

Colorado School of Mines
Office of Special Programs & Continuing Education
Energy & Minerals Field Institute

Summary of the 2013 Government Field Program
August 5 – 10, 2013

The 2013 EMFI Government Field Program began in Denver on Monday, August 5, with an orientation breakfast at the Hotel Monaco. **Tom Sladek** introduced the EMFI staff -- **Jim Burnell, Dixie Termin, Tim O'Leary and Nick Jones**. The participants introduced themselves and identified their respective affiliations. Some represented offices in the legislative and executive branches of the federal government, and some represented state agencies of Colorado. **Nigel Middleton**, Senior Vice President for Strategic Enterprises at the CSM, welcomed the participants to the latest edition of the Energy and Minerals Field Institute and emphasized the importance of the EMFI to the CSM's core missions of education and outreach. **Barry Martin**, Director of the Office of Special Programs and Continuing Education (SPACE) at the CSM, also welcomed the group. The EMFI has been an important activity at the CSM since 1978, and plans are evolving to expand its scope to other regions and to other activities in the ever-changing energy and minerals industries.

Jim Burnell then reviewed the operational guidelines and practices which help the EMFI meet its objectives while protecting the safety and well-being of the participants. These ranged from the importance of punctuality and attendance at all scheduled activities, to the wearing of appropriate clothing and safety gear and the use of communicators during site visits, to restraints on cell phone use during instructional portions of the trip. Tom Sladek reviewed the itinerary, beginning with the opening ceremonies in Denver and proceeding through the towns of Brighton, Fort Lupton, Loveland, Gypsum, Glenwood Springs, Somerset, Montrose, Cimarron, Rifle, Craig, Steamboat Springs, Kremmling, and Estes Park, to the final stop in Golden: 5-1/2 days later and 975 miles down the road. Dixie Termin reviewed the arrangements for meals and hotel stays and cautioned the participants that it might be necessary to share a room from time to time.

The tour began with a presentation by Tom Sladek on Colorado's energy situation. Colorado is the 8th largest state and enjoys the highest average elevation. More than 85% of the state's 5.2 million people live in the Front Range Urban Corridor, which runs north from Pueblo through Denver to the Wyoming border. Colorado's population density is relatively low; household income is relatively high; and energy costs are relatively low, largely because of a friendly climate and cheap natural gas.

Colorado has abundant coal, oil, natural gas, uranium, sunlight, wood, corn, and wind and the world's largest deposits of oil shale. Colorado produces much more energy than it consumes, and overall energy production is rising rapidly. The most active area right now is Weld County north of Denver, where crude oil is extracted by directional drilling and hydraulic fracturing of the Niobrara shale beds.

Some 65 electric and gas utilities produce and deliver energy within Colorado. These range in size from Xcel Energy Inc. (which serves Denver and areas to the west) to rural electric coöperatives (which serve large areas but small populations) to municipal utilities that serve only one town each. At present, about 66% of the electricity generated in Colorado comes from coal, 20% from natural gas, and 14% from renewable energy resources. Although coal mining is still economically important, coal use is declining

and the use of natural gas and renewables is rising. This is a result of the state's renewable energy standard and of an air-quality program which will convert some power plants from coal to gas.

The 2013 EMFI visited many of Colorado's important energy and minerals locations, including:

- Xcel Energy's dispatch center which manages electricity flows into and out of the utility's grid;
- A factory in Brighton that manufactures nacelles for Vestas wind turbines;
- A peaking power plant in Fort Lupton which uses gas combustion turbines in combined cycle;
- A drilling rig in Weld County which seeks crude oil in the Niobrara formation;
- A mine and a factory in the town of Gypsum that makes wallboard from the mineral gypsum;
- Two underground coal mines near the town of Somerset;
- A dam and hydroelectric power plant near the town of Cimarron;
- An aboveground coal mine and a baseload power plant in the town of Craig; and
- A factory in Kremmling that makes pellet fuel for wood stoves from trees.

Xcel Energy's Dispatch Center

A short walk took us to the first of our sites -- the Denver headquarters of *Xcel Energy Inc.*, where the utility's energy dispatch center is located. Minneapolis-based Xcel Energy is investor owned and supplies electricity to 3.3 million customers in eight states through three operating companies – Northern States Power, Southwestern Public Service Company, and Public Service Company of Colorado. Xcel generates about two-thirds of its electricity and buys the rest from power authorities and other utilities. Xcel operates 81 generating stations, with a total capacity of 17 gigawatts. Energy sources include coal, natural gas, uranium, wind, water, fuel oil, sunlight, and biomass.



Commanche Generating Station, near Pueblo
At 1426 MW, the largest power plant in Colorado
It burns Wyoming coal in 3 units
and is operated by Xcel Energy

Xcel's service area in Colorado includes most of the densely populated Front Range communities located in the foothills of the Rockies and the high plains to the northeast, plus a large piece of northwestern and south central Colorado. Xcel owns all or part of 17 generating stations in Colorado with a total capacity of 5.7 gigawatts. The bulk of that capacity is from plants fired with fossil fuels – 60% from coal and 34% from natural gas. Only 6.5% is associated with renewable resources, and 86% of that 6.5% is provided by a single hydroelectric plant – the Cabin Creek pumped storage facility, which is located near the mountain town of Georgetown.

The small position that renewables have in Xcel's supply portfolio is a problem because Xcel is required by Colorado law to supply 30% of its electricity sales from renewable resources by 2020. To make up the difference, Xcel purchases relatively small amounts of solar-generated electricity from businesses and individuals and contracts with independent generators (notably large wind farms) to fulfill the remaining requirements for capacity and energy. Xcel also buys and sells non-renewable electricity from and to power authorities and other utilities, as required to satisfy the demands on its system. Energy from renewable resources always receives the highest priority.

The coal-fired power plants and some of the gas-fired plants are *baseload* facilities, meaning that they run all the time at near their design capacity to satisfy that portion of the power demand that changes relatively little with season or time of day. At the other extreme are sources of *peaking* or *load-following* generation that are used when Xcel must respond rapidly to short-term excursions in the demand for electricity. Some of these peaking plants are hydroelectric facilities where generation can be turned on or off quickly without endangering the equipment. (Xcel's Cabin Creek hydro plant is a notable example. It can reach its full generating capacity of 324 megawatts almost instantaneously.) Other peaking plants burn natural gas or fuel oil in large combustion turbines (similar to jet engines used in aircraft) that incorporate electrical generators. Much of the time these plants stand idle, which is good because their thermal efficiencies are low, and they are expensive to operate. Xcel's Zuni Generating Station is a unique peaker that can make up to 65 megawatts of electricity and also supply up to 300,000 pounds of steam per hour to a district heating system that serves many buildings in downtown Denver.

In the middle ground are sources of *intermediate* generation, which allow a utility to respond economically to longer-term, relatively gradual changes in demand, such as seasonal rise and fall in electricity for street lighting. Intermediate plants typically convert natural gas to electricity in combustion turbines and use some of the heat in the exhaust gases from the turbines to raise steam, which spins steam turbines to produce more electricity. These "combined-cycle" plants are more efficient than the peaking plants, but it takes more time to start and stop them. They are also more efficient than coal-fired baseload plants, and the facilities are cheaper to build and maintain. However the fuel is much more expensive. Xcel's Fort St. Vrain generating station is an intermediate generation facility with a unique history. It operated as a nuclear power plant until 1989, when it was decommissioned and re-powered as a natural gas-fired combined-cycle power plant.

Xcel must supply its customers (and other entities in its power pool) with electricity wherever and whenever there is a demand for it, while satisfying national, regional, and state standards for responsiveness, line voltage, frequency, stability, reliability, and other parameters. The increasing importance of renewable energy resources such as wind and sunlight has introduced additional challenges, because the output from some renewable energy facilities can vary substantially with time of day and season. Xcel attempts to predict the extent and timing of such variations and to compensate for them by buying and selling power in the regional market and by using energy storage facilities (such as Cabin Creek) and peaking plants (such as Zuni) which can respond rapidly to changes in power demand. The monitoring and prediction functions and the buying, selling, and dispatching of electricity are carried out in Xcel's energy dispatch center.

Our guide to the dispatch center was **Michael Boughner**, who works on generation control, dispatch, trading, and market operations for Xcel's subsidiary Public Service Company of Colorado. The dispatch center resembles a trading floor on Wall Street, and it plays a crucial role in the utility's operations. Workers monitor forecasts of temperature, wind, and precipitation and attempt to satisfy predicted demands for electricity with supplies from Xcel's generating stations and from the interconnected power pools, such as the Western Area Power Administration. We were there on a relatively calm morning. It must be much more lively during an ice storm or a tornado.

Vestas Nacelle Factory



Vestas Wind Turbines - Nacelles on towers behind blades

Following our Xcel tour, we returned to the hotel and boarded the Arrow Stage Lines bus where we would spend much time over the next five days. We endured our first exposure to The Clicker Board, EMFI's proprietary tracking tool that helps avoid leaving people behind. We drove 25 miles north to the town of Brighton for a tour of a wind machine factory operated by **Vestas-American Wind Technologies Inc.** The tour was arranged by **Susan Innes**, Senior Manager of Public Affairs for Vestas, and hosted by Production Quality Manager **Scott Winner** and Production Manager **Chris Welsh**.

Danish-based Vestas has been around since 1898. The company started as a blacksmith shop and has grown into the world's largest producer of wind turbines and one of the leading developers of wind energy projects. Since Vestas entered the wind business about 30 years ago, more than 43,000 Vestas turbines, with a total generating capacity exceeding 50 gigawatts, have been installed in 69 countries.

Vestas has four manufacturing plants in Colorado. Blades are made in Brighton and Windsor, and towers are made in Pueblo. The Brighton plant we visited makes nacelles – housings that sit atop towers and contain the equipment that converts the mechanical energy of the rotating blades into electricity. During good times, the factory assembles about 1400 nacelles per year. The present output is somewhat less, because the recession and the political turmoil in Washington have made life difficult for the US wind industry. Things are looking up, however, and Vestas recently secured large orders for wind farms in South Africa, Brazil, and other locations.

We donned hard hats, hard-toe shoe covers, and orange vests and toured the factory in small groups. At each step in the manufacturing process, a worker explained the procedures that are followed and discussed how the plant's integrated monitoring and communications processes are used to avoid accidents, promote operational stability, and foster quality control. The ruggedness of the equipment and the close tolerances of the manufacturing processes are very impressive.

J. M. Shafer Generating Station



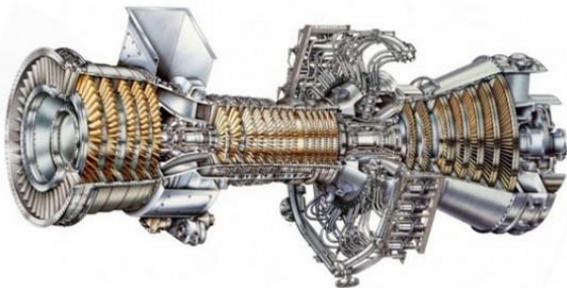
J. M. Shafer Generating Station in Fort Lupton
Natural gas fuel. Combined cycle operation.
272 MW from 5 units. Owned by Tri-State.

We clicked aboard the bus and drove 10 miles north to **J. M. Shafer Generating Station**, which is located near the town of Fort Lupton and is owned and operated by Tri-State Generation and Transmission Association. The host for our visit was **Richard Rhoads**, manager of Shafer station.

Tri-State generates some electricity in its own power plants, purchases additional electricity from other suppliers, and transmits the combined juice to 44 electrical coöperatives,

which serve 1.5 million consumers in 200,000 square miles of Colorado, Nebraska, New Mexico, and Wyoming. Tri-State is owned by the 44 coöps and has its headquarters in Westminster, 12 miles northwest of Denver.

Tri-State owns all or parts of the three types of power plants. Capacities of the six *baseload* plants range from 100 MW for Nucla Station in western Colorado to 1800 MW for the San Juan Generating Station near Farmington, New Mexico. These plants all burn coal and are intended to run essentially all the time at close to their design capacities. Nucla Station is unique in that the coal is burned in a fluidized bed boiler. The other plants use more-conventional waterwall boilers.



GE LM6000 gas combustion turbine generator, in schematic
43 MW & 41% thermal efficiency at standard conditions

Tri-State employs three sources of *intermediate* generation: Brush Generation Facility (307 MW), Rifle Generating Station (85 MW), and J. M. Shafer Generating Station (272 MW). And there are four *peaking* plants, with capacities ranging from 100 to 160 MW. As noted, peaking plants allow response to rapid, short-term changes in electricity demand and to changes in the output from renewable-energy facilities. Rural coöperatives, such as Tri-State and its member utilities, are subject to Colorado’s renewable energy standard, just as Xcel is, although

the requirements are less stringent. By 2020, the coöps must obtain 20% of their electricity from renewable resources, versus the 30% target for Xcel and other investor owned utilities.

The power plant in Fort Lupton was built in 1994 and was purchased by Tri-State in 2011. Tri-State re-named the plant for J. M. Shafer, who worked for the association for nearly 40 years, including four years as executive vice president and general manager. Tri-State also owns all or parts of three other power plants – Nucla Station (coal-fired, 100 MW), Craig Station (coal-fired, 1311 MW), and Rifle Generating Station (gas-fired, 85 MW) – that the EMFI has visited in recent years.

After our tour we drove 35 miles north to the city of Loveland, for our overnight stay at the Embassy Suites. Before dinner, **Jim Burnell** presented “Geology 101” – a gallop through 4.6 billion years of geological history which explained why rocks are the way they are and helped set the stage for the rest of the EMFI tour.



Bill Barrett Corporation Oil Rig

On Tuesday August 6, **Duane Zavadil**, Senior Vice President for Government and Regulatory Affairs for Bill Barrett Corporation, came to our hotel to explain how crude oil is extracted from the deeply buried beds of shale rock in the Niobrara Formation of the Denver-Julesburg Basin. Duane explained the drilling and completion practices and took us through the several sequential steps required to recover

Source: U.S. Energy Information Administration based on data from various published studies. Canada and Mexico plays from ARI. Updated: May 9, 2011

useful energy from a challenging environment. He then accompanied us to a rural site east of Greeley where Barrett's drilling contractor is hard at work. We donned flameproof Tyvek coveralls, hardhats and safety glasses, and visited each of the major unit operations. We did get to climb the many steps to the production platform, but we did not get splashed with drilling mud.

The Niobrara formation was laid down about 85 million years ago during the Late Cretaceous era. Not much happened for quite a while after that, but today the Niobrara is a hotbed of exploration activity. Hectic oil and gas exploration programs are also underway in the Bakken shales in North Dakota, Antrim shales in Michigan, Marcellus shales in the Northeast, and the Barnett and Eagle Ford shales in Texas. There are several reasons. First, the price of crude oil in global markets has risen to record heights, and it has remained there, more or less, throughout the world-wide recession. Second, exploration, drilling, and completion technologies have evolved to the extent that recovery of fuels from the deeply buried shale beds is finally practical. Third, the price of natural gas has fallen, and it is more profitable to drill oil wells than gas wells.



EMFI helps Bill Barrett find petroleum

The third factor has had a profound effect on Colorado. In the summer of 2010, dozens of rigs were active along the Colorado River between Glenwood Springs and Grand Junction, seeking natural gas in the tight gas sands of the Piceance Basin. By the summer of 2012, most of those rigs had moved east and south and were looking for oil in the shale beds of the Niobrara and similar formations. This dislocation upset the economies of some small communities in western Colorado, which for years had struggled to accommodate an energy boom, but it helped the Front Range communities, which supply workers, supplies, and services to the drilling industry. It also benefitted the owners of land over the energy-rich shale beds (especially owners of rights to extract that energy) who can charge royalties on the energy produced. And it helped state and local governments, which can collect sales taxes on supplies and services, property taxes on real estate improvements, and severance taxes on energy production. One energy company – Anadarko – has announced plans to spend \$1 billion per year on developments in the area, and Noble Energy has announced plans to spend up to \$1.5 billion per year.

The Niobrara shale beds are tricky targets. They are easy to find (they lie under hundreds of square miles of surface) but relatively thin (200 to 400 feet in eastern Colorado) and difficult to reach (3,000 to 14,000 feet down). Resources of gas and oil are very large, but the fuels are trapped between thousands of thin layers of shale. Only recently has a combination of drilling technologies provided a practical way to extract the energy. The key elements are:

- **Mud motors** – Hydraulic motors are mounted at the tip of the drill pipe and spin the bits that cut the rock. The motors are powered by drilling mud pumped through the pipe to flush out pieces

of broken rock and to lubricate and cool the cutting bits. It is no longer necessary to spin the entire length of pipe, which means deeper wells can be drilled. Also the speed of the motors can be adjusted so that one section of the bit head cuts faster than the other sections, causing the pipe to turn in that direction. This allows directional drilling. A rig can drill vertically to the shale beds and then horizontally along the beds. This exposes the pipe to greater lengths of the shale and, therefore, to larger amounts of the oil and gas that the shale contains.

- **Remote sensing** – A rugged electronic system is installed in the drill pipe and transmits positioning data (depth, compass heading, inclination) to a receiver on the drill rig. The information indicates where the pipe is located and where it is heading, which allows the operators to fine-tune the drilling process.
- **Improved drill rigs** – Modern rigs can drill many holes from a single pad, and this can be used to maximize fuel production while minimizing impact on the surface. In a simple scheme, a rig drills its first hole vertically into the shale bed and then switches to horizontal drilling and drives the pipe north through the shale for several thousand feet. The rig then moves a few feet to the right and drills a second hole that heads east through the shale; then another move and third hole heading south; and then a fourth hole heading west. When all four pipes are in place, product can be pulled from a broad circular area into a single pad, which can be connected to a single storage tank or pipeline.

Modern rigs also automate many of the processes – such as raising and connecting the numerous lengths of pipe – that have traditionally been done manually. These operations are now much faster and much safer than in the past.

- **Improved well completion practices** – Completion is the process of preparing a well for production. A key step is hydraulically fracturing the formation to increase its permeability and thereby to establish pathways for the hydrocarbons to reach the well. Fracturing can be helpful in any formation but it is absolutely essential in the tight gas sands in western Colorado and in the shale formations in the east. First the pipe passing through the formation is perforated at numerous locations along its length. Then a slurry of water, sand, and chemicals is injected at enormous pressure through the perforations and into the formation. This raises the surface of the earth above the affected area and causes cracks in the formation. When the pressure is relieved, the cracks cannot close completely because they are held apart by the sand grains. The injected water is withdrawn, and oil and gas begin to flow through the cracks to the wellbore.

The use of hydraulic fracturing has been quite controversial. Millions of gallons of water are required, and such water may not readily be available in the arid West. There is also concern that the chemicals in the fracturing slurry could cause harm if they found their way to sources of drinking water. And there is concern that the fractures created by the process could extend to natural vertical fractures or to abandoned wellbores, and this could allow the hydrocarbons released from the shale to spread through the subsurface and contaminate water supplies. Those concerns engendered a large number of technical studies and numerous policy initiatives, especially local level. Some towns banned fracking within their boundaries; others required large buffer zones between drilling activities and sensitive areas such as schools and hospitals. Those conflicts will reach fruition in the fullness of time, but right now the USA

is on track to become a major producer of crude oil, capable of satisfying its own demand for crude oil and of selling large quantities of crude to other nations.

American Gypsum's Mine and Wallboard Plant

We left the Barrett site late in the morning and drove 185 miles west to the small town of Gypsum, in Eagle County. The area around Gypsum was first settled in 1881, and the town was incorporated in 1911. The present population is about 6480, and the largest industries are ranching and American Gypsum's Eagle Plant, which manufactures drywall from paper, water, and gypsum minerals obtained from an open pit mine north of the town.

The mineral gypsum has served many useful purposes for thousands of years. Gypsum deposits are found in many regions, including the Montmartre district of Paris, the Cave of the Crystals in Mexico (where gypsum crystals are as long as 40 feet), and dunes near the north pole of Mars. One of the largest deposits is in the White Sands National Monument in New Mexico, where gypsum sand covers 270 square miles.



American Gypsum's Eagle Plant,
in Gypsum, Colorado

Gypsum is a powerful agricultural fertilizer, providing essential sulfur to plants. It also is very soft and can easily be carved into decorative forms. Ancient Egyptians used alabaster, a type of gypsum, to make statues, jewelry, funerary jars, and other items. Heating gypsum makes it even more useful. Gypsum's chemical name is calcium sulfate dihydrate. Each molecule consists of a molecule of calcium sulfate with two molecules of water attached. When heat is applied, the water molecules are driven off, and the mineral becomes simply calcium sulfate, which is even softer. It can easily be ground to a fine powder, and in this form

it is known as plaster of Paris. The powder can be mixed with water and cast into molds, or it can be shaped into useful items, such as a cast for a broken arm. Within a few minutes, the water recombines with the calcium sulfate, and the rigidity of the original mineral is re-established. This feature accounts for American Gypsum's interest.

American Gypsum is headquartered in Dallas and has production plants in New Mexico, Oklahoma, South Carolina, and Gypsum, Colorado. Hosts for our tour of the Gypsum mine and drywall manufacturing plant were **Brian Bloess**, Human Resources and Safety Manager, and **Steve Onorofskie**, Mine Superintendent. At the mine, overburden (dirt and rock above the gypsum seam) is broken by machines and explosives and hauled to a storage area. The gypsum is hammered, ripped, and crushed into pieces small than 6 inches and hauled to the processing plant, where it is crushed and heated to make very fine calcium sulfate powder. The powder is mixed with water, and this slurry is spread onto a constantly moving sheet of paper a little over four feet wide. Another sheet of paper is laid on top of the slurry, and the edges are rolled up and sealed to make a gypsum sandwich. By the time the sheet reaches the end of its long conveyor belt, the slurry has hardened such that the sandwich can be cut into

pieces either 8 or 12 feet long. These are stacked on pallets and shipped to retail outlets for sale to homeowners and construction contractors.

American Gypsum is the fifth largest producer of gypsum wallboard in North America. In a good year, it ships about four billion square feet of wallboard from its four plants. Recent years have not been good, but demand is rising, prices are up, and the outlook is favorable.

Underground Coal Mines near Somerset

After our tour, we drove west through beautiful Glenwood Canyon to Glenwood Springs, where we spent the night at the Hot Springs Lodge. On Wednesday August 7, we rose early and drove south along the Roaring Fork and Crystal rivers, past Carbondale and Redstone and Marble and over McClure Pass to Somerset, where we divided into groups to tour two underground coal mines: Arch Coal's *West Elk Mine* and the *Bowie No. 2 Mine* of Bowie Resources Ltd. We were not able to tour Oxbow Mining's Elk Creek Mine, which was recovering from a fire.



Roof Supports (Shields) for Longwall Mining



A coal shearer in action.
Shields above and to the right. Conveyor below.

Our hosts were **Sherry Wilson, Weston Norris, John Poulos, and Jane Watson** at West Elk and **Jake Wilson and Art Etter** at Bowie. We received training in the use of respirators and other safety gear and the processes for emergency evacuation. Each of us was equipped with hard hat, light, respirators, coveralls, gloves, dust masks, and formidable rubber boots, and we entered the mines in diesel trucks.

Both mines use longwall mining technology. Longwall mining began in England in the 17th century and became widespread in the 1950s and 1960s. It is now a very important technology for the large-scale extraction of bulk minerals such as coal and trona. More than half the coal mined in the United States is produced by longwall mines.

The first step is to create a tunnel with boring machines or continuous miners. Bolts are installed in the ceiling of the tunnel to prevent rock falls, and a large number of roof supports, or shields, are placed along the length of the tunnel, facing the panel of coal which is to be removed. A conveyor belt is installed in front of the shields, together with a track on which a cutter wheel, or shearer, moves. The shearer passes along the face of the panel, breaking the coal and dropping it onto the conveyor, which transports the coal beyond the panel area and drops it into haulage vehicles, which carry the coal to other conveyors, which

move it out of the mine. When the cutter has completed its pass, hydraulic systems move the shields forward, into the mined-out area, and the process is repeated until the whole panel has been removed. The mine roof collapses behind the shields.

Longwall operations are highly mechanized and very big. A panel may be two miles long and 800 feet or more in width. The longwall system will use dozens of individual shields. About 80% of the coal in a panel can be recovered, compared with about 60% for more traditional room-and-pillar mining. Longwall can also be used for deeply buried seams, where room-and-pillar is impractical. However there are concerns. Subsidence is immediate and, over time, it can disturb the surface above the mine, which could be problematic if that surface has structures on it or is otherwise valuable.

Morrow Point Dam

Following a box lunch and a Q&A session at West Elk, we boarded the bus and headed southwest some 80 miles through the towns of Paonia, Delta, Olathe, and Montrose to the outskirts of the village of Cimarron and the visitor center for *Morrow Point Dam and Power Plant*. We were met there by our hosts -- **Denny Johnson** and **Corey Anderson** -- from the Bureau of Reclamation office in Montrose. Denny provided an overview of the Bureau's major programs, with emphasis on development of renewable energy technologies and the integration of the Bureau's generating stations with regional electricity grids. We then received a thorough tour of the turbine hall, control room, and other crucial segments of the facility.



Morrow Point Dam & Power Plant
U.S. Bureau of Reclamation
Cimarron, Colorado

Morrow Point and its neighbor, Blue Mesa Dam, are located on the Gunnison River and are part of the Colorado River Storage Project, which was authorized by Congress in 1956 and serves Colorado, Utah, Wyoming, New Mexico, and Arizona. Glen Canyon, Flaming Gorge, and Navajo dams are also part of the CRSP. Morrow Point was the first thin-arch, double-curvature dam to be completed by the Bureau of Reclamation. It was completed in 1970. It is 468 feet high and has a crest length of 720 feet. The reservoir can hold 117,000 acre feet (3.8 billion gallons) of water.

Like the other CRSP dams, Morrow Point has multiple uses: flood control; water storage for municipal, industrial, and agricultural users; recreation; and generation of electricity from renewable resources. The power plant chamber is tunneled into the canyon wall in the left abutment, about 400 feet below ground surface. Electricity is generated by two 87 megawatt generators driven by two 83,000-horsepower turbines. Power is distributed through the regional grid to Salt Lake City and the southwestern states. The plant is remotely operated and has a peaking role: providing power intermittently to enable the grid to follow peaks in demand.

Following our tour, we drove back through Montrose and north through Delta and Cedaredge and over beautiful Grand Mesa to Rifle, for our overnight stay at La Quinta Inn & Suites.

Craig Station and Trapper Mine

On Thursday, August 8, we drove straight north from Rifle for about 90 miles to **Craig Generating Station**, near the town of Craig. Our host was **Marv Weible**, Operations Superintendent. He discussed the station's function in the regional power grid and described the technologies and operations that transform fossil fuel into electricity.



Craig Generating Station

Three baseload units burning pulverized coal.
Operated by Tri-State G&T Association
Trapper Mine is left of the coal storage yard.

Craig Station is a coal-fired power plant run by Tri-State Generation and Transmission Association. The station is one of Tri-State's six baseload power plants. It is intended to run constantly at close to its design capacity, except when maintenance is required. Tri-State owns about half of the facility and receives about half of the generation.

We were treated to a comprehensive tour of the 1,311 net megawatt facility, including a peek into the firestorm in an operating boiler and an elevator ride to the roof, where we viewed the coal storage yard, the plant's flue gas desulfurization units, adjacent Trapper Mine, the town of Craig, and the high voltage transmission lines that carry electricity from Craig to more populous areas of Colorado. Trapper supplies most of Craig Station's coal. The rest is brought in by train from nearby Colowyo Mine, which was recently purchased by Tri-State.

There are three generating units at Craig Station. Each unit burns pulverized coal in a waterwall boiler – a large rectangular box, lined with refractory bricks, with tubes embedded in its walls that carry water past the burning coal dust. The water is converted to steam and leaves the boiler at high pressure and temperature. It passes through a steam turbine, which spins a generator, which generates electricity. Spent steam from the turbine is condensed to liquid water, which is pumped back to the boiler. The burning coal produces fly ash, bottom ash, and gases, including sulfur dioxide. Two of the units use wet scrubbers to remove fly ash and to clean the gases. One unit uses a dry lime scrubber and a baghouse. Low-NOx burners are used on all units to reduce production of nitrogen oxides. The plant is adding a selective catalytic reduction system to further reduce NOx emissions. Bottom ash, fly ash from the baghouse, spent lime from the dry scrubber, and sludges from the wet scrubbers are sent to Trapper Mine, where they are buried in a mined-out area. Liquid wastes are evaporated, and the residues are disposed in Trapper Mine.

Following the tour, **Paul Griffin** and **Andy Berger** of Tri-State's government relations department described a collaborative campaign by utilities, politicians, regulators, and public interest groups to negotiate a State Implementation Plan to accommodate new air quality regulations. The plan includes converting several aging coal-fired power plants to burn natural gas and reducing emissions of nitrogen oxides from Craig Station.

We then drove to adjacent *Trapper Mine*, where we were met by **Forrest Luke**, Environmental Manager. Forrest described the history of Trapper Mine and its present operations, with help from **Graham Roberts** and **Tim Cummins**.

Coal is a sedimentary rock that was formed by the accumulation and preservation of plant materials, usually in a swamp environment where enough oxygen was present to support microbial action but not enough to completely oxidize the organic substances into carbon dioxide and water. As plant debris accumulated in a swamp, heat produced by the microbial action accumulated in the layers, and the rising temperature (and pressure) caused changes to occur in the physical and chemical characteristics of the organic matter, eventually producing the mineral that we now call coal. The cumulative changes are called “coalification.” One very significant aspect of coalification is a decrease in the content of light, volatile organic compounds and an increase in the carbon content of the debris, a process called “carbonization.”



Coal mining at Trapper Mine

The extent to which coalification (and carbonization) had proceeded before the swamp dried up determines the “rank” of the coal. There are four ranks: lignite, sub-bituminous, bituminous, and anthracite. Lignite – the lowest rank – is essentially de-watered and slightly carbonized peat. Anthracite – the highest rank – is nearly 90% carbon. Trapper produces sub-bituminous coal (about 2 million tons per year) and delivers all of it to its only customer, the adjacent Craig Generating Station.

Trapper is a strip mine. Its coal seams are buried under fairly thin layers of inert material, called overburden, which must be stripped away so that the coal can be removed. First the topsoil is scraped off and stored in a reserve area so that it can be used to reclaim the disturbed land after mining is completed. Then holes are drilled through the overburden to the top seam of coal. The holes are packed with explosive material, which is detonated to lift and loosen the rocks and dirt. A huge mechanical shovel called a dragline picks up the loosened material and places it in a mined-out area. The exposed coal seam is then ripped or drilled and blasted. Broken coal is loaded into trucks and hauled to Craig Station, where it is crushed and burned in the power boilers.

Much of Mr. Luke’s presentation was focused on environmental planning and the reclamation programs that Trapper Mining employs and how pleased they are with the results. After a Q&A session, we rode the bus to an active mining area where we watched one of Trapper’s three draglines at work. A dragline’s bucket can move the equivalent of 1-1/2 truckloads of dirt and rock in one gulp. We also had the opportunity to observe a working face, where coal was being extracted and loaded into large trucks.



Trapper Mine’s Queen Anne dragline

On the ride back to the Trapper office, the group observed the results of the land reclamation programs. This included seeing antelope and deer grazing on top of what was once an exposed coal seam. And while coal mining has a checkered past in the West, the Trapper people pointed out that their environmental efforts are more normal than exceptional in the modern industry.

During our 42 mile ride from Craig to Steamboat Springs, **Tom Sladek** discussed the status of unconventional energy resources in the Nation's energy mix. In a broad sense, these include any resource other than the currently big players -- coal, uranium, large hydro, and crude oil and natural gas from traditional geological regimes. Examples of unconventional fuels include liquid fuels and combustible gases derived from oil shale, coal, and tar sands; fuels and chemicals from agricultural and forestry commodities and residues; fuels, heat, and electricity from wastes such as scrapped tires and municipal solid wastes; and liquid fuels and chemicals made by transforming natural gas and industrial gases. Another example that is of special significance to the USA is oil and gas from nontraditional regimes, such as tight sands and shale deposits.

"Unconventional" is a troublesome label for these diverse resources but it's more accurate than "manufactured" or "synthetic" because all fuels are manufactured or synthesized in some way, and some allegedly synthetic fuels were used long before their modern "conventional" counterparts. Fuels were produced from oil shale in Austria and Switzerland in the 14th century, for example, and England issued a crown patent in 1694 for an oil shale retorting process. There were at least 50 commercial oil shale plants in operation in the eastern USA in 1859, when the world's first commercial oil well was drilled in Pennsylvania. "Coal oil" lighted lamps on the American frontier, and "town gas" obtained by gasifying coal illuminated streets, stores, and houses before and after 1859. Then there are whale oil and alcohol from wood and many other liquids and gases that were, in their day, important and economical energy resources.



Shell's Pearl GTL Project,
under construction in Qatar in 2010

Unconventional fuels are currently important in several countries and are on the rise in many others, including the USA. Huge quantities of crude oil are extracted from the tar sands resources in Alberta, Canada. In South Africa, SASOL gasifies coal and converts the gases to liquid fuels and chemicals. SASOL also runs a gas-to-liquids plant in Qatar, as does Royal Dutch Shell. Shell opened its first GTL plant in Malaysia in 1993 and recently announced plans to install the technology in other countries. The substantial oil shale industries in China and Estonia are growing, and new oil shale plants are being developed in Morocco, Jordan, Israel, Sweden, Canada, Australia, and the USA. Brazil and Germany have

small but stable oil shale industries. Many European countries subsidize the use of vegetable oils in diesel engines, and the USA subsidizes the use of ethanol from crops as motor fuel.

Plants that manufacture unconventional fuels can be very expensive to build and operate, and their products must be sold at high prices to pay off the investments and produce profits. Development of

tight oil and gas resources, which is proceeding at a feverish pace in the USA, does not require expensive manufacturing facilities, but it does require expensive technology, and it is therefore subject to the same pricing concerns.

In general, current prices of conventional fuels are high enough to make many unconventional fuels practical, but those prices could collapse, as they have before, and drive the unconventional plants out of business. Capital cost overruns are a serious risk, especially when a manufacturing plant is the first of its kind. Shell's experience in with the Pearl GTL project in Qatar is a good example of this type of risk. (Pearl wasn't Shell's first GTL plant, but it was the first really big one.)

When Shell announced the Pearl project in 2004, the estimated capital cost was \$5 billion. By 2007, the estimate had risen to \$18 billion. If that sum were borrowed at 2007 interest rates, the liquid products would have to sell for at least \$66 per barrel, just to service the debt. In 2007, Saudi Arabia's oil minister said his government favored moderate oil prices and would be content with a price range of \$50 to \$55 per barrel. Crude prices are much higher than that now, so Pearl should be safe, but prices don't have to stay high. Other unconventional fuel initiatives have not fared so well. For example, development of the tight gas sand resources in western Colorado began when natural gas prices were more than \$5 per unit and were forecast to rise above \$18. Gas prices are now less than \$4, and work on the tight sands has largely been suspended.

We spent early Thursday evening in a conference room at the Steamboat Grand Hotel, discussing possible energy futures. The session was facilitated by **K.K. DuVivier**, EMFI participant and professor of law at the University of Denver. K.K. first presented three scenarios developed by the International Energy Agency and published in *World Energy Outlook 2012* in November 2012. The scenarios attempted to distinguish the possible futures that might arise from continuation of current policies, from imposition of new policies to encourage some energy resources and discourage others, or from substantial policy changes intended to make the world much more efficient in its use of energy.

In its most-likely scenario, IEA forecast that the world will fail to put the global energy system onto a more sustainable path, that global energy demand will continue to rise at least through 2035, and that fossil fuels will continue to dominate the global energy mix. IEA also forecast that development of oil and gas from "tight" deposits in the USA will have far-reaching effects. By 2020, the USA could become the world's largest oil producer, and by 2030 North America could become a net exporter of petroleum.

Table 1.1 Definitions and objectives of the WEO-2012 scenarios

	Current Policies Scenario	New Policies Scenario	450 Scenario	Efficient World Scenario
Definitions	Government policies that had been enacted or adopted by mid-2012 continue unchanged.	Existing policies are maintained and recently announced commitments and plans, including those yet to be formally adopted, are implemented in a cautious manner.	Policies are adopted that put the world on a pathway that is consistent with having around a 50% chance of limiting the global increase in average temperature to 2 °C in the long term, compared with pre-industrial levels.	All energy efficiency investments that are economically viable are made and all necessary policies to eliminate market barriers to energy efficiency are adopted.
Objectives	To provide a baseline that shows how energy markets would evolve if underlying trends in energy demand and supply are not changed.	To provide a benchmark to assess the potential achievements (and limitations) of recent developments in energy and climate policy.	To demonstrate a plausible path to achieve the climate target.	To explore the results of improving energy efficiency in every way that makes economic sense.

Scenario Descriptions from IEA's *World Energy Outlook 2012*

Confluence Energy

On Friday, August 9, we drove 52 miles southeast over award-winning Rabbit Ears Pass to the small town of Kremmling, to visit a wood pelletizing plant. The plant was established by **Confluence Energy LLC** in response to Colorado's "red tree" problem. Red trees are pine trees that have died because of infestations by pine bark beetles. The beetles chew holes through a tree's bark and lay their eggs within. The beetles carry a fungus, which grows in the holes and eventually chokes off the tree's circulatory system. The fungus leaves a blue stain in the wood, which some consider decorative, but it is the red needles – denoting a dead pine tree – that have attracted the most attention. Foresters predict that 95% of Colorado's lodgepole pines may soon be dead or dying. The dead trees present a serious fire hazard, and when they fall they will create a major impediment to travel through the forests, especially for people and other large animals.

Some Colorado communities have taken advantage of the epidemic, by using the dead and dying trees as a fuel source, replacing expensive fossil fuels, especially propane. For example, the middle school in Oak Creek replaced an aging coal-fired heating system with a modern system that burns wood pellets made from beetle-killed pine. Those pellets are manufactured 50 miles away, at the Confluence Energy facility. About 200 tons per day of logs are shredded and dried and pressed into pellets. The pellets are about ¼-inch in diameter

and a few inches long. They are sold in bags in retail markets from Nevada to Pennsylvania and delivered in bulk to larger users, such as the Oak Creek school. Confluence Energy has also added several new products to their line. *EcoSponge* is an absorbent product utilized in bioremediation and the solidification and stabilization of soils. *EcoChar* is a low-cost activated carbon medium used in water filtration. *EcoSeal* consists of small engineered wood pellets and is used in oil drilling applications.

Rocky Mountain National Park

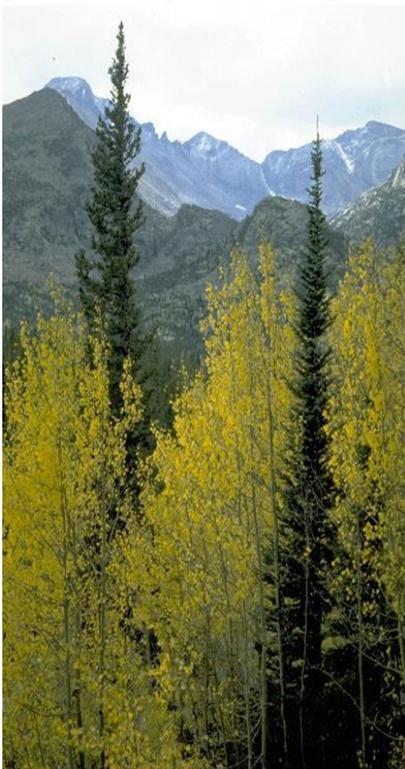
Another 40-mile drive took us to the town of Grand Lake and the entrance to **Rocky Mountain National Park**. The park occupies 415 square miles and is surrounded by national forests. It contains the headwaters of the mighty Colorado River, and the Continental Divide runs through it. There are more than 60 named peaks taller than 12,000 feet, and the tallest – Longs Peak – rises to 14,259 feet. Nearly 3 million people visit the park each year, making it the 6th most



Lodgepole pines killed by bark beetles



Confluence Energy LLC
with a backlog of pellet fuel



Long's Peak from an aspen
grove in Rocky Mountain
National Park

popular national park. Our guide to the park was **Larry Gamble**, chief of planning and compliance for the park. He pointed out many of the park's outstanding natural features and discussed the ongoing research activities. These include a multi-year study of the effect of nitrogen deposition on the park's ecological systems. Some of the nitrogen is released to the environment as emissions from fossil fuel power plants and production sites. Some is released from animal feedlots and from fertilizers used on agricultural lands. The nitrogen is problematic because it helps invasive plant species survive the harsh climate in the Park's upper reaches, thereby allowing them to displace the more delicate native species.

Park personnel have also struggled with the red tree problem, since many of the park's trees are lodgepole pines and most of those died several years ago. The dead trees that are still standing are a safety risk because they could fall without warning on people and structures. The trees that have fallen impede traffic on access roads and hiking paths. Rangers and their contractors cleared the residues from key areas, used as much of the wood as possible, and burned the rest. This has produced some anomalies. Timber Creek Campground, for example, has no timber in it.

We enjoyed a box lunch with Ranger Gamble at the Alpine Visitor Center at the top of Trail Ridge Road. Rain and snow enhanced the experience, but there were few complaints. We then drove down past the Park's east entrance to the historic Stanley Hotel in Estes Park, for dinner and an overnight stay. The Stanley was built by the inventor of the Stanley Steamer (an early automobile) and opened as a summer resort in 1909. It has hosted the glitterati of many eras since then, including Stephen King, who was inspired to write his horror story *The Shining*. The Stanley was not depicted in either King's novel or in Stanley Kubrick's 1980 film. However a 1997 TV miniseries version of the book was filmed there. Kubrick's film plays in a continuous loop on the hotel's cable system. Future visitors should not watch it if they hope to sleep well.



The historic Stanley Hotel in Estes Park, Colorado

Saturday, August 10 began early with breakfast at the Stanley. A very useful group wrap-up session followed, during which participants commented on the sites we had visited and the content of the program and suggested mechanisms to ensure continuation of the EMFI. We then drove 75 miles south and east to Denver International Airport, where most of the group departed either by plane or car. Staff returned the bus to Golden, unloaded surplus supplies, and celebrated the end of another successful and rewarding Energy and Minerals Field Institute.

Over the previous 5-1/2 days, we had spent more than 20 hours in the bus and driven more than 975 miles -- roughly the distance from Denver to Chicago or Los Angeles, from Brisbane to Melbourne, from Vienna to Istanbul, from Washington DC to Ft. Lauderdale, or from Mexico City to Cancun. We would love to do it again.