minerals, such as spodumene in pegmatites, through open-pit or underground mines. The ore is then processed and concentrated using a variety of methods to produce pure lithium or lithium compounds. In New Mexico, lithium has been recovered from the Harding mine in Taos County.

So when we talk about renewable energy, it is important to remember that the infrastructure needed to produce and store renewable energy has to be built from raw materials that are either mined or recycled.

Global Use of Renewable Energy Douglas Bland



Worldwide renewable electricity capacity. *Source: U.S. National Renewable Energy Laboratory.*

Energy use around the globe is on the rise, because the population is increasing and improvements in the standard of living involve higher energy consumption. The U.S. Energy Information Administration estimates that world energy consumption will increase by 56% between 2010 and 2040. Where will new energy supplies come from? Currently, the vast majority of energy comes from non-renewable fossil fuels like coal, oil, and natural gas. While new fossil fuel supplies will continue to be tapped, renewable energy development is increasing rapidly in the United States and around the world. Renewable energy includes hydropower, wind, solar (photovoltaics and concentrating solar power), geothermal, biomass, and biofuels. The lead article in this issue of *Lite Geology* explains each of these types of energy.

Why is renewable energy use growing? Fossil fuel supplies are becoming more expensive to develop, and eventually will run out. There is an effort to transition to renewable energy economies before that happens, which will also extend the life of non-renewable resources. Burning fossil fuels releases carbon dioxide, a potent greenhouse gas that contributes to climate change, whereas most renewable energy sources do not. Over the past few years, technological improvements have greatly reduced construction costs of wind and solar electricity facilities, making them more competitive with conventional non-renewable sources. In addition, most countries currently must import fossil fuels to meet their energy demands, and would rather utilize their own renewable resources to improve their energy security. For a billion people world-wide that currently have no access to electricity, constructing local power plants that use wind or solar energy can be much more cost effective than connecting to distant fossil fuel plants, or building new ones that must be supplied by far-away fuel sources.

Spain has become a leader in solar energy, although this industry is now troubled due to unsustainable government financial subsidies. The 150 MW Andasol solar power station, shown above, is a commercial parabolic trough solar thermal power plant, located in southern Spain. The Andasol plant uses tanks of molten salt to store solar energy so that it can continue generating electricity even when the sun isn't shining. This photo shows the first phase only; the facility is now three times this size. *Source: en.wikipedia.org/wiki/Renewable_energy_commercialization#mediaviewer/File:12-05-08_AS1.JPG. From Wikimedia Creative Commons.*

Governments of many countries now have policies that encourage development of renewables and offer financial incentives. Renewable

Top Five Countries 2013 Statistics for Renewable Energy Development					
	1	2	3	4	5
Total investment in renewables	China	United States	Japan	United Kingdom	Germany
Share of gross domestic product invested	Uruguay	Mauritius	Costa Rica	South Africa	Nicaragua
Hydropower capacity	China	Turkey	Brazil	Vietnam	India
Wind power capacity	China	Germany	United Kingdom	India	Canada
Solar photovoltaic capacity	China	Japan	United States	Germany	United Kingdom
Concentrating solar capacity	United States	Spain	United Arab Emirates	India	China
Geothermal power capacity	New Zealand	Turkey	United States	Kenya	Philippines
Solar water heating capacity	China	Turkey	India	Brazil	Germany
Biodiesel production	United States	Germany	Brazil	Argentina	France
Fuel ethanol production	United States	Brazil	China	Canada	France

Capacity information refers to new additions during 2013. *Source: Renewables 2014 Global Status Report, by the Renewable Energy Policy Network for the 21st Century.*

energy accounts for 23% of all electricity generation worldwide. Of that total, about 75% is from hydropower, however, that's down from 90% in 2000 even though hydropower capacity has actually grown. Today, wind and solar are the fastest growing sources of renewable electricity. In 2013, renewables accounted for more than 56% of net additions to global power capacity, demonstrating that countries everywhere are embracing renewable energy. The U.S. has added large amounts of wind and solar capacity in recent years, but these two sources still account for less than 5% of our total electricity. Adding hydropower and other renewables boosts the total to about 13%. Coal (39%), natural gas (27%) and nuclear energy (19%) supply the bulk of our power. While there is no U.S. federal policy, over 30 states have set aggressive goals of their own (including New Mexico), aiming for 30% or more renewable energy within the next decade.

Elsewhere, in 2013 China's new renewable power capacity surpassed new fossil fuel and nuclear additions for the first time. In Paris, France, the Eiffel Tower is expected to produce about 10,000 kilowatt hours of electricity per year with two newly installed wind turbines, located within the lattice structure of the tower, about 400 feet above ground level. The vertical-axis turbines will generate enough electricity to power the commercial areas of the tower. For more info, see: **www.cbsnews.com/news/eiffel-tower-going-green-with-two-wind-turbines.**

Renewables in the European Union represented 72% of new electricity generation in 2013. Perhaps no country has embraced renewable energy more than Germany. Twenty million Germans live in "100% renewable energy regions." Giant wind turbines are springing up as far as 60 miles offshore in the North Sea, and solar photovoltaic panels are on roofs everywhere. In the first half of 2014, Germany generated 31% of its power from renewable energy sources, far more than any other large industrial country. Much of this has replaced electricity from natural gas, largely purchased from Russia.

However, these changes have devastated Germany's utility companies, whose profits have collapsed. Their long-term business models were based on generating electricity and supplying markets with power from fossil fuels, and incorporating renewables requires major changes. Wind and solar power are intermittent, because the wind doesn't always blow and the sun doesn't always shine. Backup power from storage or other sources is required, unlike power generated from coal or natural gas. In addition, small local renewable power plants are eating into demand from large regional plants.

Rules and policies to govern these changes have yet to be finalized in Germany (and in the U.S.), and are sorely needed for a smooth transition.

An estimated 6.5 million people worldwide work directly or indirectly in the renewable energy sector. Over $100 billion was invested in renewable energy development worldwide in 2012, demonstrating a high level of commitment. Some policy experts predict that within 50 years virtually all electricity worldwide will come from renewables, which will require even higher levels of financial commitment. Many other experts do not expect this to occur, especially considering new technological advancements allowing production of vast shale oil and gas reserves. Even though the pace of future renewable energy development is unknown, substantial increases are a virtual certainty.

International Renewable Energy Facts

- The installed global renewable electricity capacity doubled between 2000 and 2012.
- China leads all other countries in total electrical generation from renewable energy.
- Uruguay aims to generate 90% of its electricity from renewable sources by 2015 (mostly hyrdopower).
- Denmark has the highest per capita renewable energy capacity.
- In 2012, Bulgaria, Estonia, and Sweden met the 20% target set by the European Union for all member countries for renewable energy consumption.
- In 2012, the United States produced 61% of the world's ethanol (mostly from corn), followed by Brazil at 26% (mostly from sugar cane).
- Tunisia is planning a two gigawatt solar facility to provide solar power to Europe through an undersea cable from the North African coast to Italy.

Renewable Energy Water Use

Shari A. Kelley

In the last issue of *Lite Geology,* we talked about water use in coal-fired power plants using once-through and recycled-water technologies. These wet-cooling methods of condensing steam after it has passed through the turbine consume 42 to 942 gallons of water per megawatt-hour (gal/MW-hr) of electricity generated, depending on the coal plant design. In sharp contrast, renewable energy sources such as solar-photovoltaic and wind-generated power use only 29.8 and 0.6 gal/MW-hr, respectively; the water is primarily used for cleaning. These numbers reflect water use for the operational phase of power generation and do not include water used in the manufacturing or construction of the power source components.

Solar photovoltaic panels and wind turbines generate power directly, therefore they don't require separate power plants that use water. However, concentrating solar power, biomass energy, and geothermal technologies can variably use little water or a lot of water, depending on the cooling system used at the power plant. Plants using wet recirculating systems use considerably more water than those using dry cooling, but the wet-cooled plants are more efficient in the arid Southwest. The following table summarizes water consumption for the more water-intensive renewable energy sources. The values on the high end of geothermal water use are for EGS (Enhanced Geothermal Systems), where water must be added to start the system. The water needed to grow biomass energy crops is not considered in this table.

Technology	Wet-cooled (gal/MW-hr)	Dry-cooled (gal/MW-hr)
Concentrating solar power	790–1,000	26–78
Biomass Energy	235–550	35
Geothermal	1,800–4,800	0–850
Hydropower	4,500	

Although renewable energy technologies hold the promise of helping with the reduction of carbon emissions and reliance on fossil fuels, these benefits must be weighed carefully against the use of diminishing water supplies in arid environments to meet our energy demands. Improved power plant design and efficiency continue to decrease our need for precious resources.

For additional information:

- **globalchange.mit.edu/files/publication/MITJPSPGC_Rpt221.pdf**
- **belfercenter.ksg.harvard.edu/files/ETIP-DP-2010-15-final-4.pdf**
- **www.nrel.gov/docs/fy11osti/50900.pdf**

Earth Briefs—Bird Mortality at Wind Farms Douglas Bland

Wind farms that generate electricity, like all large industrial facilities, create impacts on wildlife and the environment. Impacts include wildlife habitat loss from construction activities, habitat alteration from soil erosion and introduction of non-native vegetation, collisions of birds with wind turbines (windmills), destruction of nests of ground-nesting birds, increased predation by providing additional perches for raptors, noise, and motion of operating wind turbines. Of all these impacts, the largest concern is collisions. Estimates of bird deaths caused by collisions vary widely, but average around 250,000 annually in the U.S. Concern over bird mortality is a real issue that has been raised by conservationists, and utility companies are working to address it.

Why do birds hit the turbines? Modern turbines look like they turn slowly, but actual speeds at the ends of the enormous rotors (blades) can exceed 100 miles per hour. In spite of their excellent eyesight, research shows that birds don't pay much attention to what's ahead of them. Instead, they're focused on the ground or the areas beside them because they're hunting or looking for places to land. In addition, birds have relatively poor hearing; human ears can detect wind turbines at roughly twice the distance that birds can. With over 46,000 turbines in the U.S., about five deaths per turbine occur on average each year. The vast majority of deaths are songbirds, but significant numbers of waterfowl and raptors are also killed. Raptors such as golden eagles, red-tailed and other hawks, American kestrels, and great horned owls are of particular concern because of their long lives, slow reproduction rate, and their relatively small numbers. Raptors tend to fly in the area swept by the rotors. Annual raptor wind farm mortality may be as high as 40,000.

Resident birds are at a greater danger than migratory birds, because birds typically migrate at altitudes of 500–2,500 feet above the ground, which is above the top of the turbine blades. Location also plays a major factor. Facilities located in canyons and passes (which tend to have greater wind speeds) or along major avian flyways can have significant mortality, whereas those in open areas away from flyways have very little.

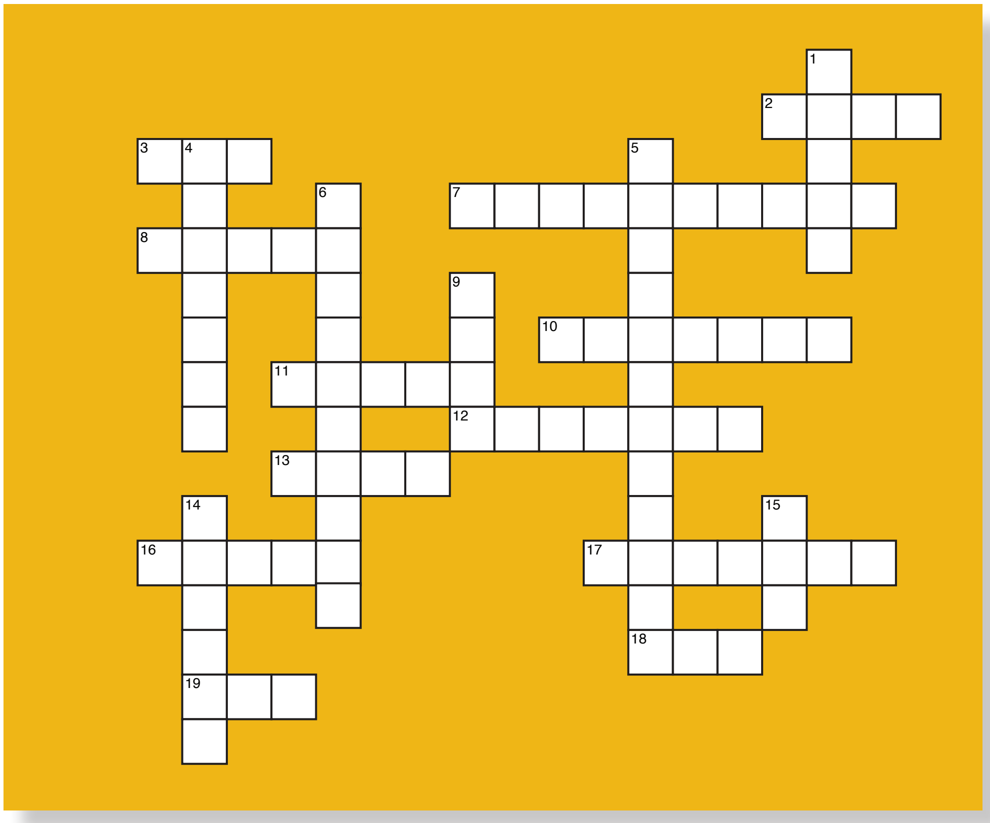
So, how big is this problem? The total U.S. bird population is estimated at 10-20 billion, and about five billion die every year. Average estimates (again, the numbers vary widely) of other causes of bird deaths include: communication towers (including 190,000 cell towers)–6.8 million, cars and trucks –75 million, hunting–110 million, buildings and windows –600 million, and cats (domestic and feral)–possibly over a billion! However, the largest cause is loss of habitat due to development. Comparing wind farm bird mortality of around 250,000 with deaths from other causes, the numbers might seem small, but that doesn't mean we shouldn't focus on local impacts on specific species. As more wind turbines are built, the problem is expected to increase.

What can we do about it? Studies have shown that latticed support towers offer numerous perching sites, which attract birds. Solid tubular towers eliminate this issue, and are now almost exclusively used. Larger, slower-moving blades cause fewer collisions, and generate the same power as several smaller turbines. Older towers often used guy wires to hold them up, which were hazards, but these are rarely used today. Efforts to increase turbine visibility to birds include painting them in high-contrast colors, fitting them with noisemaking devices, and installing ultraviolet lamps to alert birds to spinning blades, but the impact of these experimental measures is not yet clear. In Spain, wind energy companies have shut down wind farms when large numbers of migrating birds approach, showing some success. However, the most effective way to reduce mortality is to site wind farms in locations where they will have the least impact.

On a related note, bats seem to be attracted to wind turbines, resulting in as many as 600,000 collision deaths each year. Most of these are in the Appalachian Mountains. One study showed that turning off the turbines during low wind speeds, when bats are most active, reduced mortality by 73%.

Renewable Energy Crossword Puzzle

Douglas Bland



ACROSS

2. Form of energy related to the atmosphere
3. British thermal unit
7. This energy can heat greenhouses
8. Group of solar panels or modules
10. Another term for plant matter
11. Radiant energy produced by the sun
12. Concentrating solar power plants use these
13. "End" products from these generate methane gas
16. This is used to create crude oil
17. This releases methane gas
18. Microalgae convert this into energy
19. Biomass can be converted into this

DOWN

1. Coastal areas harness this kind of energy
4. Machine used to generate energy from wind
5. Solar technology that uses panels
6. A water wheel creates this
9. A collection of wind turbines
14. Fuel from wastewater facilities
15. Hydroelectric plants usually require this

The answers to the clues are located in the *New Mexico's Renewable Energy 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

TELLURIUM

Virgil W. Lueth

Large mass of native tellurium (bottom half of the specimen) with quartz and pyrite from the Lone Pine Mine, Catron County, New Mexico. The specimen is approximately three inches across, and some of the crystals are among the largest known for the mineral. NMBGMR Mineral Museum specimen no. 11394, gift of the 3M Company. Minnesota Mining and Manufacturing (3M) originally developed the Lone Pine to mine tellurium for early photocopy machine technology. *Photograph by Virgil W. Lueth.*

DESCRIPTION: Tellurium is both an element and a naturally occurring mineral. Its color and streak are tin white with a metallic luster. It can form prismatic crystals in the hexagonal system, but is most commonly found as fine-grained and granular masses, although exceptional crystals are reported up to 1.5 inches (3.5 cm). It displays a perfect prismatic cleavage. It is relatively soft (2–2.5 on the Mohs Hardness Scale), although it is somewhat brittle and has a high specific gravity. High grade tellurium deposits are typically small, making tellurium supplies difficult to maintain. Most tellurium is recovered as a byproduct of mining other metals.

WANTED FOR: Tellurium has a wide variety of uses, most notably in the semiconductor and photovoltaic industries. It is commonly used as cadmium telluride in solar panels where it produces some of the most efficient units. It is used in the electronics industry for semiconductors and for re-writable compact and optical disks. Tellurium is also used in thermoelectric devices and infrared detectors. It can be used as a coloring agent in ceramics, as an additive for fiber optics, blasting caps, tires, and medicine.

HIDEOUT: Tellurium is found in hydrothermal veins, often with gold, pyrite, galena, alabandite, quartz, and carbonates. Most often found with other tellurium-bearing mineral compounds, known as tellurides, that are commonly associated with sulfur and selenium.

LAST SEEN AT LARGE: Native tellurium (called that when the element forms naturally by geologic processes) has been verified at both the Lone Pine Mine in Catron County and Hilltop Mine in Dona Ana County. Unverified reports suggest it is present at the La Luz Mine (Bernalillo County), Burro Mountains (Grant County), Sylvanite district (Hidalgo County) and Chloride district (Sierra County). In some of these unverified occurrences, known telluride minerals have been identified and may have been mistaken for native tellurium after some rudimentary chemical tests.

ALIASES: Tellurium gets its name from Latin for the Earth, tellus.

New Mexico's Enchanting Geology

Stacy Timmons

WHERE IS THIS?

El Vado Lake, looking north from the western shoreline near the dam. *Photo courtesy of Douglas Bland.*

Along the Rio Chama in northern New Mexico are the state parks of El Vado and Heron Lakes. These large water reservoirs help manage water delivery to more populated regions of the state through the San Juan-Chama Project, and provide opportunities for boating, fishing, camping, hiking, and winter recreation.

Geologically, these state parks lie on the margin of the San Juan Basin, within the Colorado Plateau province. Around these lakes, the landscape geology is dominated by Late Cretaceous age rocks, which formed as the region was intermittently covered by oceans approximately 80 to 100 million years ago. The photo above shows high mesas on the horizon capped by Mesaverde Group rocks, with the Mancos Group forming the hill slopes and shoreline outcrops. Subsequent to deposition, the region was uplifted well above sea level during Laramide deformation, about 75 to 80 million years ago. Recent fluctuations in water levels at El Vado created the linear shorelines as the lake level has declined due to drought.

In this issue of *Lite Geology,* we have focused on renewable energy resources. Several dams in New Mexico provide renewable energy through hydroelectricity, including the dam built to create El Vado Lake, pictured above. New Mexico's hydroelectric capacity is about 78.3 megawatts from five different facilities, with El Vado dam producing 8.8 megawatts.

For more information about visiting these parks, please contact New Mexico State Parks or check out these websites:

- **www.emnrd.state.nm.us/SPD/elvadolakestatepark.html**
- **www.emnrd.state.nm.us/SPD/heronlakestatepark.html**
- **geoinfo.nmt.edu/tour/state/el_vado/home.html**

Classroom Activity Susan Welch

A New Mexico Road Trip: Finding Your Vacation CO_2 Footprint

Energy is required to transport you from place to place. In the United States, the transportation sector consumes 28 percent of total energy supply and is responsible for about 33 percent of the greenhouse gases emitted each year, which contribute to global climate change. When one gallon of gasoline is burned, about five pounds of carbon are produced. But when hydrocarbons combine with oxygen during combustion, almost 20 pounds of carbon dioxide (CO_2), a potent greenhouse gas, are generated for each gallon of gasoline consumed. The CO_2 is released into the atmosphere from your car's tailpipe.

To figure out how much CO_2 you would generate on a four-day road trip vacation in New Mexico, plan a journey. Where would you go? What stops would you make along the way?

1) Design a route and enter the start and end points for each segment of your trip in the two left-hand columns of the data chart below. Limit your segments to five or less. Find the mileages for each segment using **mapquest.com**.

2) Select a vehicle make and model for your trip, then find its fuel economy ratings at **www.fueleconomy.gov**. Fill in the information below.

Vehicle make and model: ______________________

Fuel type: ______________________

Fuel economy in miles per gallon (MPG) ________________

To	From	Miles	Gal. of Fuel Consumed	Total CO_2 Emissions

3) Now that you know the route for your trip and the fuel economy for your vehicle, fill out the rest of the chart by using the data and formulas provided below to calculate how many gallons of fuel will be required, and the amount of CO_2 emissions for your trip.

The EPA uses the following CO_2 emission values. Circle the value you will use in your calculations.

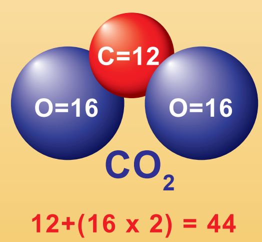
- Gasoline CO_2 emissions = 19.6 pounds per gallon
- Diesel CO_2 emissions = 22.4 pounds per gallon
- Miles driven ÷ MPG = total gallons consumed

Total gallons consumed x CO_2 emissions in pounds per gallon = Total CO_2 emissions

How can 20 pounds of carbon dioxide come from six pounds of gasoline?

It seems impossible that a gallon of gasoline, which weighs about 6.3 pounds, could produce 20 pounds of CO_2 when burned. However, most of the weight of the CO_2 doesn't come from the gasoline itself, but the oxygen in the air. When gasoline burns, the carbon and hydrogen separate. The hydrogen combines with oxygen to form water, and carbon combines with oxygen to form CO_2.

A carbon atom has a weight of 12, and each oxygen atom has a weight of 16, giving each single molecule of CO_2 an atomic weight of 44 (12 from carbon and 32 from oxygen). Therefore, to calculate the amount of CO_2 produced from a gallon of gasoline, the weight of the carbon in the gasoline is multiplied by 44/12 or 3.7.



Since gasoline is about 87% carbon and 13% hydrogen by weight, the carbon in a gallon of gasoline weighs 5.5 pounds (6.3 lbs. x .87). We can then multiply the weight of the carbon (5.5 pounds) by 3.7, which equals 20 pounds of CO_2.

Data Sources

Physical and chemical properties of gasoline: U.S. Department of Energy (DOE), Alternative Fuels Data Center (AFDC), Properties of Fuels.

Profile of a New Mexico Earth Science Teacher

James Rathjen lives in Pojoaque, New Mexico, and is a Level III Secondary Science Master Teacher who has been teaching science at Pojoaque Valley High School for 15 years. James is a unique educator because he has a dual role, teaching both secondary and college level students. He is an adjunct professor at Northern New Mexico Community College in Espanola, where he teaches freshman and sophomore classes in astronomy and geology. James grew up in Midland, Texas. He pursued his college degrees in Texas also, earning his undergraduate and advanced degrees in geology. James joined the Rockin' Around New Mexico teacher's workshop for the 2011 trip to the Jemez, and has attended each session since.

James Rathjen attended the 2014 session of Rockin' Around New Mexico. He is standing at the South Overlook at Freeport McMoRan's Chino Mine near Silver City, New Mexico. *Photo courtesy of James Rathjen.*

School, grade level and subjects taught:

At Pojoaque Valley High School, I teach earth science, physical science, and anatomy/physiology. I also taught middle school science and math for five years before taking the position in Pojoaque. Before coming to New Mexico, I obtained my certification for secondary earth science and biology in Texas (lifetime certification) and taught in Midland, Texas, for four years.

I have been an Adjunct Professor with the Math and Sciences Department at Northern New Mexico Community College for almost 20 years. I also was an Assistant Instructor at the University of Texas at El Paso (UTEP) for four years before attending graduate school to earn my PhD at UTEP.

Educational Background:

- PhD, Geology, University of Texas at El Paso, 1998
- Master of Science, Geology, Sul Ross State University, 1985
- Bachelor of Science, Geology, Texas Tech University, 1982

Teacher for scale. James measures the height of the haul truck tire at Chino Mine. *Photo courtesy of James Rathjen.*

Awards:

Grants that I was awarded for classroom projects include funding from Los Alamos National Laboratory Foundation, PNM Classroom Innovations Grant, KOB-TV/Phillips Laboratories, and others. Projects ranged from weather stations, seismometer installation, water analyses with GPS synchronization, astronomy, and renewable energy.

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

It is important for students to study earth science because it affects them every single day and night. It is important for them to understand how humans affect our planet, from global warming, species extinction, habitat destruction, to depletion of non-renewable resources. Local weather and broader scale climate affects them every day. I received a grant that focused on wind energy to power our greenhouse. I teach a unit on renewable energy, including wind, solar, and hydroelectric. I keep emphasizing to students that they will probably see the end of a petroleum-based world. Clean alternative energy sources will have to be implemented, which is what my students' generation can help solve.

How did you decide to go into teaching science?

After earning my master's degree in geology, I worked in the oilfield in Texas doing mud logging and exploration work. My intent was always to go into teaching at the college level, so after moving to El Paso and earning my PhD in geology, I worked my way north along the Rio Grande Valley, applying for teaching jobs. I eventually found teaching positions in Espanola both in secondary schools and at the local community college.

Favorite lesson in Earth Science:

I teach a unit to help students understand the structure of the Earth in which they create a scale model of a slice of the Earth's interior on a large sheet of paper. Working in groups to make several models, we then combine them to assemble the entire cross-section of the Earth.

My lesson is modified from Earth's Interior Structure, by Larry Braille at Purdue University. The main link is found at: **http://web.ics.purdue.edu/~braile/edumod/earthint/earthint.htm**.

How did you fall in love with geology?

My father was a petroleum geologist. I loved going out to the well site to catch and look at samples. As a student, I loved being out in the field and solving geologic puzzles. To this day I am in my "element" when I am in the field.

What are some of your field trip destinations for your geology classes?

We explore local sites including the Valle Grande, Ghost Ranch, and Kasha-Katuwe Tent Rocks National Monument to see geology. For specimen collecting sites, I like to visit the Harding Mine at Penasco, and the Taos area for fossils and the coolest staurolites.

Muleshoe Mound is a mound almost 400 feet high that was constructed mostly by microbes and fenestrate bryozoans with a significant contribution from crinoids on the mound flanks. *Photo courtesy of Peter Scholle.*

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

I like amateur astronomy, and I have two 8-inch reflector telescopes. I love looking at the planets, especially Saturn (cool rings!) and Jupiter. I also like viewing deep space objects such as Andromeda Galaxy, the Crab Nebula, Orion Nebula, and the Pleiades.

Favorite geologic feature in New Mexico:

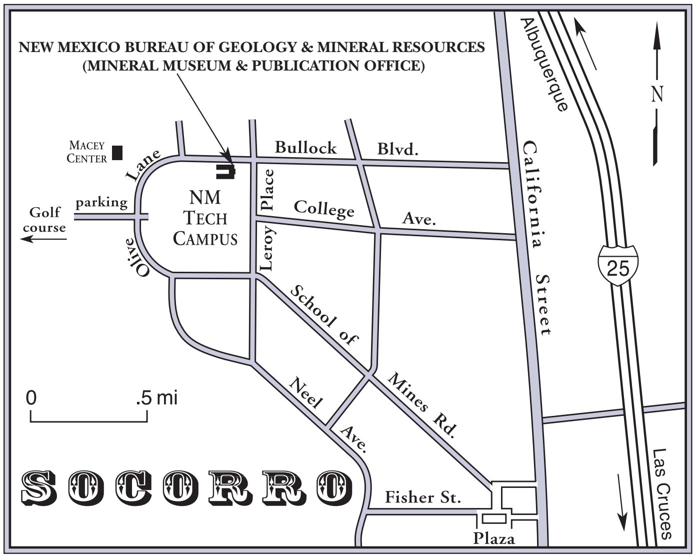
Muleshoe Mound is just south of Alamogordo. I spent a lot of time there while I was an undergraduate at Texas Tech University, along with my Professor Dr. Tom Dekeyser and a graduate student, Bill Jackson. We dirt camped at the mouth of San Andres Canyon. Each day we hiked up from our camp

Right: A close-up photo of the window-screen like fenestrate bryozoans that are the main non-microbial builder of the bioherms. Here they weather out of the rock and are easily visible because these were replaced by silica (originally they were calcite). Some recent papers argue that these bioherms, in the Alamogordo area and in other localities, formed around and were localized by seafloor methane vents. This is something seen today in many places, including the Gulf of Mexico. Even though these mounds reached more than 300 ft elevation above the seafloor, they show no sign of wave action, and no presence of photosynthetic organisms, and so are thought to have formed at considerable water depths on a ramp that got deeper to the south. The bioherms in Alamogordo are much smaller and they get progressively higher as one goes south. *Photo courtesy of Peter Scholle.*

to Muleshoe Mound, which was about a mile and a half. Then we had to climb the mound to do our sample collecting for petrographic analyses. The biggest obstacle for this field work was making sure that we had enough water. Fortunately, at camp there was a water pipe with a leak so we could bathe every day and cook dinner after a long day in the field.

Right: This shows a rock made of nothing but crinoid plates. Crinoids really did not build the mound cores, but they colonized the flanks and added to the size of the structures. Because they consist of a stack of plates like checkers or poker chips, their debris easily rolled down the flanks of the steep-sided mounds and accumulated as solid beds of crinoids around the mounds. *Photo courtesy of Peter Scholle.*

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 new Bureau of Geology building at the corner of Leroy Place and Bullock Street 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: **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

New Building Nears Completion for the Bureau of Geology

We're moving! The New Mexico Bureau of Geology & Mineral Resources is relocating to a new building, and we expect to have most functions up and running by the beginning of May, 2015. The new building will house all our staff, archives, and laboratories, which currently are scattered in five locations across the New Mexico Tech campus. The newly constructed building is located between MSEC, the building that houses the Earth and Environmental Science Department, and the Skeen Library. It is 53,000 square feet, LEED certified (**new.usgbc.org/leed**), and includes new public spaces that allow easy access to an expanded **Mineral Museum**, the **Geologic Information Center** (which contains our library and archival materials), our **Subsurface Data Library** (including petroleum, coal, and mineral records), and our **analytical laboratories**. Most of the funding for the new building was provided by **General Obligation Bond C** for higher education capital improvement projects, which was approved by voters during the November 2012 election.

New Mexico Bureau of Geology's new building is located at the corner of Leroy Place and Bullock Street on the New Mexico Tech campus. The Mineral Museum is on the right and the Publication Sales office is on the left of the front main entrance. *Photo by Leo Gabaldon.*

The Publication Sales Office

Is located at the New Mexico Bureau of Geology and Mineral Resources (see our new location, above).

Open 9 a.m. to 4 p.m. Monday–Friday (closed for lunch from 12 to 1).

Call 575-835-5490 for phone orders or information, or visit our website at: **geoinfo.nmt.edu/publications**.

The Publication Sales Office offers a wide selection of resources for teachers, including publications on New Mexico's geology. Many are written for the amateur geologist and general public.

Find our new publications at:
geoinfo.nmt.edu/publications/new/.

We offer:

- Topographic maps for the entire state of New Mexico
- Geologic maps for selected areas of New Mexico
- Popular and educational geologic publications
- U.S. Forest Service maps
- A 20% discount for teachers

RENEWABLE ENERGY RESOURCES

The National Energy Education Development (NEED) project provides curricula and other resources about all aspects of energy. The mission of NEED is to promote an energy conscious and educated society by creating effective networks of students, educators, business, government, and community leaders to design and deliver objective, multi-sided energy education programs. To learn more about NEED and to access its programs, visit the website at **www.need.org**.

Energy curricula relating to renewable energy:

Energy House

Students learn about efficiency, conservation, and economic returns by using various materials to insulate a cardboard house and then test its efficiency.
www.need.org/files/curriculum/guides/Energy%20House.pdf

Energy Flows

Students learn about the forms of energy, how energy is converted from one form to another, and how energy flows through systems in this hands-on activity.
www.need.org/files/curriculum/guides/Energy%20Flows.pdf

Energy of Moving Water

Students review all the forms of energy, with a focus on electricity. Exercises demonstrate how water can provide mechanical energy that could be converted to electrical power.
www.need.org/files/curriculum/guides/Energy%20of%20Moving%20Water%20Student.pdf

ROCKIN' AROUND NEW MEXICO

July 8–10, 2015
Socorro, New Mexico

This summer our annual teacher workshop, Rockin' Around New Mexico, will be located in Socorro, New Mexico. Several geologic topics will be explored with in-class activities and local field trips, including hydrology and structural features of the Rio Grande Rift that relate to its seismic history. The workshop will conclude with instruction on seismic hazards and school safety in New Mexico. 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) program at New Mexico Tech. Interested teachers should contact Susie Welch at 575-835-5112, or **susie@nmt.edu**.

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SOLUTION TO CROSSWORD PUZZLE