EMFI Government Field Program

August 13 – 18, 2012

Trip Summary

The 2012 EMFI Government Field Program began in Denver on Monday, August 13, with an orientation breakfast at the Hotel Monaco. **Gary Baughman**, Director of the EMFI, introduced the EMFI staff **-- Jim Burnell, Paul Quinn**, **Tom Sladek, Dixie Termin, Kaitlyn Tripp.** 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 Colorado School of Mines (CSM), welcomed the participants to the 28th edition of the Energy and Minerals Field Institute's Government Field Program and emphasized the importance of the EMFI to CSM's core missions of education and outreach. **Barry Martin**, Director of the Office of Special Programs and Continuing Education (SPACE) at 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 activities in the ever-changing energy and minerals industries.

Gary Baughman then reviewed the operational guidelines and practices which help the EMFI meets 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 the ban 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, Greeley, Estes Park, Grand Lake, Steamboat Springs, Craig, Parachute, Glenwood Springs, Somerset, Montrose, Cimarron, Ouray, Ridgway, Naturita, Gateway, and Grand Junction to the final stop in Golden – 5-1/2 days later and 1,058 miles down the road. Dixie Termin reviewed the arrangements for meals, hotel stays , and related logistical items.

The tour began with a presentation on energy production and use in Colorado by **Tracee Bentley**, Associate Director of Policy and Legislation at the ***Colorado Energy Office.*** Tracee discussed how Colorado's coal mines, oil and gas fields, renewable energy facilities, and some 65 electric and gas utilities produce and deliver energy to the state's five million people, plus a substantial surplus for export to other states. Colorado voters have required the State to increase the importance of renewable energy in the State's energy mix, and the declared policy of Colorado's governor is that all sources of supply should be used in the most economically efficient and environmentally sound manner. The Energy Office has many programs underway to support those initiatives, as well as programs to promote weatherization, energy efficiency, and the use of natural gas in vehicles.

A short walk took us to the Denver headquarters of ***Xcel Energy Inc.***, for a tour of Xcel's dispatch center. Minneapolis-based Xcel Energy is an investor-owned utility that 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, from within its three operating companies. 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
Burns Wyoming coal in 3 units
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 east, plus a large portion of northwestern 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 20% 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 *peak-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, as it can reach its full generating capacity of 324 megawatts almost immediately.) 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 relatively 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 additional 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. Employees 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. Fortunately, we were there on a relatively calm morning, as it would be much more lively during an ice storm or tornado.

Following our tour, we returned to the hotel and boarded the bus where we would spend much time over the next five days. We endured our first exposure to the "Clicker Board," EMFI's tracking tool that helps avoid leaving people behind, and met the final member of the EMFI team – **Nick Jones,** a faithful colleague and a driver with Arrow Stage Lines. We drove 25 miles north to the town of Brighton for a tour of a wind machine factory operated by ***Vestas-Americas Wind Technologies Inc***. The tour was arranged by **Susan Innes,** Senior Manager of State Government Relations for Vestas, and hosted by **Nicholas Lenssen**, Specialist in Wind Market Intelligence.

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 Wind Turbines - Nacelles on towers behind blades

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 – the 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. These are not good times, so the present output is somewhat less.

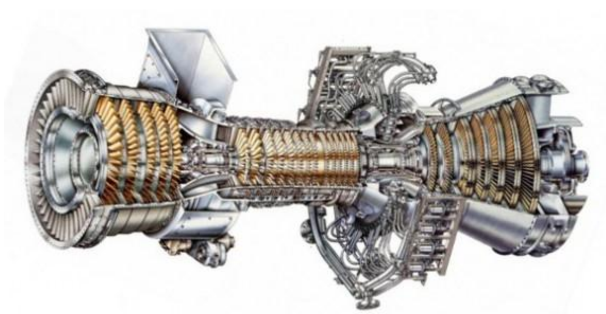
We donned hard hats, hard-toe shoe covers, and orange vests and toured the factory in small groups. At each step in the manufacturing process, a worker explained the procedures that are followed and discussed how the plant's integrated monitoring and communications processes are used to avoid accidents, promote operational stability, and foster quality control. The ruggedness of the equipment and the close tolerances of the manufacturing processes are very impressive. At the final stop, we climbed inside a completed nacelle and enjoyed the "new nacelle" smell, one of the many things that make shopping for a nacelle such a memorable experience.

We clicked aboard the bus and drove 10 miles north to the ***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.

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

Tri-State generates some electricity in its own power plants, purchases additional electricity from other suppliers, and transmits the combined power to 44 electrical cooperatives, 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 cooperatives and has its headquarters in Westminster, 12 miles northwest of Denver.

Tri-State owns all or part of the three types of power plants. Capacities of the six *baseload* plants range from 100 MW at the Nucla Station in western Colorado to 1,800 MW at 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. The Nucla Station is unique in that the coal is burned in a fluidized bed boiler, whereas the other plants use more conventional water-wall 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: the 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 cooperatives, 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 coops must obtain 10% of their electricity from renewable resources, versus the 20% 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) – all of which the EMFI has visited in recent years.

We then drove another 35 miles north to the city of Greeley, for our overnight stay at the Hampton Inn. 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.

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

On Tuesday, August 14, we drove east from Greeley to 70 Ranch, where ***Bill Barrett Corporation*** is drilling for oil among the shale beds in the Niobrara Formation of the Denver-Julesburg Basin. We met our host – **Duane Zavadil**, Senior Vice President for Government and Regulatory Affairs for Bill Barrett Corporation – at the drilling site. He explained the drilling and completion practices and took us through the several sequential steps required to recover useful energy from a challenging environment. As is normal in the fossil fuel business, geology is a key to understanding.

The Niobrara was laid down about 85 million years ago during the Late Cretaceous era and today the Niobrara is a hotbed of exploration activity. Bill Barrett Corporation alone has six drilling rigs in operation. 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, Barnett and Eagle Ford shales in Texas, and other similar deposits around the world. There are several reasons: first, the price of crude oil in global markets has risen to record highs, and it has remained there, more or less, throughout the world-wide recession. Second, exploration, well drilling, and well completion technologies have evolved to the extent that recovery of fuels from the deeply buried shale beds is finally practical. And third, the price of natural gas has fallen, and it is more profitable to drill oil wells than gas wells.

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 are now 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.

While the revenue is welcomed into the local economy, another issue issue relates to the proximity of the drilling and production activities to residential areas, and the fact that often those individuals having surface rights (and, therefore, those impacted by the surface operations) do not also own the minerals underlying their property. While State regulations typically attempt to resolve these "split estate" conflicts through various means, the "Not In My Back Yard" (NIMBY) issue has become increasingly apparent as the resources overlain by residential communities are being exploited.

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 rotate 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 for 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 wells from a single pad, and this can be used to maximize fuel production while minimizing impact on the surface. For example, in a simple scheme, a rig might drill its first hole vertically into the shale bed and then switch to horizontal drilling and drive the pipe north through the shale for several thousand feet. The rig would then move a few feet to the right and drill a second hole that heads east through the shale; then another move and a 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.

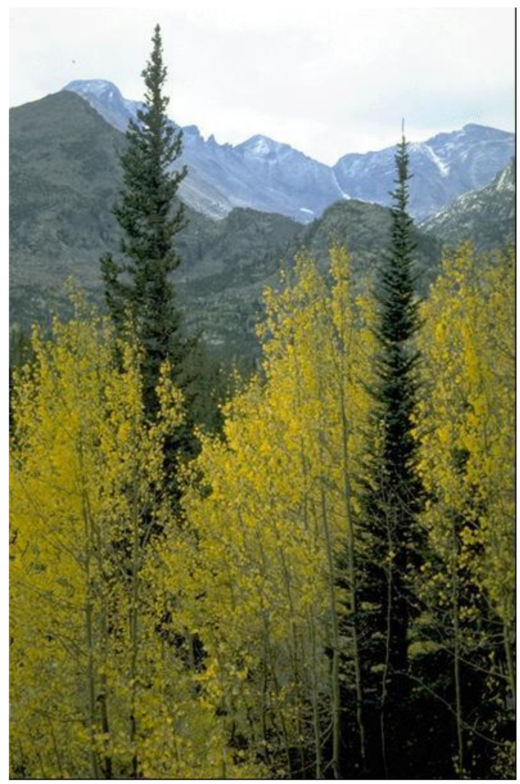
  Modern rigs also automate many of the processes – such as raising and connecting the numerous lengths of pipe – that have traditionally been done manually. These operations are now much faster and much safer than in the past.

- ***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 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, causing 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.

These concerns have been cited by many individuals and organizations within the impacted areas, just as similar concerns have been voiced in Ohio, Pennsylvania, and elsewhere. Hydraulic fracturing operations have been conducted millions of times in hundreds of thousands of wells in the U.S. since 1947, and many studies conducted over the years have provided no conclusive evidence of these negative environmental impacts. Nevertheless, the geology, history of previous drilling activity, formation depth, location of aquifers, regulatory safeguards, and a host other factors unique to many of the areas now being developed warrant serious attention to these matters.

Another 50-mile drive took us to the town of Estes Park and the eastern 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 most popular park in Colorado and the 6th most popular park in the nation. In May 2010, TripAdvisor.com named the park as the No. 2 Outdoor and Adventure Destination in the world. No. 1 was the Queenstown area in New Zealand, where the Lord of the Rings trilogy was filmed.



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

Our guide to the park was **John Mack,** Chief of the Natural Resource Management Branch at Rocky Mountain National Park and an employee of the National Park Service. He pointed out many of the Park's outstanding natural features and discussed the research and maintenance activities conducted and managed by the Park's scientists and their contractors. These included an ongoing struggle to deal with the destruction of many of the Park's trees by Mountain Pine Beetles, which is a serious problem throughout the Rocky Mountain area. 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. In the Park, the main concern is protecting visitors from falling dead trees.

Park personnel are also engaged in 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, and 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.

We enjoyed a box lunch with Ranger Mack at the Alpine Visitor Center at the top of Trail Ridge Road, and then drove down past the Park's west entrance; through the mountain towns of Grand Lake, Parshall, Flat, Troublesome, and Kremmling; and over Rabbit Ears Pass to our hotel for the night – the Steamboat Grand in the ski resort town of Steamboat Springs.

On Wednesday morning, August 15, we drove 43 miles west through the town of Craig to the ***Trapper Mine***, our first coal mine. 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. The Trapper Mine produces sub-bituminous coal (about 2 million tons per year) and delivers all of it to its only customer, the adjacent Craig Generating Station.

Forrest Luke, Environmental Manager for Trapper Mining Company, described the history of Trapper Mine and its present operations, with help from **Jim Mattern**, the mine manager. Trapper is a surface mine, with its coal seams 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 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 standard than exceptional in the modern industry.


View of Craig Station from Trapper Mine

Our next stop was the adjacent ***Craig Station***, a coal-fired power plant run by ***Tri-State Generation and Transmission Association***. Craig 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 electricity generated.

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, 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 the 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, while 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 the

Trapper Mine, where they are buried in a mined-out area. Liquid wastes are evaporated, and the residues are disposed of in Trapper Mine.

Our next stop was 106 miles south of Craig at the ***Battlement Mesa Activity Center***. The Battlement Mesa community was a product of the oil shale boom of the late 1970s and the bust of the early 1980s. The activity center is a pleasant facility overlooking the oil shale cliffs near the town of Parachute. We paused there for a tea break and to hear two presentations on energy development along the Colorado River and in the Piceance Basin. The presenters were **Keith Lambert**, former mayor of the ***City of Rifle*** and now a member of the City Council, and **Glenn Vawter**, Executive Director of the ***National Oil Shale Association***, who was accompanied **by Roger Day**, Chairman of the Association.

Glenn Vawter summarized the history of oil shale development around the world, with emphasis on current research programs in Colorado and Utah. Oil shale is a fine-grained sedimentary rock that contains a complex solid hydrocarbon substance called kerogen. When retorted (heated in vessels called retorts), kerogen decomposes to form combustible gases, liquids, and solids. The liquid products are the most interesting because they could displace conventional petroleum.

Oil shale resources have been found on all of the inhabited continents. Although some of these have supported synthetic fuel industries at various times in the past, oil shale always has had trouble competing with conventional crude. Today substantial operations exist only in Estonia, China, and Brazil. High oil prices have had an effect, however. Operations in Estonia and China have already expanded, and additional projects are under development in Jordan, Israel, Morocco, China, and elsewhere. In the USA, the U.S. Bureau of Land Management has a leasing program underway which could eventually lead to commercial production on lease tracts in Colorado and Utah. Time will tell whether this program achieves its stated objectives or whether it will join the initiatives in the 1940s, 1960s, 1970s, and 1980s, which dissipated rapidly when oil prices collapsed.

The ebb and flow of interest in oil shale has affected the City of Rifle perhaps more than any other community in Colorado. Rifle also endured a surge in natural gas exploration and production activities that, until recently, filled its hotels with drillers and its streets with water tankers and fracing trucks. The industry has moved on, at least for a while, and the city also has evolved. Rifle helped create a large photovoltaic facility on land obtained from the federal government and built a wastewater reclamation plant on the same site. The city is attempting to foster high-tech programs, including cooperative efforts with Colorado Mountain College and especially in the area of fuels from biomass and other forms of unconventional energy.

After our break, we drove east from Parachute past Rifle to Glenwood Springs, where we spent the night at the Hot Springs Lodge. On Thursday, August 16, we rose early and drove south along the Roaring Fork and Crystal Rivers, past Carbondale and Redstone, and over McClure Pass to Somerset, where we divided into groups to tour three underground coal mines: Arch Coal's ***West Elk Mine***, Oxbow Mining's ***Elk Creek Mine***, and the ***Bowie No. 2 Mine*** of Bowie Resources Ltd. Our hosts were **Sherry Wilson**, **Weston Norris**, and **Wendell Koontz** at West Elk; **Rob Thurman**, **Mike Ludlow**, **Jens Lange**, and **Jim Kriger** at Elk Creek; and **Jim Abshire** 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, respirator, coveralls, gloves, and formidable rubber boots, and we entered our assigned mine in a diesel truck.

All three mines use longwall mining tehnology. 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.

Roof Supports (Shields) for Longwall Mining

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.

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

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.

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: **Mike Pulskamp** from the office of the ***U.S. Bureau of Reclamation*** in Denver and **Scott Henslee** and **Randy Kramer** from BuRec's office in Montrose. Mike 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

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

electricity grids. Scott and Randy provided a thorough tour of the turbine hall, control room, and other crucial segments the facility.

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.

On our way back towards Montrose, we paused at ***Black Canyon of the Gunnison National Park*** and looked at some of the oldest rocks on earth. Then we drove 55 miles past Montrose and Ridgway to Ouray – "The Switzerland of America" – for our overnight stay at the Ouray Victorian Motel.

Black Canyon of the Gunnison National Park

On Friday, August 17, we drove about 70 miles through Ridgway and Placerville (gateway to the town of Telluride and its ski resort and film festival) to the town of Naturita and the Uravan uranium mining district.

Naturita is in the Uncompahgre Valley – one of Colorado's most stunningly beautiful areas – and on the Unaweep/Tabeguache Scenic and Historic Byway, a 138-mile driving tour that offers dramatic views of the San Juan Mountains. The byway passes through Unaweep Canyon and the desert-like Dolores River Canyon and up into the high plains around Grand Junction. Ancient rock outcroppings and red sandstone formations, still holding fossils from Precambrian times, mark the trail. The drive is especially spectacular when wild flowers peak in July or when the aspen trees change color in September. The area is surrounded by federal land, including the Uncompahgre National Forest, which encompasses more than a million acres.

We stopped at the ***Naturita Community Library***, where librarian **Allie Sutherland** provided a meeting room and a talk on how the library building was completed, despite difficult times, through heroic efforts by many people. The building itself is remarkable. It is made from bales of straw and covered inside and out with stucco manufactured from locally obtained materials. In 2010, the Colorado Association of Libraries gave the building its Library Project of the Year award. In 2011, the Library Journal declared the library to be "a labor of love" and the Best Small Library in America. That award was sponsored by the Bill and Melinda Gates Foundation. Also in 2011, it has been alleged, the library of the Town of Naturita (population 655) spent more on its programs for children than did the library system of the City of Chicago (population 2,851,268).

The Uravan mineral belt occurs in the counties of San Miguel, Montrose, and Mesa in Colorado and Grand County in Utah. It contains numerous scattered deposits of uranium and vanadium, and in the early 20th century, it was the most productive source of uranium in the United States. The Uravan mineral belt includes the mining districts of Slick Rock and Gypsum Valley in Utah and Uravan and Gateway in Colorado. A few miles north of Naturita is the site of the former town of Uravan, where uranium was processed in the 1940s for use in the Manhattan Project, which built the atomic bombs that were dropped on Japan in 1945.

In the 1950s, the U.S. Atomic Energy Commission promoted a uranium boom which attracted prospectors to southwestern Colorado. The boom continued until the 1960s, when the government began to reduce its requirements for uranium. Although the government's procurements of uranium ended in 1970, a new market – nuclear power plants – began to emerge. That market collapsed in the late 1970s, when orders for new power plants were cancelled and low-cost uranium from Canada became available. Most of the miners and mill hands moved out, and Uravan became a ghost town. It was listed as a Superfund site by the U.S. Environmental Protection Agency, and an extensive environmental cleanup was conducted from 1986 to 2001. All that remains of Uravan is a wide spot on State Highway 141.

Jane Thompson grew up in Uravan during the uranium boom. She is now active in the ***Rimrocker Historical Society***, which has a museum in Naturita and holds an annual barbecue and reunion for Cold Warriors at the Uravan site. Jane joined us at the library and shared her recollections of Uravan during its glory days. She and her grandson, **Spencer,** then took us on a special tour of the museum, and after that we returned to the library for a box lunch and to hear a presentation by Jim Burnell on the importance of strategic minerals (and especially the rare-earth elements) in the world's economy. Then we drove north to the Uravan site, walked the ground, and continued on to the Gateway Canyons Resort, where we spent Friday night. Along the way, we stopped to examine, from a distance, the Hanging Flume, another ghost of the early days of mining in southwestern Colorado.

Saturday August 18 began early with breakfast at Gateway Canyons. 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 the 75 miles to Grand Junction Regional Airport, where most of the group left the bus to catch flights back home.

We followed I-70 past Battlement Mesa and Glenwood Springs, through splendid Glenwood Canyon, past the ski areas of Eagle and Summit counties, and under the continental divide in the Eisenhower–

Johnson Memorial Tunnel to Golden and the end of another successful and rewarding Energy and Minerals Field Institute.

The grand canyon of the Dolores River, between Naturita and Gateway