

INFORMATION SERIES 80

Colorado Mineral and Energy Industry Activities 2016-2017

by Michael K. O'Keeffe and Karen A. Berry



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Cover: Cement plant stockpile in Weld County, Colorado. Photo credit: Larry Scott for the CGS.
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ECONOMIC SUMMARY

In 2016, Colorado produced many mineral and energy commodities. Top commodities, in terms of production value, include natural gas, oil, gold, molybdenum, sand and gravel, cement, crushed stone, clay, and industrial gases (carbon dioxide and helium). The total value of mineral and energy fuels production in Colorado for 2016 is estimated to be \$11.62 billion, a 6.4% decline from the \$12.41 billion production value in 2015. The mineral production value for 2016 is separated into commodity types in **Figure ES-1**. Natural gas and oil production accounted for most (76%) of Colorado's total mineral and energy production value in 2016. Estimated mineral and energy production values for 1994 through 2016 are shown in **Figure ES-2**. From 1994 to 2008, mineral and energy fuel production value increased primarily due to rising natural gas production and prices. In 2009, the production value decreased dramatically due to a major decline in natural gas and oil prices. However, between 2009 and 2014, the oil market rebounded mainly due to increases in oil prices and production. Production values decreased between 2014 and 2016 primarily due to lower oil and natural gas prices.

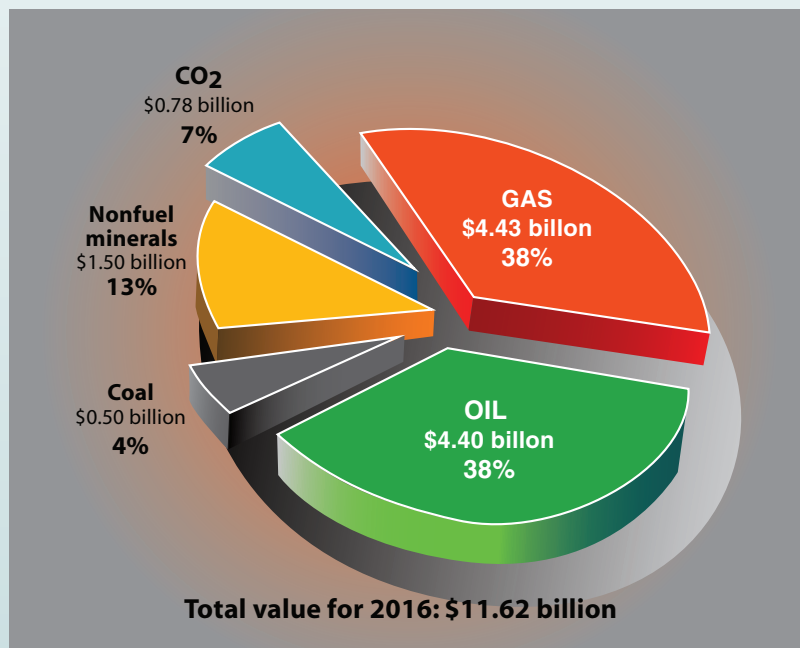


Figure ES-1. Colorado mineral production value by commodity (U. S. dollars).

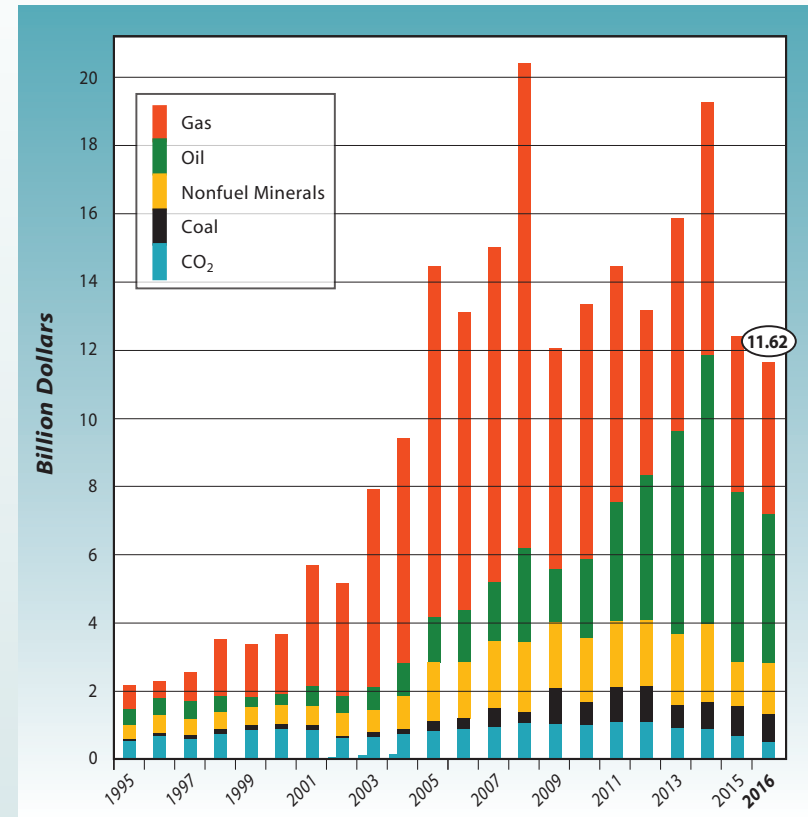


Figure ES-2. Mineral and energy fuel production value in Colorado, 1995–2016.

Significant production increases up to 2014 are largely due to the utilization of horizontal drilling and hydraulic fracturing techniques for oil and natural gas in the Niobrara Formation, largely in Weld County. The total estimated value of oil and natural gas production in 2016 is \$8.84 billion, a decline of 8% from the 2015 value of \$9.56 billion. Colorado oil and natural gas production remains higher than historical values but production values have decreased primarily due to lower oil prices. According to the U.S. Department of Energy-Energy Information Agency (EIA), Colorado has the sixth largest reserves of natural gas and eighth largest proven oil reserves in the U.S.

The estimated value of Colorado coal production in 2016 is \$499 million, down 26% from the 2015 value of \$676 million. The continued reduction in coal

production is due primarily to the nationwide trend away of generating energy from coal-fired power plant energy and increased use of natural gas and renewable energy. Colorado remains as the 11th largest coal producer in the U.S., as it was in 2015, with both underground and surface mines currently in operation on the Western Slope.

Nonfuel mineral production includes metals, industrial minerals, and construction materials. At the time of this report, the United States Geological Survey (USGS) estimates that the total value of Colorado's production of nonfuel minerals in 2016 is \$1.51 billion. Although the past 2015 nonfuel mineral production value for Colorado was estimated at \$2.41 billion by the USGS, this number will likely be revised to \$1.34 billion for 2015 due to error in the amount of molybdenum production. Based on this revised number, the 2016 Colorado estimate is approximately 13% higher than the 2015 estimates. Although just one mine in the state publicly reported gold production in 2016, Colorado remains the third largest producer of the metal in the U.S. as it was in 2015. Two Colorado mines continue to produce molybdenum, albeit at lower volumes due to lower prices, and the state was the second largest producer of this metal in 2016.

Carbon dioxide produced in Colorado is used primarily for enhanced oil recovery in the Permian Basin oil fields of Texas. The production value in 2016 was an estimated \$778 million, a 6% decrease from the 2015 value of \$830 million.

There was no uranium mining in Colorado in 2016. Continued low uranium prices account for the lack of mining. However, company consolidations and project development were ongoing in 2016.

SEVERANCE TAX REVENUE

Severance taxes are state taxes collected on companies who produce nonrenewable resources including oil, gas, coal, molybdenum, and gold. Energy and mining companies who extract these resources pay a majority of the severance tax on top of other taxes including income, sales, and property taxes. A portion of the severance tax funds are distributed to counties, municipalities, and school districts. Severance tax funds are also used to support the Colorado Geological Survey (CGS), Parks and Wildlife and programs within the Colorado Department of Natural Resources (DNR).

In fiscal year (FY) 2016, July 1st thru June 30th, Colorado will have collected an estimated \$84.1 million in severance taxes, a decrease of 71% from the \$292.7 million collected in FY 2015. The Colorado Department of Local Affairs (DOLA) administers the distribution of severance tax revenue to affected county and local governments. **Figure ES-3** shows the annual severance taxes collected since 1994. The map in **Figure ES-4** shows the distribution of FY 2016 severance taxes to each county.

Severance tax collections continue to come in at low levels in early FY16-17. Recent low levels of collections are caused by several factors. The ad valorem tax credit for State severance taxes is one factor. Oil and gas producers are able to claim a credit against severance taxes for property taxes paid, called the ad valorem credit. The credit has contributed to recent volatility in revenue. Property taxes on oil and natural gas are based on the prior year's production. Following a high production year, the amount of the ad valorem credit claimed is large because it is based on a higher production value. Oil and gas producers

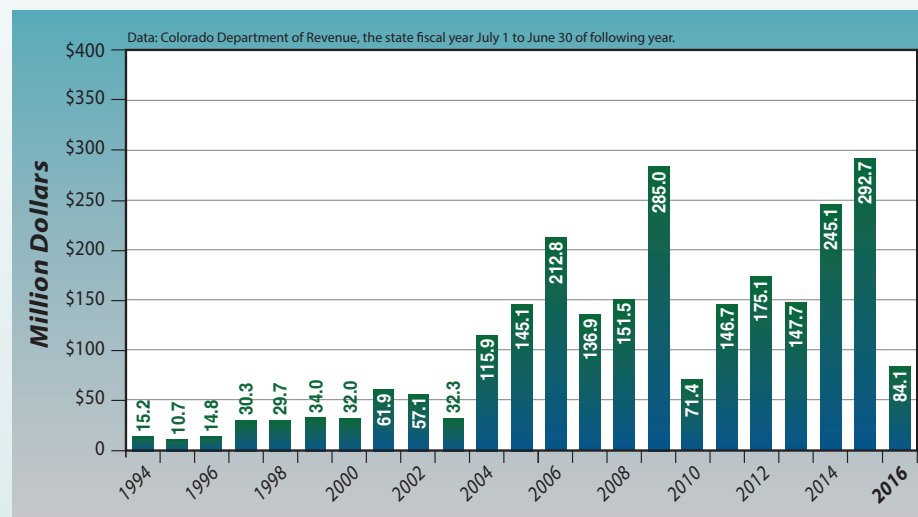
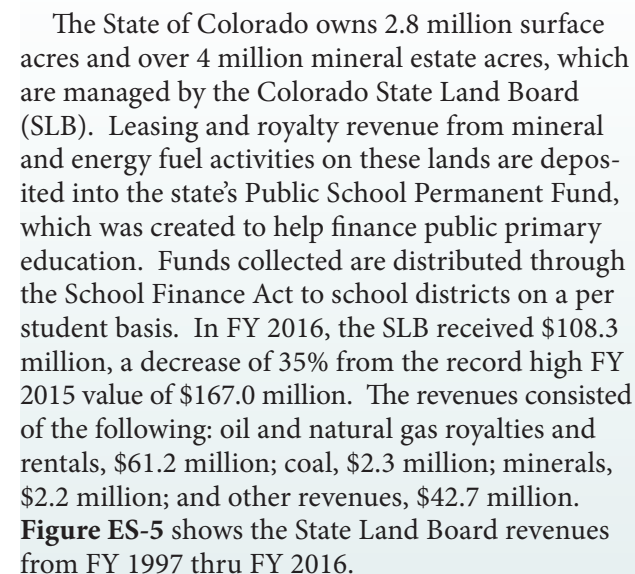


Figure ES-3. Colorado mineral severance tax collected revenues 1994–2016.



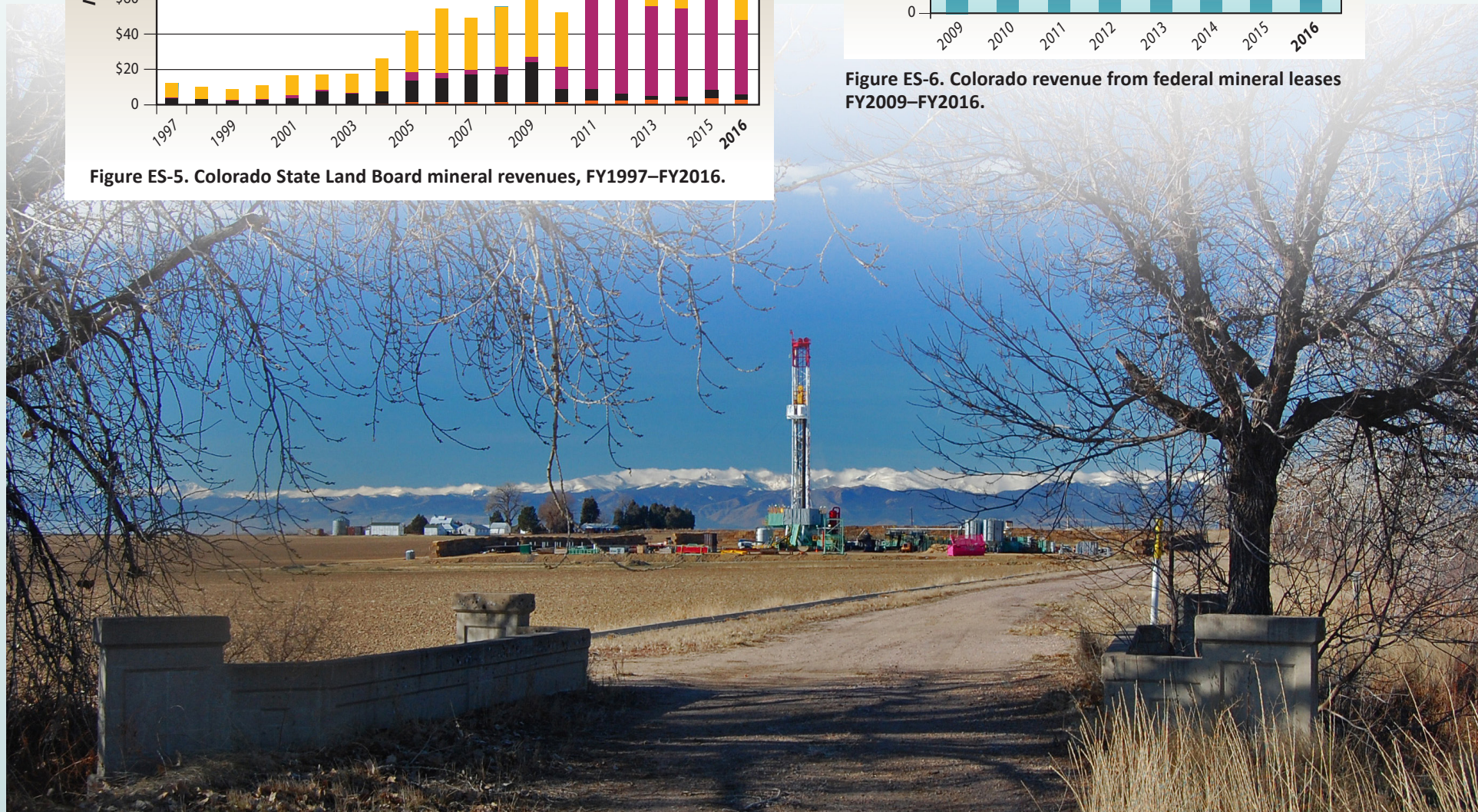
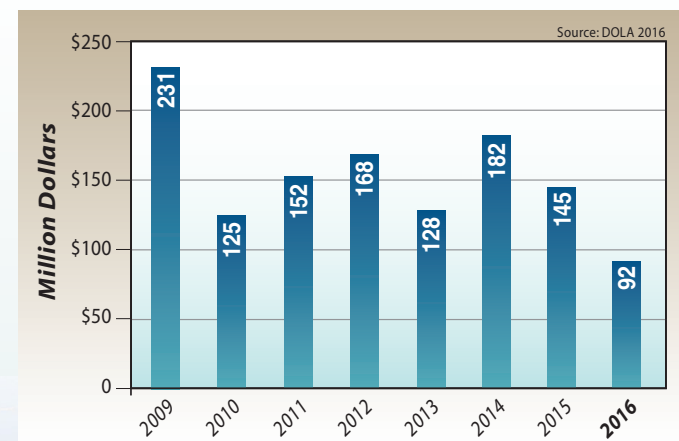
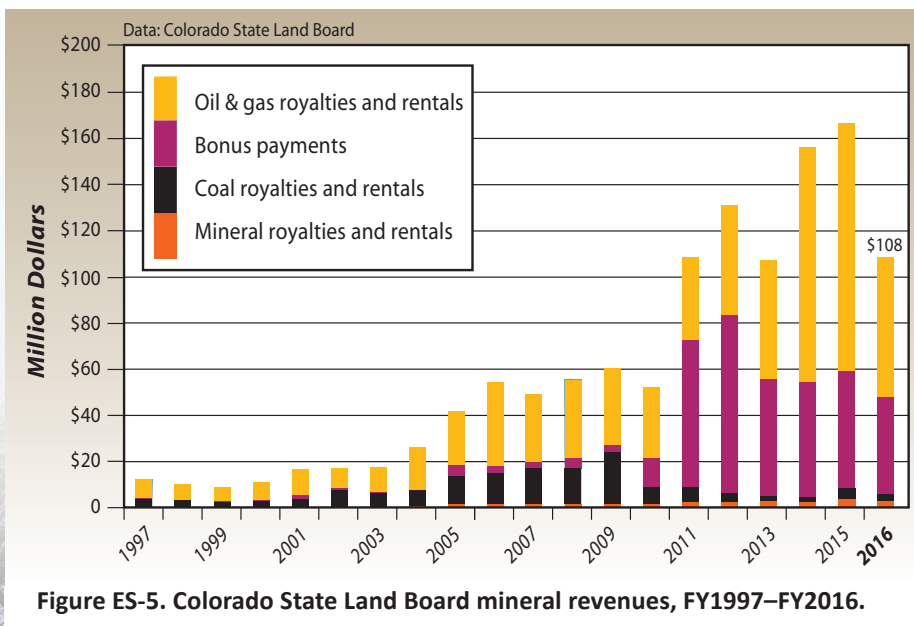
STATE LAND BOARD MINERAL REVENUE



Lands owned by the federal government constitute over 35% of Colorado's acreage. The State of Colorado receives 49% of the rental, royalty, and bonus revenue from mineral and energy fuel leases on federal land. The DOLA distributes a portion of these funds to local governments affected by mineral and energy development. In FY 2016, mineral lease revenues totaled approximately \$92.1 million, a decline of 36.6% from the \$145.3 million received in FY 2015. **Figure ES-6** shows the revenue from federal mineral leases from 2009 to 2016.

are then able to reduce severance taxes by a larger amount. This results in lower severance tax collections from lower production as well as the larger impact of the ad valorem credit.

Severance tax revenue has also been negatively impacted by an increase in amended returns filed in response to a 2016 Colorado Supreme Court ruling. Following the (BP America v. Colorado Department of Revenue) ruling, taxpayers can claim additional severance tax deductions related to certain costs incurred in their oil and gas extraction activities. In addition to lowering future severance tax collections, this decision also increased the refunds being made to severance taxpayers for past tax years.



CONVENTIONAL ENERGY RESOURCES: OIL AND GAS

1.0 SUMMARY

After a period of steady growth between 2010 and 2014, the production value of Colorado oil and natural gas declined in 2015 and again in 2016. The combined value of Colorado oil and natural gas production declined 7.6% from an estimated \$9.56 billion in 2015 to an estimated \$8.84 billion in 2016. The 2015 oil and natural gas production value estimate had declined 38% from an estimated all-time high of \$15.3 billion in 2014. Oil production declined slightly in 2016 and natural gas production increased slightly in 2016. Average market prices declined for both oil and natural gas in 2016.

In 2016, declining prices spurred some companies to sell assets or layoff staff while others continued drilling especially in the Denver-Julesburg (DJ) Basin. Examples include:

- Encana Corp. (Encana), a major producer with headquarters in Denver, cut an additional 20% of its staff in 2016 and sold its northern Colorado operations in the DJ Basin to newly formed Crestone Peak Resources. In 2017, Caerus Oil and Gas LLC (Caerus), a Denver company, finalized its purchase of Encana's natural gas assets in the Piceance Basin.
- Marathon Oil also announced plans to sell its natural gas assets in the Piceance Basin on Colorado's Western Slope.
- WPX Energy sold its Piceance Basin assets to Terra Energy Partners LLC (Terra Energy).
- Noble Energy focused their 2016 drilling and development efforts in the DJ Basin. At the end of 2016, Noble Energy's sales volume from the DJ Basin accounted for approximately 28% of their total consolidated sales volume and 29% of total proven reserves.
- Anadarko continued drilling operations in the DJ Basin focusing on horizontal development and ended 2016 with five operating drill rigs.
- PDC Energy, Inc. (PDC), increased their total proved reserves in the Wattenberg field in Weld County by 13% which represents 89% of their total reserves. PDC's 2016 production from the Wattenberg field increased by 47%, compared to their 2015 volumes, and accounted for 95% of their total 2016 production.
- At the end of 2016, Bill Barrett Corporation reported that they were drilling one well and were waiting to complete seven wells within the DJ Basin.
- At the end of 2016, the Whiting Petroleum Corp. had one drilling rig in the DJ Basin after suspending completion operations earlier in the year.

Most of the drilling activity and production increases in the last few years are in unconventional reservoirs, especially in the DJ Basin of northeastern Colorado. The Late Cretaceous age Niobrara Formation is a prolific producer of "tight" (tight in oilfield parlance refers to rocks such as shale which have low porosity and permeability) shale oil and natural gas. The EIA estimated that about 48% of total U.S. crude oil production in 2016 was from tight oil formations. Hydraulic fracturing and horizontal drilling techniques has allowed these unconventional reservoirs to be produced at a relatively low cost. Exploration and development of the underlying Codell Sandstone has also increased in the northern DJ Basin. In addition, the Piceance Basin also experienced increased exploration activity and production. In the early part of 2017, the Denver Post reported that Laramie Energy, Terra Energy, Caerus, and Ursa Resources Group II LLC were all drilling and exploring in the Piceance Basin. The map in **Figure 1-1** shows the major sedimentary basins in Colorado and the location of recent oil and natural gas drilling permits.

Conventionally produced oil and natural gas production (e.g., vertical wells, permeable sandstone or carbonate reservoirs and wells that do not require hydraulic-fracture stimulation) continued its downward decline through 2014 and 2015. Some conventional oil fields such as the Rangely field in the northern Piceance Basin, benefitted from hydraulic fracturing and horizontal drilling in the Niobrara Formation.

1.1 OIL

Between 2000 and 2010, oil production in Colorado steadily increased from about 20 million barrels of oil (BO) to 33 million BO. Oil production increased at a faster rate between 2010 and 2013 and doubled by 2013 to 66 million BO. Oil production nearly doubled again in two years with 123 million BO produced in 2015. Estimated oil production in 2016 is 116 million BO a decrease of about 6% from 2015. Average annual oil prices declined sharply in 2015 (about 51% from 2014 prices) and declined about 7% in 2016 to \$37.81 per barrel (EIA Colorado Domestic Crude Oil First Purchase Price). The estimated overall oil production value in 2016 for Colorado was \$4.4 billion, a 12% decline from the estimated 2015 production value of \$5.0 billion (**Figure 1-2**). Oil production in Colorado and the average annual price per barrel is shown in **Figure 1-3**. As of 2015, Colorado ranked eighth among the top ten states with proven oil reserves of 1.413 billion BO (**Figure 1-4**).

Oil & Gas Well Drilling Permits in Colorado

Nov 2015 - Dec 2016

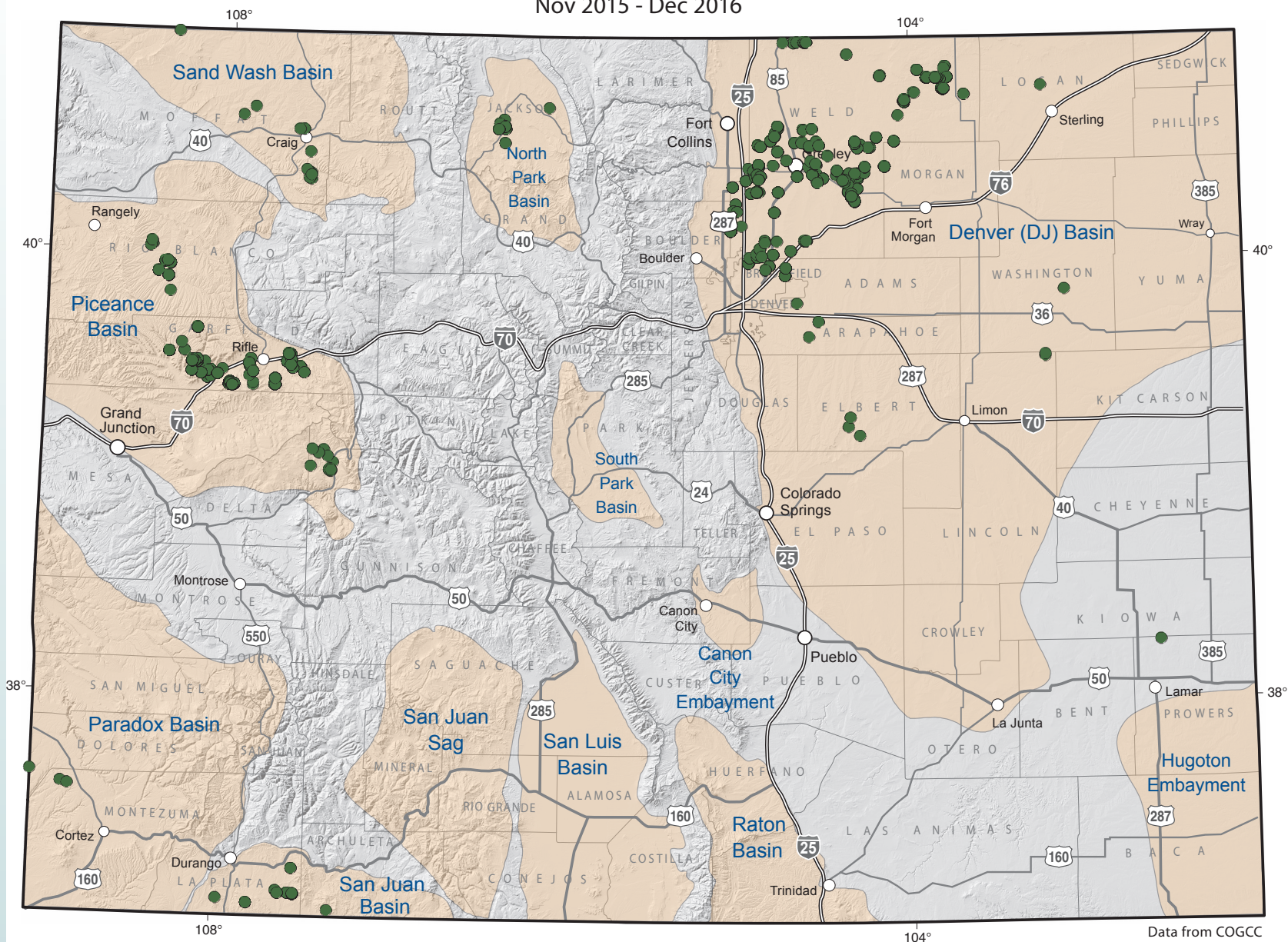


Figure 1-1. Map showing Colorado's sedimentary basins and the location of oil and gas well drilling permits from November 2015 to December 2016.

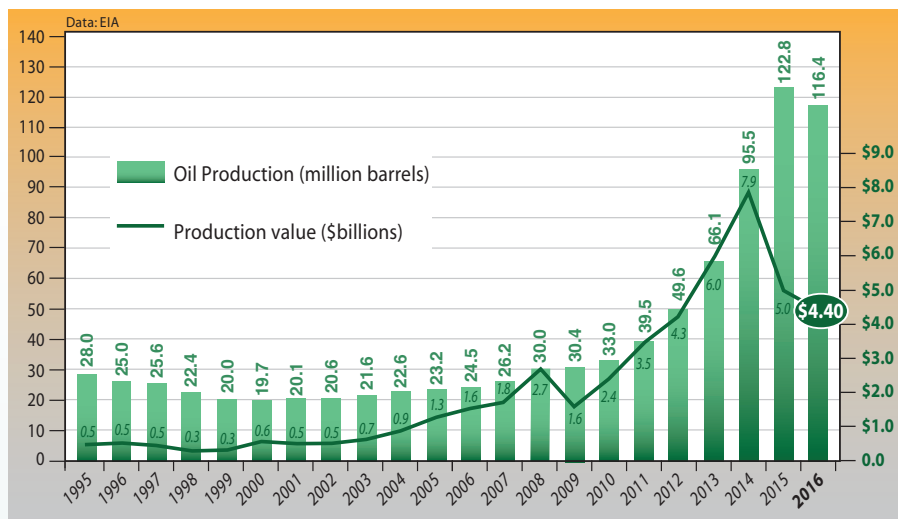


Figure 1-2. Oil production and production value in Colorado, 1995–2016.

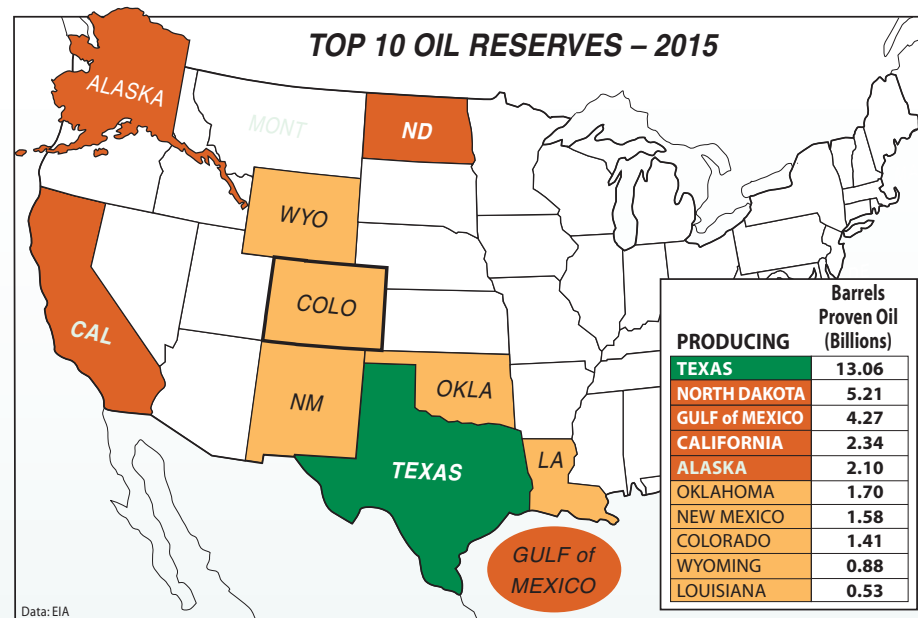


Figure 1-4. Top 10 states with proven oil reserves in 2015.

1.2 NATURAL GAS

Natural gas production in Colorado gradually increased annually from 647 billion cubic feet (Bcf) in 1997 to a high of 1,724 Bcf in 2012 and has ranged between 1,628 and 1,696 Bcf since 2013. Natural gas production in 2016 was 1,696 Bcf, a slight increase above the 2015 production of 1,689 Bcf. Henry Hub natural gas prices declined from just over \$9 per thousand cubic feet (Mcf) in 2008 to just over \$4 per Mcf in 2009. Between 2010 and 2015, these prices have ranged from \$2.72 and \$4.51 per Mcf. The 2016 average spot price was \$2.61 per Mcf (based on a heat content of 1.037 British Thermal Units per Mcf), a 4% decrease from the 2015 price of \$2.72 per Mcf (Figure 1-5). The estimated total 2016 natural gas production value in Colorado is \$4.43 billion, a decline of 3.5% from the 2015 value of \$4.59 billion. In 2015, Colorado had proven natural gas resources of 18,274 Bcf, which was the sixth largest in the U.S. (Figure 1-6).

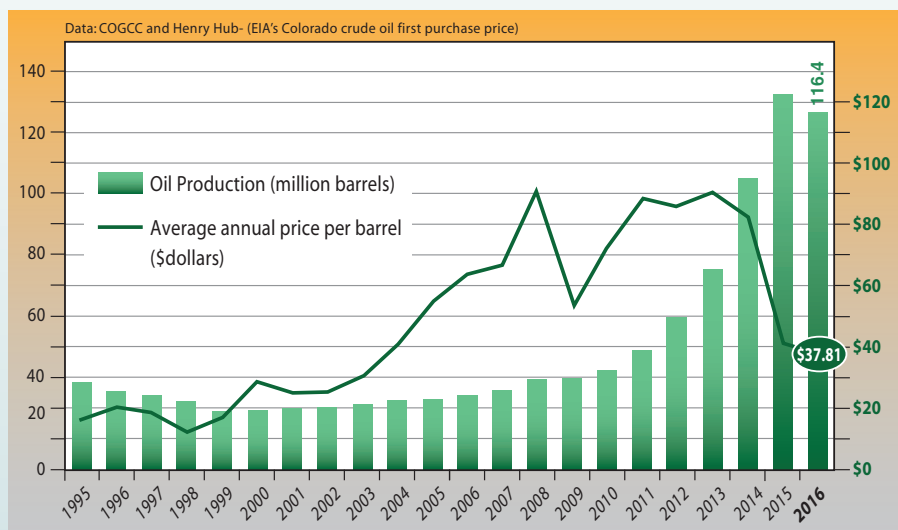


Figure 1-3. Colorado oil production and average annual price per barrel, 1995–2016.

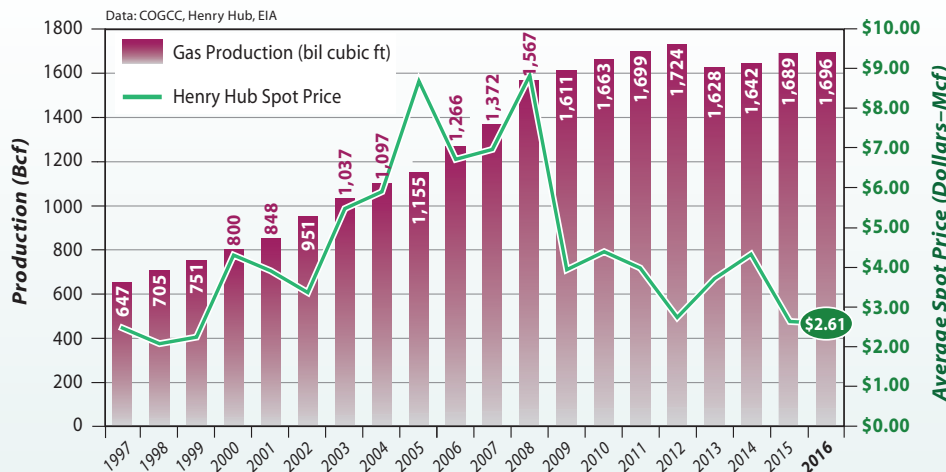


Figure 1-5. Colorado natural gas production and average spot price, 1997-2016.

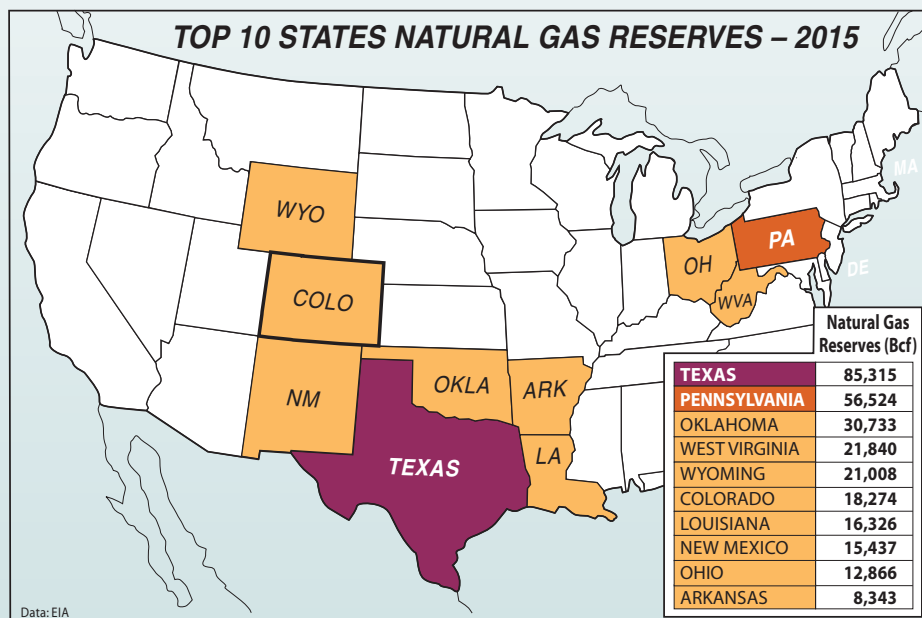


Figure 1-6. Top 10 states with proven natural gas reserves in 2015 (years end).

1.3 ASSESSMENT OF MANCOS SHALE OIL AND GAS POTENTIAL IN THE PICEANCE BASIN

In July 2016, the U.S. Geological Survey (USGS) released the results of a multiyear oil and gas assessment of the Mancos Shale in the Piceance Basin of

central and northwestern Colorado. The report states that the Piceance Basin contains undiscovered and technically recoverable resources of 66 Tcf (trillion cubic feet) of natural gas, 74 million BO, and 45 million barrels of natural gas liquids. These estimates were much higher than a previous assessment conducted in 2003. The resources are classified as continuous unconventional (tight) resources in the Mancos Shale (U.S. Geological Survey Fact Sheet 2016-3030). In 2017, the BLM proposed an oil and gas lease sale to tap into this potential resource and offered 28 parcels covering 27,281 acres. Approximately 81 percent of the acres were sold with an average bid of \$13.64 per acre.

1.4 COALBED METHANE

Coalbed methane production is a significant contributor to natural gas production in Colorado. However, production became stagnant in 2004 and started declining in 2012. **Figure 1-7** shows the annual coalbed methane production versus conventional natural gas from 1995 to 2016. Coalbed methane production reached its highest percentage of 59% of all natural gas production during 1998. The percentage share continuously declined to about 19% (314 Bcf) in 2016. This decline is largely due to the tremendous increase of production of unconventional reservoirs by the utilization of horizontal drilling and hydraulic fracturing techniques.

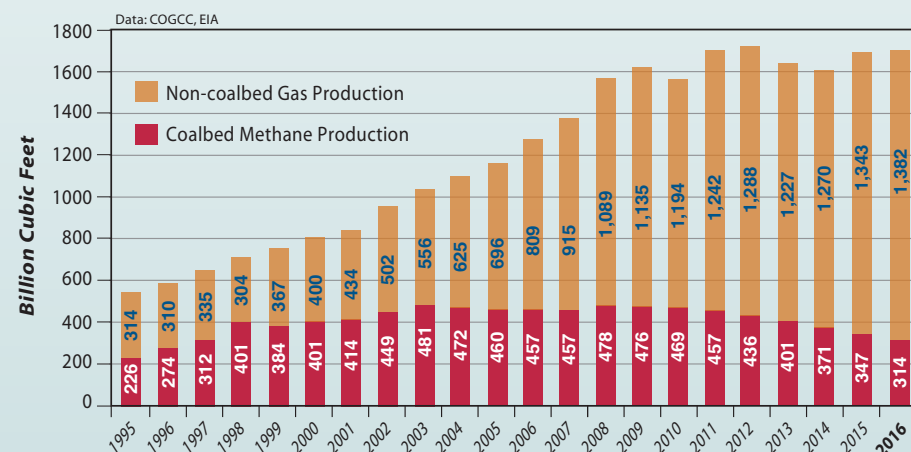


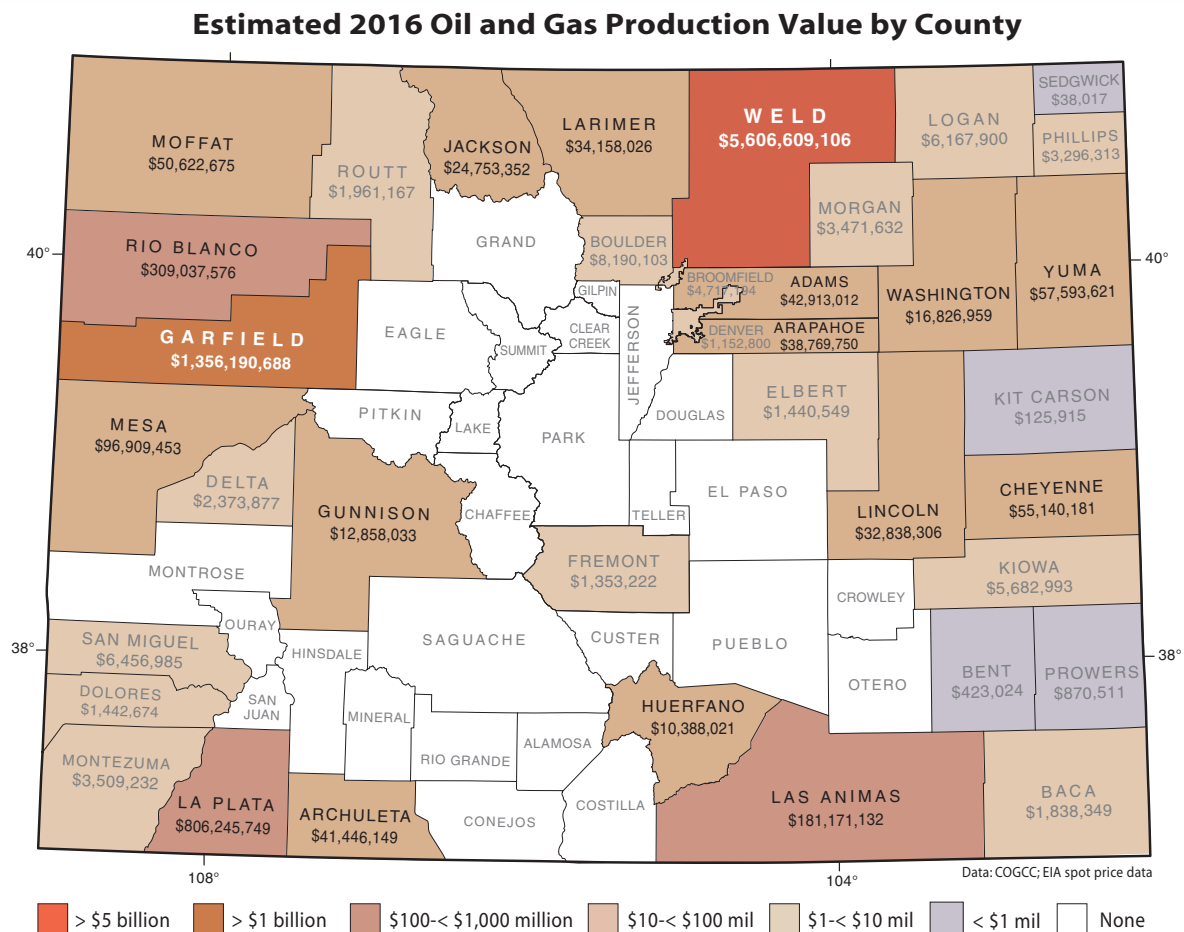
Figure 1-7. Coalbed methane vs. non-coalbed natural gas production in Colorado, 1995-2016.

1.5 COUNTY RANKINGS OIL AND NATURAL GAS PRODUCTION

Thirty seven of Colorado's 64 counties currently produce crude oil and/or natural gas. To rank each county's contribution to the state's total production value, production from each county was multiplied by average annual prices. We used the EIA's 2016 "Colorado First Purchase" price of \$37.81 per BO for the average annual price of oil and the average spot price for natural gas of \$2.61 per Mcf. **Figure 1-8** shows the estimated total oil and natural gas production value by county.

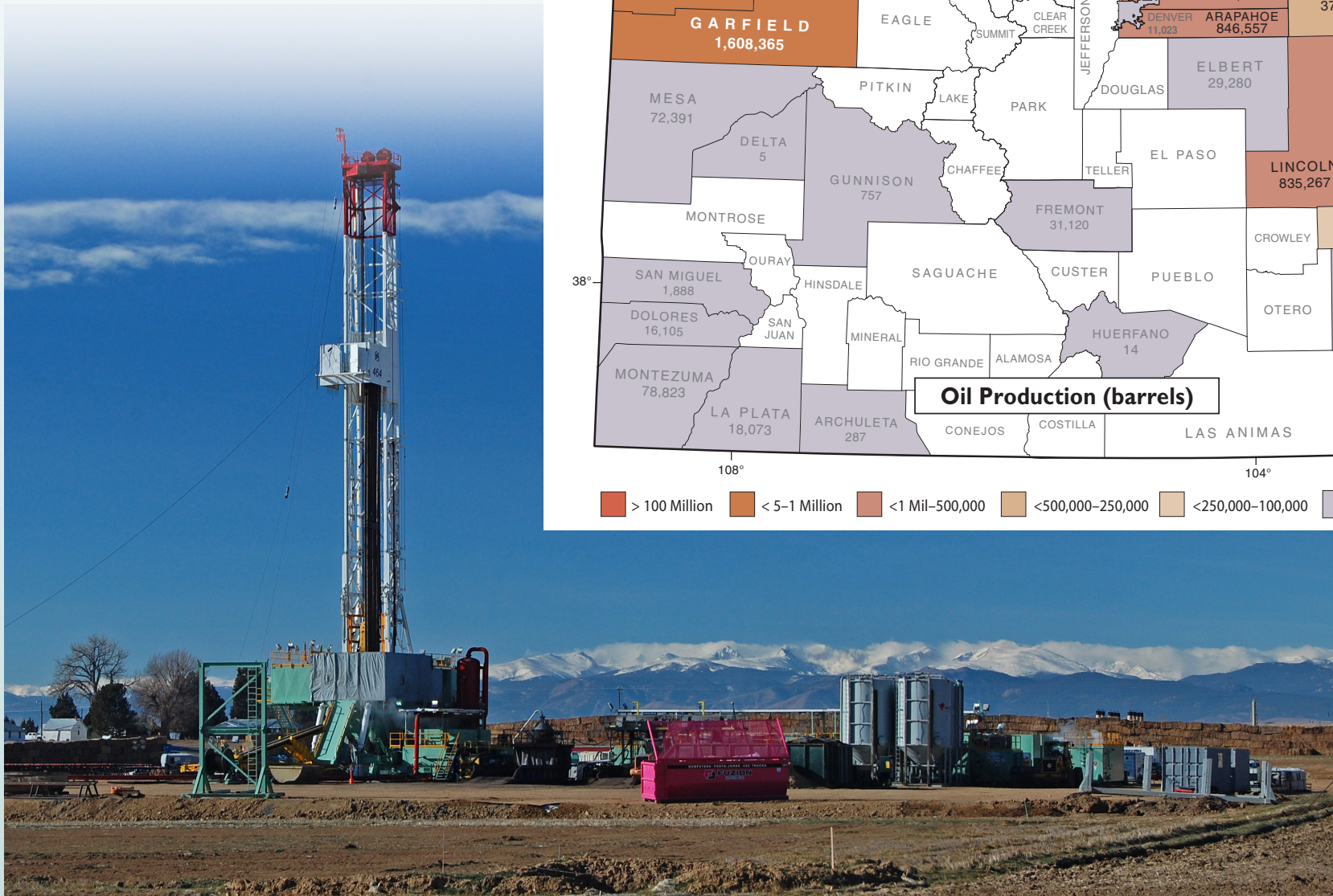
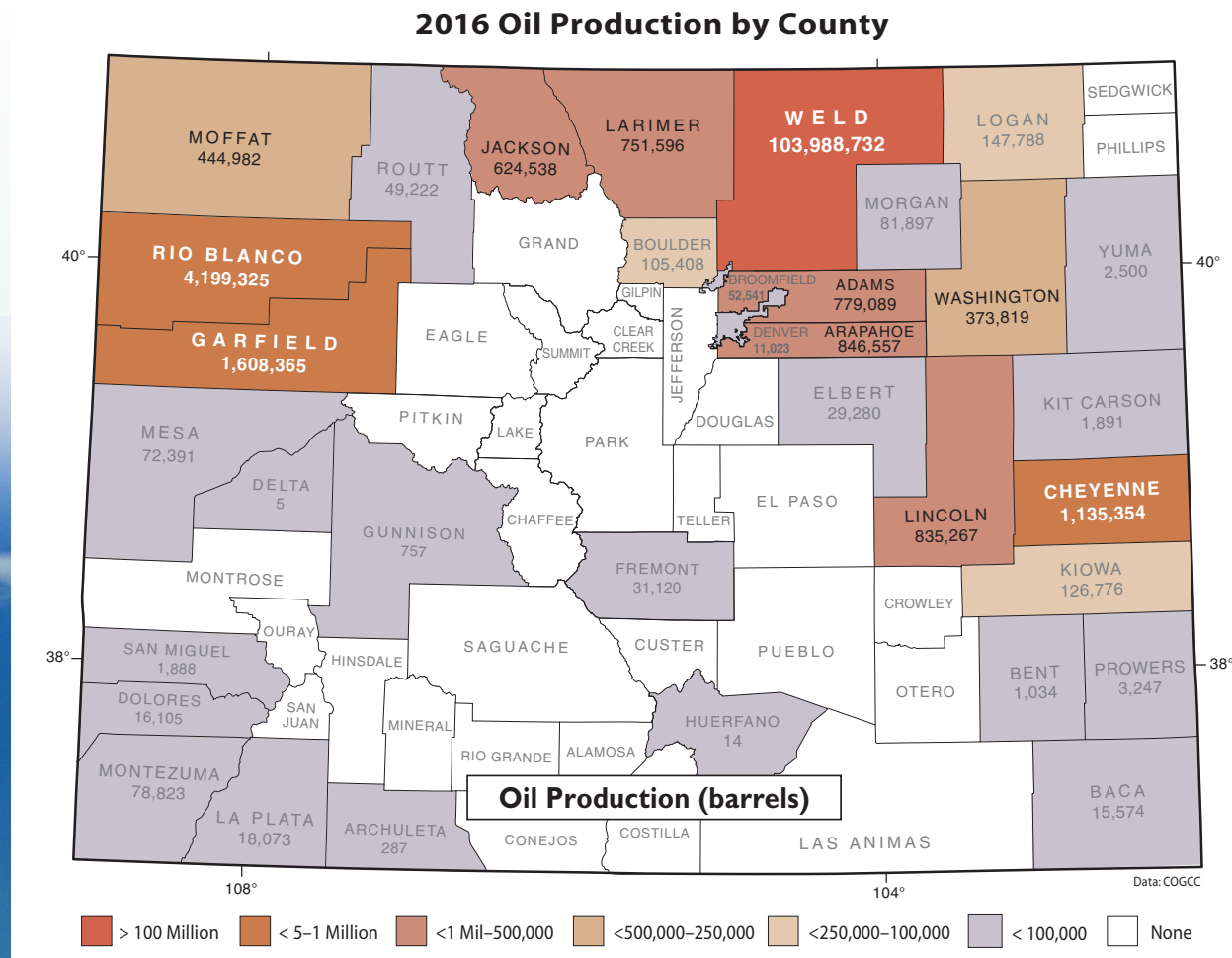
Weld County is the single largest producer of oil and natural gas in Colorado with an estimated total production value of about \$5.6 billion, an 8% decline from the 2015 estimate of \$6.1 billion. Garfield County is the second largest producer of natural gas with an estimated total oil and natural gas production value of \$1.4 billion, a 7% decline from the 2015 estimate of \$1.5 billion. La Plata, Rio Blanco, and Las Animas counties have a combined oil and natural gas production value of \$1.30 billion, a decline of 3% from the 2015 value of \$1.34 billion.

Figure 1-8. Estimated oil and natural gas production value by county in Colorado, 2016.

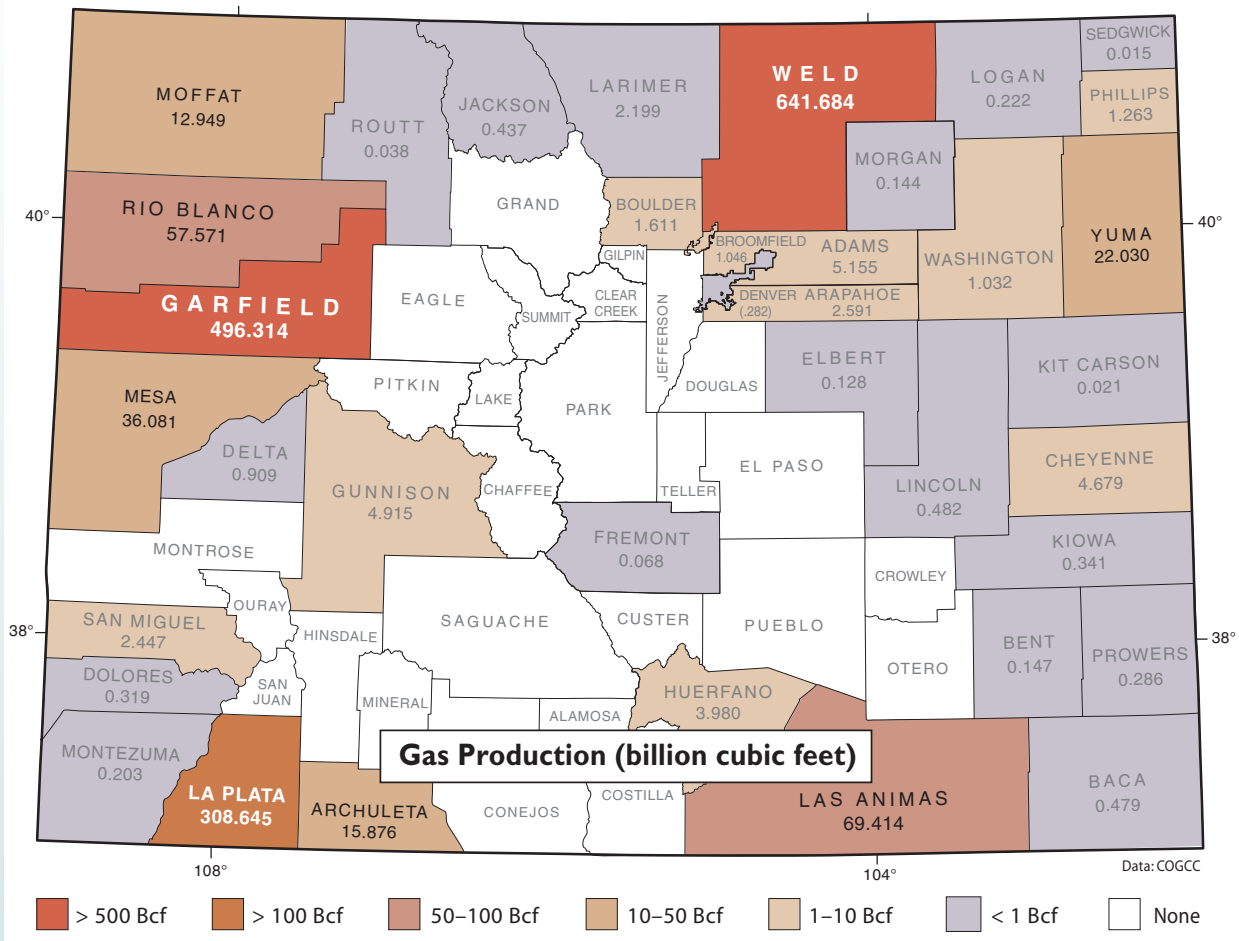


The total 2016 estimated oil and natural gas production value for Colorado is \$8.84 billion, an 8 percent decline from the 2015 estimated value of \$9.56 billion. **Figures 1-9** and **Figure 1-10** show the estimated oil and natural gas production by county for 2016, respectively.

Figure 1-9. Total oil production by county in Colorado, 2016.



2016 Natural Gas Production by County



1.6 DRILLING PERMITS

Most new oil and natural gas drilling permits are still centered in Weld County, with lesser amounts in the other oil and natural gas producing counties. COGCC data indicate 2,835 drilling permits were approved in 2016, a decline of 5% from the 2,987 permits approved in 2015. As of October 2017, 2,952 drilling permits were approved. **Figure 1-11** shows the number of annual oil and natural gas drilling permits in Colorado from 1994 to 2016.

Figure 1-10. Total natural gas production by county in Colorado, 2016.



Photo Paul Margan, CGS

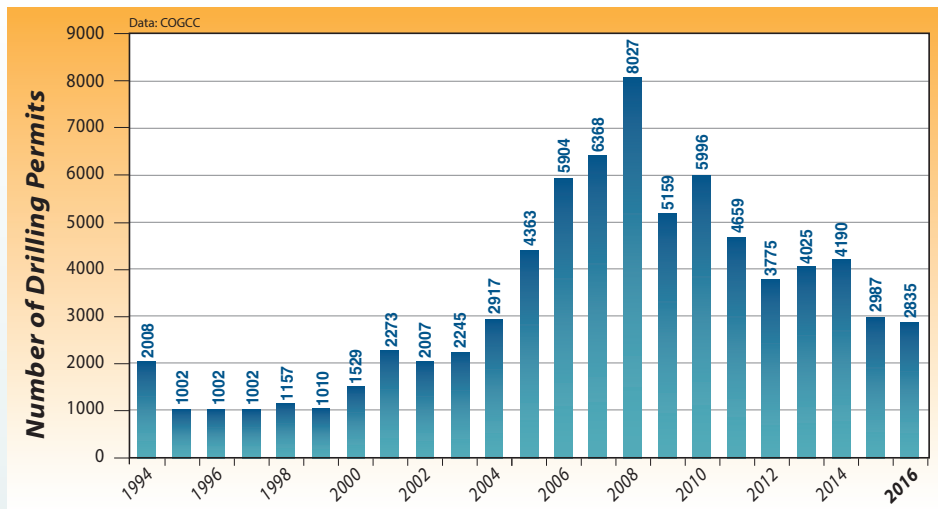


Figure 1-11. Annual oil and gas drilling permits in Colorado, 1994–2016.

1.7 OIL SHALE

More than half of the world's known oil shale resources are located in the Eocene age Green River Formation, which covers about 16,000 acres in the Green River Basin in Wyoming, the Piceance Basin in Colorado, and the Uinta Basin in Utah. Estimated resources are 4.3 trillion BO, which can be recovered from solid bituminous material called kerogen. The Piceance Basin in Colorado contains an estimated 1.525 trillion BO with an estimated 920 billion BO in place at an oil yield of 15 gallons per ton (gpt) or greater and 352 billion BO at an oil yield of 25 gpt or greater (U.S. Geological Survey Fact Sheet 2012-3145).

Oil shale is different from oil produced from shale reservoirs, which is currently being recovered mostly by unconventional drilling methods from the Cretaceous age Niobrara Formation in the DJ Basin of northeastern Colorado. Recovery of oil from oil shale is more difficult and expensive than oil from conventional or unconventional petroleum resources. In general, heat must be applied to the kerogen layers to release the oil allowing the product to flow.

The Colorado BLM office awarded seven Oil Shale Research, Development, and Demonstration Leases during the period from 2005 to 2009. The following companies were awarded leases: Shell Frontier Oil and Gas, Inc. (Shell), three leases; Chevron USA (Chevron), one lease; ExxonMobil Exploration Co. (ExxonMobil), one lease; America Shale Oil, LLC (American Shale Oil), one

lease; and Natural Soda Holdings, Inc. (Natural Soda), one lease. In 2012 and 2013, Shell and Chevron discontinued oil research on their leases. In March 2016, ExxonMobil discontinued their research program on their lease citing the current oil price as a factor in the decision. American Shale Oil discontinued their research program in 2016 after running short on funding and is currently working on decommissioning the project. Natural Soda is operating a sodium bicarbonate in-situ solution mine in the Piceance Basin. A sister company of Natural Soda, Simple Oil (both owned by Enirgi Group), plans to utilize their solution mining skills to develop a process to solution mine the oil shale beds.

For more than a century, projects have been developed to mine these oil shale deposits; however, none of these projects has been economically successful. The current low price for oil and other economic factors continue to slow development of these resources. As a result of a new Colorado tax credit program, and the Rural Jump-Start Tax Credit Program, two companies have been developing methods to extract hydrocarbon resources from oil shale. General Syn-fuels International is working on an insitu process using heat to remove oil and gas from the oil shale. Reportedly, the company is working on a prototype to be completed in 2018. Qmast LLC, also part of the credit program, is also working on removing hydrocarbons from shale, tar sands, tight shales, and conventional oil and gas reservoirs using a 500 kilowatt prototype microwave system.



Oil Shale deposits visible in bands at top of Roan Plateau cliffs, Garfield County.

CONVENTIONAL ENERGY RESOURCES: COAL

2.0 COAL

Colorado coal continues to be a major source of the state's electrical power. In 2016, according to the EIA, 55% of the electricity generated in Colorado came from coal, 23% from natural gas, 17% from wind, 3% from hydroelectric, 1% from solar, and 1% from other sources. In 2015, 60% of the electricity generated in Colorado came from coal and 22% from natural gas indicating a move away from energy production from coal. Almost half of coal produced in Colorado is sold out of state. As reported last year, the decline of the use of coal for electricity generation is due to greenhouse gas regulations and taxes designed to cut carbon dioxide emissions, lower natural gas prices, and the declining costs and growing use of renewable energy sources. Across the U.S., a record number of coal-fired power plants have been converted to less expensive and cleaner burning natural gas. Twenty-seven coal-fired plants totalling 22 gigawatts of capacity were scheduled for early closure or conversion in 2017.

In 2010, Colorado passed the Clean Air, Clean Jobs Act which promotes the replacement of Front Range coal-fired power plants with natural gas plants. Since then, the Arapahoe Station in Denver, the Clark Plant in Cañon City, and the Cameo power plant near Grand Junction were all shut down between 2012 and 2013. Xcel Energy converted the last remaining coal-fired unit at the Cherokee Generating Station in Denver to natural gas in 2017. The Valmont power plant east of Boulder announced that the company stopped burning coal in March 2016 and continues to use gas-fired electrical generation. Also, in 2017, Xcel Energy announced an agreement to retire two of its three coal-burning units at the Comanche Generation Station in Pueblo.

Coal production from Colorado mines in 2016 is 12.81 million tons, a decline of 32% from the 2015 value of 18.73 million tons. The value of Colorado coal production in 2016 was \$499 million, down 26% from the 2015 value of \$676 million (**Table 2-1 and Figure 2-1**). The estimated average value of a ton of Colorado coal was \$38.98 in 2016. Colorado coal production and average prices since 2004 are shown in **Figure 2-2**. Employment in the Colorado coal mining industry in 2016 was 1,086, an 18% decline from the 2015 count of 1,326 (**Figure 2-3**).

The two most important physical and chemical characteristics of coal used in power plants are its heat content and its chemical quality. Coal in Colorado that is mined today ranges in heat content from subbituminous to bituminous. Subbituminous coal has a heat value of 8,500 to 13,000 British thermal units per pound (Btu/lb.) and bituminous coal has a heat value of 11,000 to 15,000 Btu/lb. (Indiana Center for Coal Technology Research). Colorado, along with other western states, has high quality coal including:

- Average ash content of Colorado coal ranges from 6.4 % in the South Park region to 12.7% in the San Juan region.
- Average sulfur content varies from 0.3% in the Denver region to 0.8% in the Cañon City and San Juan regions.
- Average mercury content varies from 0.02 parts per million (ppm) in the Green River and Uinta regions to 0.185 ppm in the Cañon City region (**Table 2-2**).

A comparison of regional coal qualities is included in **Table 2-3**. Eight Colorado coal mines were active in 2016, the same as 2015. However, the Bowie #2 only produced coal for two months and went to idle status for the rest of the year beginning in March 2016 as a result of continued market declines (**Table 2-4**). At the end of 2016, only seven Colorado mines were active.

Table 2-1. Coal production, price, value, and employment, 2001–2016

Year	Production Tons (Millions)	Colorado Average Annual Coal Price \$/Ton	Product Value (Millions)	Coal Miner Employment
2001	33.41	\$17.20	\$575	1,761
2002	35.20	\$17.72	\$624	1,854
2003	35.88	\$18.21	\$653	1,859
2004	39.81	\$18.10	\$721	1,903
2005	37.82	\$21.63	\$818	1,963
2006	35.49	\$24.27	\$861	2,065
2007	36.14	\$25.99	\$939	2,069
2008	32.34	\$32.67	\$1056	2,124
2009	28.58	\$36.71	\$1049	2,247
2010	25.21	\$40.00	\$1008	2,061
2011	27.03	\$39.88	\$1078	2,254
2012	28.04	\$37.54	\$1,075	2,279
2013	24.27	\$37.58	\$912	1,857
2014	22.98	\$38.64	\$888	1,512
2015	18.73	\$36.12	\$676	1,326
2016	12.80	\$38.98	\$499	1,086

Source: DOLA, EIA, DRMS

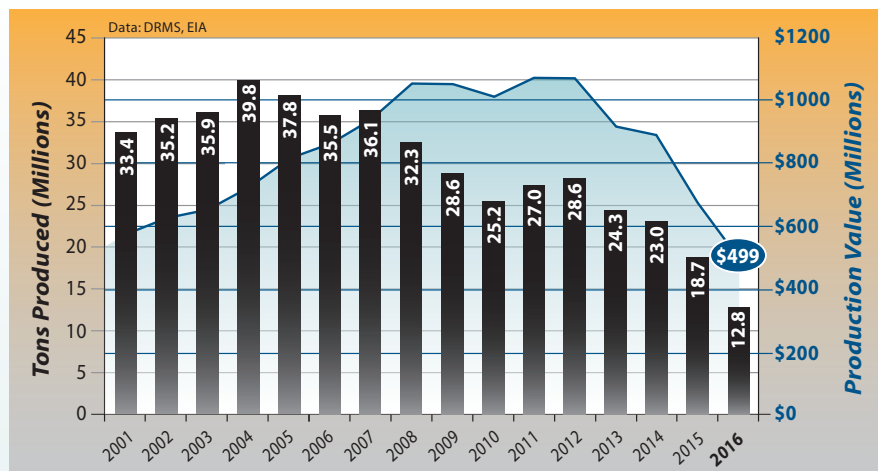


Figure 2-1. Production and value of coal mined in Colorado, 2001–2016.

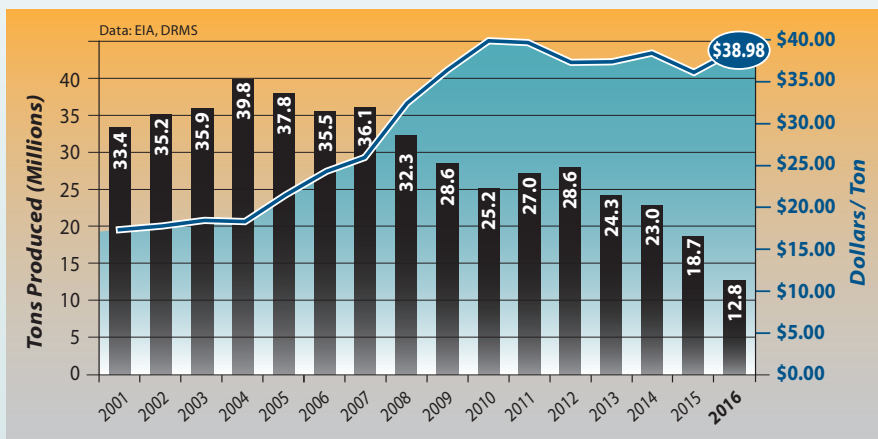


Figure 2-2. Coal production and average yearly coal price in Colorado, 2001–2016.

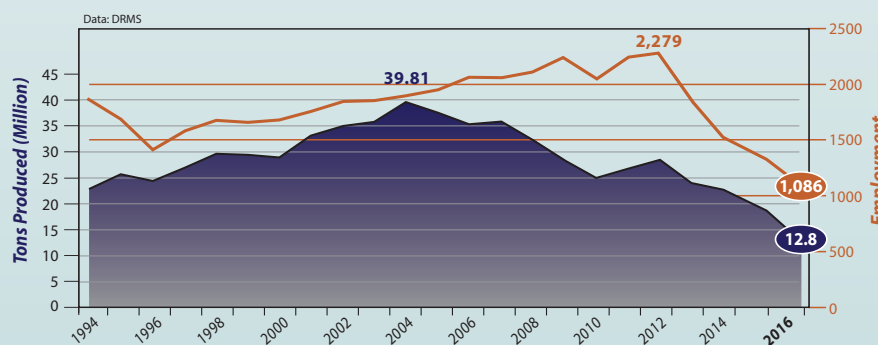


Figure 2-3. Coal production and employment in Colorado, 1994–2016.

Table 2-2. Colorado average coal quality for mineable coal beds by coal region.

Analyses	Denver Region	Green River Region	North Park Region	Raton Mesa Region	San Juan Region	Uinta Region	South Park Region	Canon City Region
Ash %	11.2	9	12.4	16.1	12.7	6.8	6.4	9.8
Sulfur %	0.3	0.6	0.5	0.7	0.8	0.6	0.5	0.8
BTU (per lb.)	9,072	10,973	9,483	12,541	12,758	11,879	9,780	11,130
Mercury (ppm)	---	<0.02	---	0.035	0.03	0.02	---	0.185

Mercury values are from the U.S. Geological Survey National Coal Quality Inventory at active mines in 2001 (Colorado Geological Survey Information Series 58).

Table 2-3. Colorado average coal quality and average coal quality in other U.S. coal producing regions.

Analyses	Colorado Average (from Table 2)	Central Appalachian Region	Illinois Basin
Ash %	10.55	7.24	11.10
Sulfur %	0.60	1.05	3.0
Btu (per lb.)	10,952	13,540	11,200
Mercury (ppm)	0.06	0.21	0.12

Arch Coal Inc. emerged from bankruptcy in 2016 and owns the West Elk coal mine in Gunnison County. Later in 2017, their proposed mine expansion plan was approved by the U.S. Forest Service (USFS) but is under public review. Also, the King II coal mine in La Plata County will run out of reserves in a few years and has requested an expansion of 950 acres to develop underground resources. Early in 2017, the Colowyo Mine in Moffat County received final approval for their Collom expansion which will add twenty years to the mine life.

In 2015, Colorado was ranked 11th in coal production in the U.S. (Figure 2-4). Wyoming, the leading U.S. producer by far, mined nearly 20 times as much coal as Colorado. The locations of Colorado's active coal mines, coal-fired power plants, and coal regions showing the types of contained coal are shown on Figure 2-5.

Table 2-4. Active coal mines in Colorado, 2016.

Mine	Operator	County	Mine Type	2016 Prod. (tons)
Bowie #2	Bowie Resources Ltd.	Delta	Underground	33,395
Colowyo	Colowyo Coal Co. L.P.	Moffat	Surface	1,851,611
Deserado	Blue Mountain Energy	Rio Blanco	Underground	1,540,801
Foidel Creek	Twentymile Coal Co./Peabody	Routt	Underground	2,594,392
King II	GCC Energy National King Coal LLC.	La Plata	Underground	628,953
New Horizon North	Western Fuels-CO LLC	Montrose	Surface	187,983
Trapper Strip	Trapper Mining Co.	Moffat	Surface	1,809,325
West Elk	Mountain Coal Co./Arch Coal	Gunnison	Underground	4,158,344
Total				12,804,804

Data: DRMS



New Horizon Mine in Montrose County. Photo from Elk Ridge Mining and Reclamation.

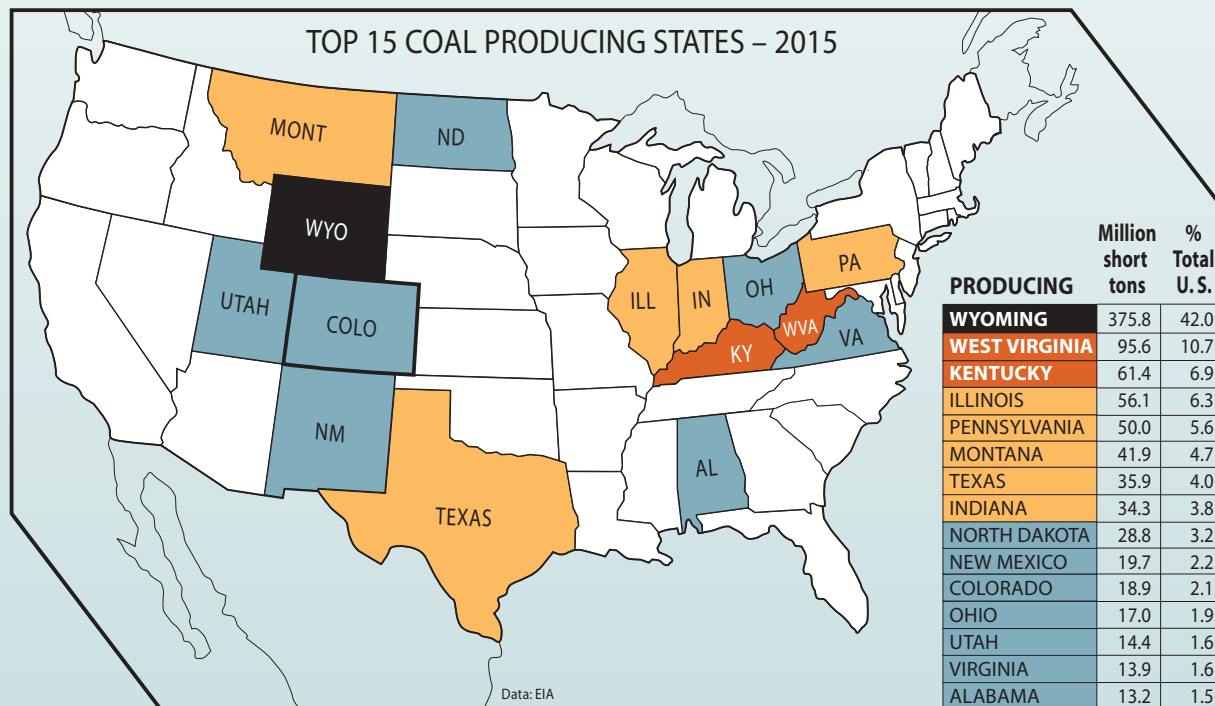


Figure 2-4. Top 15 coal-producing states in 2015.

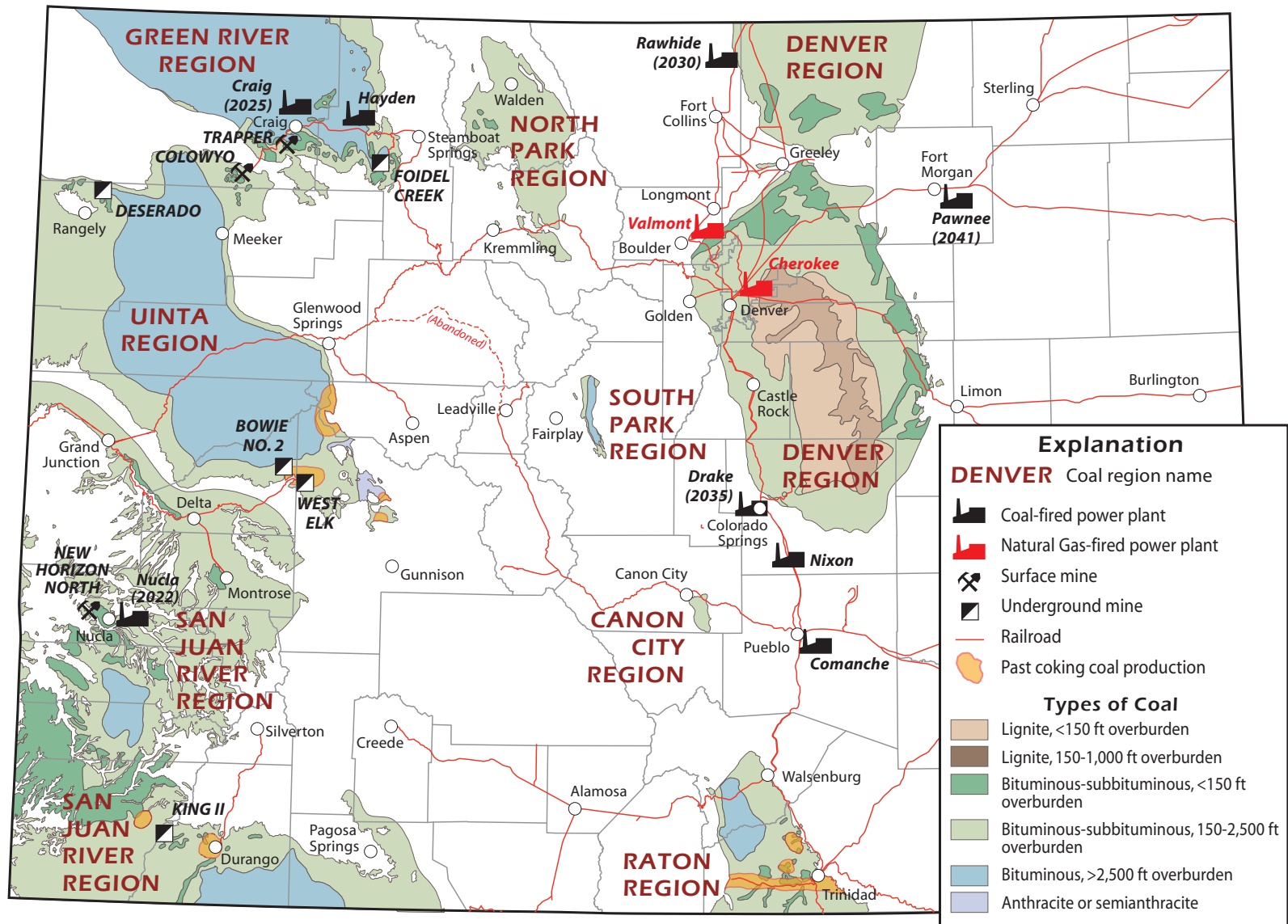


Figure 2-5. Locations of active coal mines, power plants, railroads, and coal-bearing regions in Colorado, 2016. Dates in parenthesis are estimated closure dates for given power plants.

CONVENTIONAL ENERGY RESOURCES: URANIUM

3.0 URANIUM

According to the Nuclear Energy Institute, nuclear energy accounted for 19.7% of U.S. electricity production in 2016. Nuclear energy has accounted for between 18 and 20% of U.S. electricity generation since 1990. The U.S. is the world's largest producer of nuclear power with 99 operating nuclear reactors that produced about 805 billion kilowatt hours (kWh) in 2016. Colorado is one of about twenty states that did not generate electricity from nuclear energy in 2016. About 78% of the electricity generated in Colorado during 2016 was from coal and natural gas.

Global nuclear generating capacity was about 391.6 gigawatts of electricity (GWe) in 2016, an increase from the 382.2 GWe in 2015. By the year 2035, annual consumption of nuclear-generated power is estimated to range from 399 GWe to 678 GWe (**Figure 3-1**), depending on several variables and scenarios. Considering the projections for increased nuclear power generation worldwide by 2035, there may be an increase in uranium demand without significant increases in exploration and development of uranium resources to meet the demand. Currently, most of the U.S. nuclear power is generated by reactors built between 1967 and 1990.

Figure 3-2 shows the average annual uranium prices since 2002. The average estimated price of triuranium octoxide (U_3O_8 - a popular form of uranium concentrate or yellowcake) in 2016 is \$25.86 per pound, a decrease of 30% from \$36.81 in 2015. Generally, prices have been trending downward since 2007 and after the 2011 Fukushima, Japan accident. The EIA estimated a total U.S. U_3O_8 concentrate production for 2016 of 2.9 million pounds, a decline of 12% from the 3.3 million pounds produced in 2015. A summary of U_3O_8 production in the U.S. since 1996 is included in **Figure 3-3**.

There are currently no producing uranium mines or mills in Colorado although it has been a producer in the past. Wyoming and Nebraska were the only states with producing in-situ leach operations in 2016. These mines produced the majority of uranium in the U.S. Utah has the only fully-licensed and operating conventional uranium mill in the U.S.

3.1 URANIUM EXPLORATION AND DEVELOPMENT IN COLORADO

According to the EIA, uranium exploration and development drilling activity for the U.S. decreased from 0.9 million feet in 2015 to 0.8 million feet of drilling in 2016. Estimated uranium exploration and development expenditures decreased from \$28.7 million in 2015 to \$22.3 million in 2016. Even though a number of mines and a mill are permitted in Colorado, there was little activity

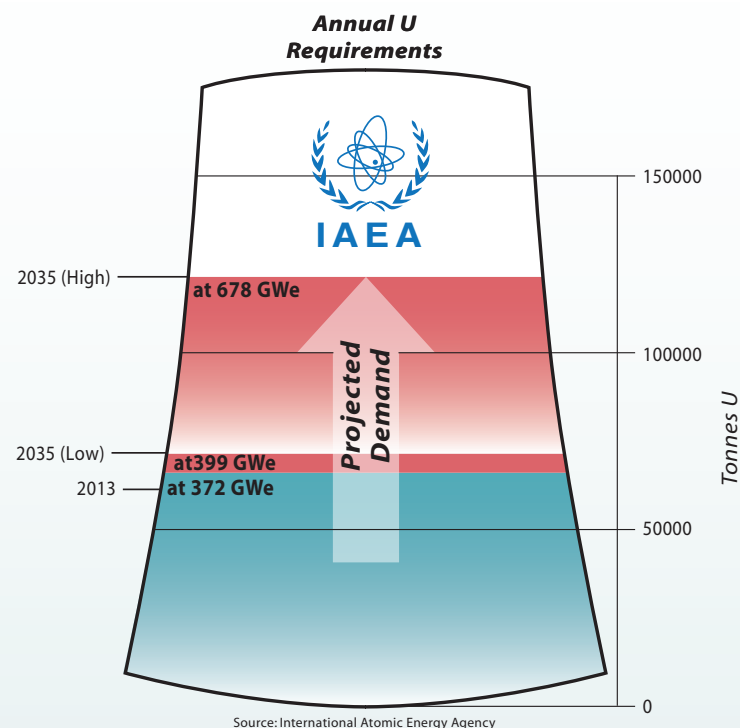


Figure 3-1. Projections of future world uranium requirements.

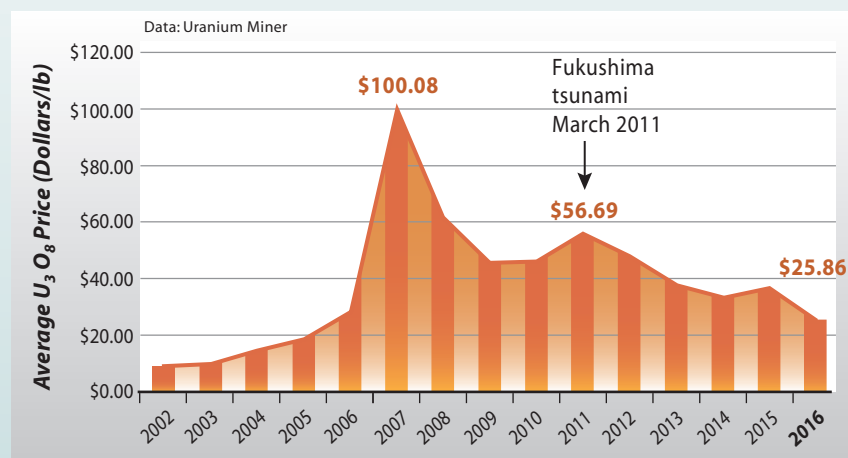


Figure 3-2. Average annual U_3O_8 price per pound, 2002–2016.

reported from these facilities. In 2017, Western Uranium Corp. (Western) announced their intent to purchase the Graysill Property from Pacific Gold & Royalty Corporation (Pacific). However, Western terminated the letter of intent late in 2017 due to potential issues with the permitting timeline and vanadium production. The Graysill Property is located in western Colorado where Pacific owns 24 unpatented mining claims that encompass the Graysill Mine in San Juan and Dolores Counties. The Graysill Mine was a past producer of vanadium and uranium. Western also continued to pilot test their ablation mining technology (AMT) and has signed a letter of intent with Pinon Ridge Corporation to use this technology at uranium recovery facilities at the Pinon Ridge mill site (proposed). Western proposes to use AMT at their Sunday Mining Complex in San Miguel County.

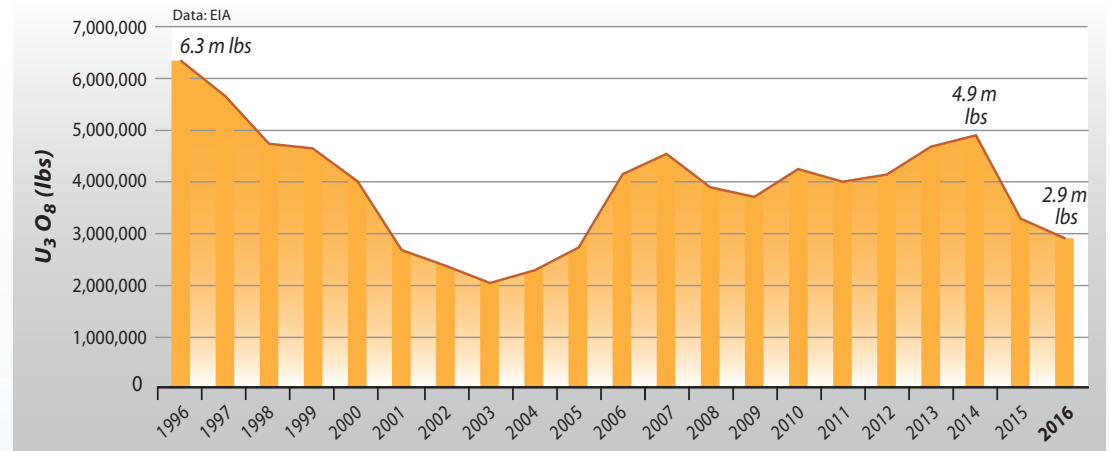


Figure 3-3. Annual production of uranium concentrate in U.S., 1996–2016.



Uranium ore loadout near Slick Rock in San Miguel County.

Photo: Mike O'Keeffe, CGS

NONFUEL MINERAL RESOURCES

4.0 NONFUEL MINERAL RESOURCES

Nonfuel mineral resources include metals, industrial minerals, and construction materials (e.g. cement, lime, sand, and gravel). The USGS estimates that the total U.S. 2016 nonfuel mineral production value was \$74.6 billion, a 1.6% increase from the revised 2015 total of \$73.4 billion. Colorado ranked 19th in U.S. production value for 2016 and produced \$1.51 billion, or about 2.02% of the estimated total production value. Although the past 2015 nonfuel mineral production value for Colorado was estimated at 2.41 billion by the USGS, this number will likely be revised to \$1.34 billion for 2015 as reported previously. Based on this revised number, the 2016 Colorado estimate is approximately 13% higher than the 2015 estimates. **Figure 4-1** shows the nonfuel mineral production value in Colorado since 1994.

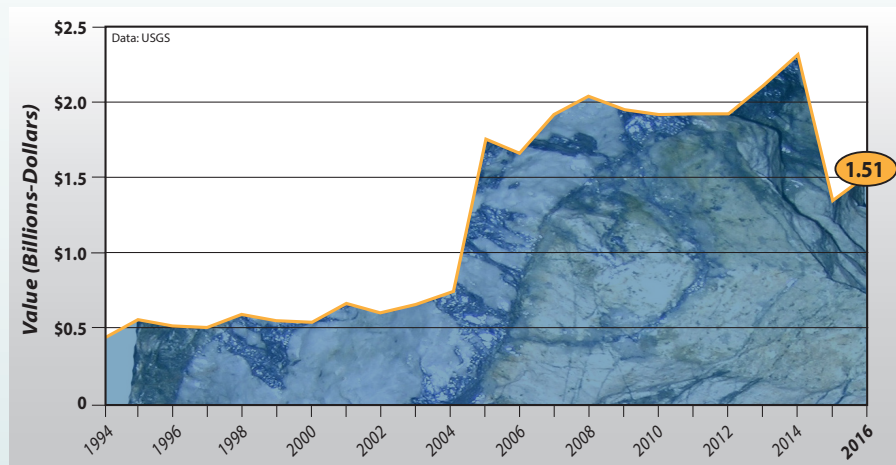


Figure 4-1. Total nonfuel mineral production value in Colorado, 1994–2016.

4.1 METAL MINING

Metals mined in Colorado include gold, molybdenum, and silver. The CGS estimates that the 2016 production value of these metals in Colorado was \$673 million. This is about a 22% increase compared to the 2015 production value of \$551 million. The increase in estimated value was due mainly to the increase in gold production in 2016.

4.1.1 MOLYBDENUM

According to the International Molybdenum Association, molybdenum is primarily used to produce engineering steels (e.g. superalloys, nickel alloys, and tool steels), stainless steel, molybdenum metal and other alloys, catalysts, pigments, corrosion inhibitors, smoke suppressants, lubricants, and chemicals in agriculture. According to the USGS, the U.S. is the third largest producer of molybdenum in the world and produced an estimated 70 million pounds in 2016, valued at an estimated \$458 million, based on average prices. This is approximately 33% lower than the 2015 estimated production of 105 million pounds. In 2016, about 76% of the molybdenum consumed in the U.S. was by producers of iron, steel, and superalloys. China is the top producer (estimated 198 million pounds in 2016) and Chile is the second largest producer (estimated 115 million pounds in 2016).

Colorado's annual production and average annual price per pound for molybdenum trioxide (MoO_3) are shown in **Figure 4-2**. Decreased production in Colorado was mainly due to lower molybdenum prices over the last two years. The average price of molybdenum was \$12.23 per pound in 2014 decreasing in 2015 to \$6.66 per pound in 2015, and decreasing to \$6.47 per pound in 2016. A majority of the 2016 primary molybdenum production in the U.S. was from two Colorado mines that produced approximately 26 million pounds combined. In the U.S., Colorado ranked second in molybdenum production following Arizona (**Figure 4-3**). In 2016, secondary production of molybdenum in Arizona, as a byproduct of copper mining, surpassed the production from Colorado. In Colorado, molybdenum is mined at the Climax and Henderson mines by Freeport-McMoRan Inc. (Freeport). Freeport estimates production from the two mines directly added about \$193.4 million to Colorado's economy in 2016 which included compensation, business taxes, and vendor purchases.

The Climax open-pit mine is located northeast of Leadville, at Fremont Pass, and includes a 25,000 metric ton per day mill with the ability to produce about 30 million pounds of molybdenum per year. The mine reopened in mid-2012 after being shut down for 17 years. Climax molybdenum production was approximately 21 million pounds in 2014, 23 million pounds in 2015, and 16 million pounds in 2016. At the end of 2016, proven reserves at the Climax mine were estimated at 161 million tons with an average ore grade of 0.16% molybdenum.

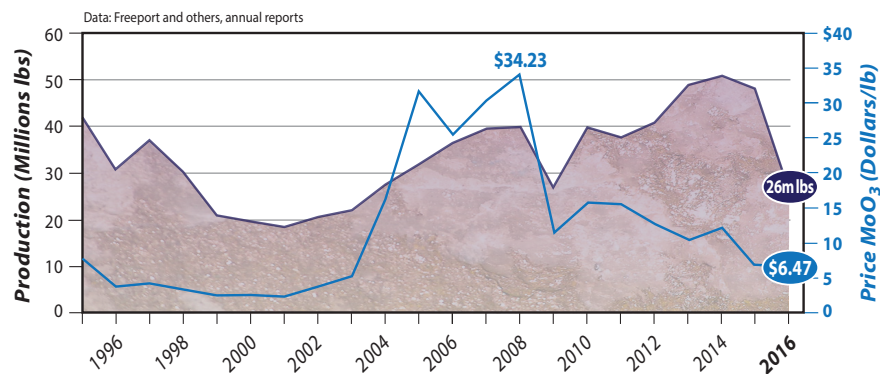


Figure 4-2. Colorado molybdenum production and average annual price per pound, 1995–2016.

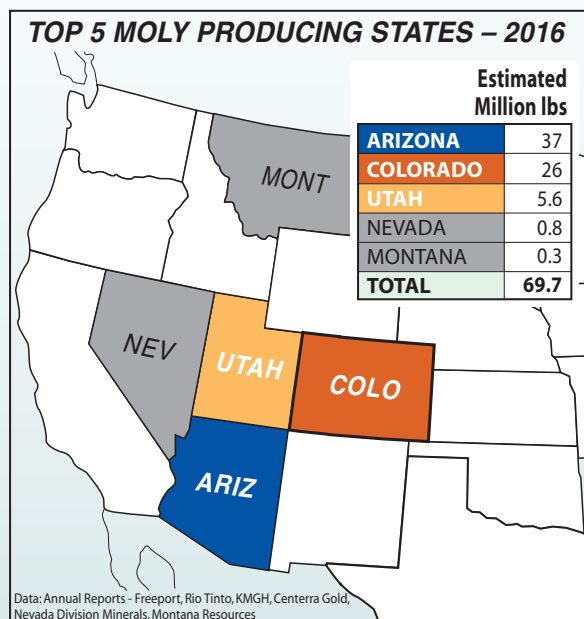


Figure 4-3. Top five molybdenum producing states, 2016.

The Henderson mine, located near Empire in Clear Creek County, has been in operation since 1976. This operation is a large block-cave underground mine connected to a 35,300 tons per day concentrator in adjoining Grand County by a 15-mile conveyor. Henderson has the ability to produce about 35 million pounds of molybdenum per year. Henderson molybdenum production was approximately 30 million pounds in 2014, 25 million pounds in 2015, and 10 million pounds in 2016. At the end of 2016, proven reserves at the Henderson mine were estimated at 69 million tons with an average ore grade of 0.18% molybdenum.

In early 2015, revised plans for the Henderson mine included a 65% reduction in operating rates potentially closing the mine in three to five years instead of the 10 years originally estimated. In August 2017, Freeport announced that the Henderson Mine is expected to remain in operation until 2026 likely due to increasing molybdenum prices in 2017. Reportedly, the mine accounted for 70% of all property taxes collected in Clear Creek County. However, as reported by the Denver Post, the tax agreement is based on a 10-year rolling average for molybdenum prices and therefore, tax payments to the county will continue to decline.

4.1.2 GOLD AND SILVER

In 2016, gold was primarily mined to be used in jewelry (40%), electrical and electronics (35%), coins (20%), and other (5%) uses which may include dentistry, medicine, and aerospace equipment (e.g. to reflect infrared radiation). According to the USGS, U.S. gold production decreased from 236 tons (6.9 million ounces) in 2015 to an estimated 230 tons (6.7 million ounces) in 2016 with an estimated value of \$8.5 billion. In 2016, the U.S. was the fourth largest producer of gold in the world following China (502 tons), Australia (298 tons), and Russia (276 tons). **Figure 4-4** shows the price of gold and Colorado gold production from 1990 to 2016. Colorado was the third top producer of gold (396,000 ounces) in the U.S. (**Figure 4-5**) following Nevada (about 5,470,000 ounces) and Alaska (about 916,087 ounces) in 2016. The average gold price in 2016 was \$1,270 per ounce.

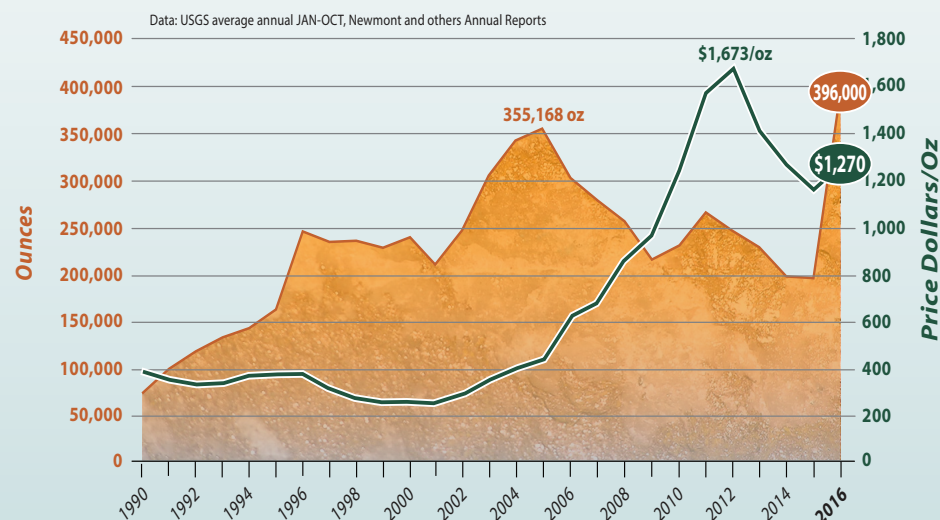


Figure 4-4. Colorado estimated gold production and average annual price per ounce, 1990–2016.

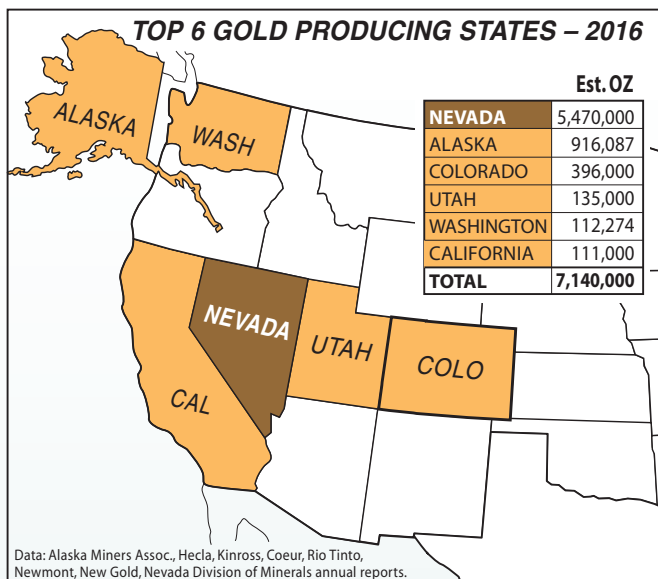


Figure 4-5. Top five gold producing states, 2016.

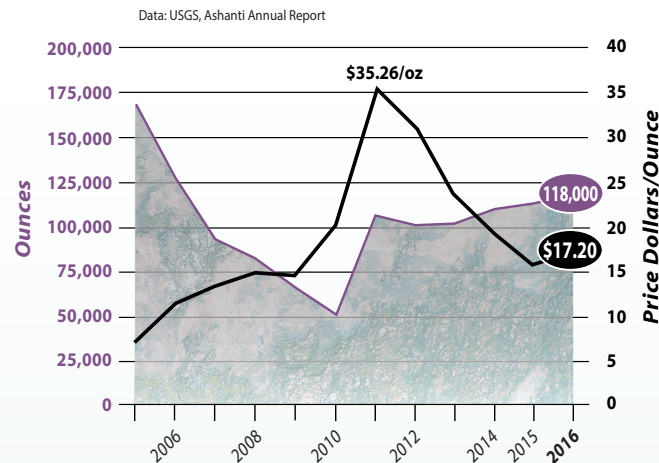


Figure 4-6. Colorado silver production and average annual price per ounce, 1990–2016.

Reportedly, global silver production declined in 2016 due to a decrease in by-product output from other mining sectors (e.g. lead-zinc and gold) (Northern Miner). The USGS estimated that the U.S. production of silver in 2016 was 1,213 tons (35.4 million ounces) with an estimated value of \$570 million. This was a slight increase from the estimated 2015 production of 1,202 tons (35 million ounces). The U.S. was ranked tenth in silver production in 2016. Mexico (estimated 6,173 tons), Peru (estimated 4,520 tons), and China (estimated 3,968 tons) ranked the highest in 2016 silver production. The 2016 uses of silver were estimated and include electrical/electronics (30%), coins/medals (27%), jewelry/silverware (7%), and photography (6%), and other applications (30%) which may include items such as antimicrobial bandages, clothing, pharmaceuticals, plastics, and batteries. **Figure 4-6** shows Colorado silver production, estimated in 2016, and the average annual price per ounce between 2005 and 2016. The average 2016 price of silver was \$17.20 per ounce.

In August of 2015, Newmont Mining Corporation (Newmont) acquired the Cripple Creek and Victor Gold Mining Company (CC&V), located near the town of Victor, CO. Newmont was the second largest producer of gold in the world in 2016. Their corporate headquarters is located in the Denver area. CC&V produced an estimated 396,000 ounces of gold in 2016, double the 197,645 ounces estimated in 2015. Silver production from CC&V was unavailable but was estimated at 118,800 ounces based on a ratio of historical gold and silver production at the mine reported by previous operators. CC&V estimated proven gold reserves at the end of 2016 were 72.5 million tons at a grade of 0.022 ounces per ton.

A smaller amount of placer gold is occasionally recovered from sand and gravel aggregate operations along some of Colorado's rivers and streams including the South Platte, Arkansas and Colorado Rivers, as well as Clear Creek. Additionally, a few small lode gold mines operated by private individuals or small groups likely produce, but do not report, small tonnages of high-grade gold and silver ore. There are currently 34 active mining permits with gold listed as the mined commodity in the DRMS database.

Lascaux Resource Capital, LLC is currently developing the Revenue-Virginus mine for potential start-up. Located in Ouray County near the town of Ouray, the Revenue-Virginus was one of the largest and most historic mines in the county. The mine opened in 1876 and by 1921 had produced gold and silver ore worth more than \$28 million. The mine produced little after the mill burned in the 1920s. The mine operation is run by Ouray Silver Mines LLC and would produce primarily silver while recovering other metals such as gold, lead, and zinc as by-products.

4.1.3 METAL EXPLORATION AND DEVELOPMENT ACTIVITIES

The precious metal exploration industry worldwide has been hurt by falling metals prices since 2012. This downward price trajectory continues to make it difficult for most companies to raise financing for exploration. SNL Metals & Mining reported that 2016 worldwide exploration budget estimates for nonferrous metals were down 21% from the total in 2015. The 2016 estimated global exploration budget for nonferrous metals was \$6.89 billion. Exploration and development projects in Colorado, as reported in the 2015-2016 CGS Mineral

and Energy Industry Activity report and updated here, that have undergone at least some recent activity are discussed below.

The Golden Wonder Mine is a high-grade telluride gold vein deposit located near Lake City. LKA International, Inc. (LKA), is currently establishing mine reserves at the property. After the first quarter of 2009, when LKA resumed exploration at the mine, 35 bulk ore samples that contained over 4,600 ounces of gold were sent for processing and had a net value of more than \$5 million. In mid-2015, LKA announced it had executed an agreement with Kinross Gold U.S.A. (Kinross) to expand mine exploration beyond the Golden Wonder active workings. An initial exploration report released in early-2016 indicated several potential targets that reportedly possess similar characteristics to targets at the surface above the previously mined area. In 2017, LKA reported that the final three holes of the initial drilling program were completed and the results were being evaluated. Later in 2017, Kinross reportedly terminated its exploration program.

The Dawson Project is located southwest of Canon City in Fremont County. Zephyr Minerals Ltd. (Zephyr) holds 100% interest in 45 unpatented claims and other interests in additional patented claims and one patented placer claim associated with this property. The Dawson Project includes five gold mineralized areas within a Precambrian-age granite and associated rocks. Zephyr completed a limited drilling program in 2016 and preliminary process plant design, preliminary tailings dam design, and additional gold targeting/modeling are currently underway. According to their website, in 2017, Zephyr reported assay results from trenching at two of the mineralized areas as well as the results from a preliminary economic assessment at one of the mineralized areas (the Dawson Segment). Reportedly, the Dawson Segment could provide 450,000 tons of mill feed at an average grade of 0.27 ounces per ton.

The San Juan Silver Project is located in the Creede mining district in Mineral County. Rio Grande Silver, Inc., a wholly owned subsidiary of Hecla Mining Company (Hecla), owns the San Juan Silver project which includes the Bulldog Mine and Equity/Amethyst vein systems. A December 2016 Hecla resource update reported that the San Juan Silver Project contained an indicated resource of about 7.6 million ounces of silver and an inferred resource of about 33 million ounces of silver. Future plans are focused on permitting associated with water discharge and an amendment to the operation plan for surface exploration drilling.

The Silver Cliff Property is located in the Hardscrabble Silver District, a historic silver-lead-zinc mining district, near Silver Cliff in Custer County. Viscount Mining Corp. (Viscount) began exploration at the property in 2016 for silver, which included geophysical surveying, detailed mapping, and drilling. In 2017, Viscount provided a summary of assay results from select samples that included relatively shallow intercepts. Results showed 57.2 ounces of silver per ton over a 20-foot interval within a 50-foot mineralized section averaging 26.9 ounces per ton. Viscount reported that their 2016 drilling shows silver mineralization is predominantly hosted in an altered tuff associated with the Silver Cliff caldera.

Colorado Potash Project Red Metal Limited (Red Metal) continues to review the economic potential of their Colorado Potash Project located in the Paradox Basin north of Dove Creek. Their principal exploration target covers a total of 166 square kilometers in the basin along the axis of the Dolores Anticline. Oil well logs indicate that potash beds, probably sylvite, reach a cumulative thickness between 49 and 98 feet.

Vanadium in Colorado is generally associated with the sandstone-hosted uranium deposits located in western Colorado, specifically on the Colorado Plateau. Because of low uranium and vanadium prices, there are currently no mines in production. The last vanadium production reported was in 2005. If Colorado uranium mining resumes in the future, vanadium would likely be produced as a by-product.

INDUSTRIAL MINERALS and CONSTRUCTION MATERIALS

4.2. AGGREGATE - SAND, GRAVEL, AND CRUSHED STONE

The primary uses of sand and gravel are concrete aggregates, road base, road coverings/stabilization, construction fill, asphaltic concrete and other bituminous mixtures, construction fill, asphaltic concrete, and concrete products. Other uses include plaster and gunite sands, snow and ice control, filtration, railroad ballast, and roofing granules. Crushed stone is primarily used for construction material especially in road construction/maintenance and cement manufacturing. For 2016, the DRMS lists over 1,000 active permits for sand, gravel, aggregate, and aggregate-related quarries in Colorado; most of these (over 80%) are alluvial sand and gravel quarries. Aggregate mining operations vary in size from small “mom and pop” operations on three acres to large quarries over 500 acres in size.

The USGS estimates that Colorado quarry operators produced 51.6 million tons of aggregate (sand, gravel, and crushed stone) in 2016, a slight decrease of 8% from the 2015 production value of 56.2 million tons (**Figure 4-7**). The estimated USGS production and prices for sand, gravel, and crushed rock are summarized below.

- Sand and gravel production in 2016 totaled 36.7 million tons, a decrease of 12.6% from the 42 million tons produced in 2015. The average price during 2016 for sand and gravel aggregate was \$6.92 per ton, a decrease of 8.0 % from the 2015 value of \$7.52 per ton (**Figure 4-8**). The estimated total value of the 2016 sand and gravel production was \$254 million, a decline of 20% from the \$316 million value in 2015.

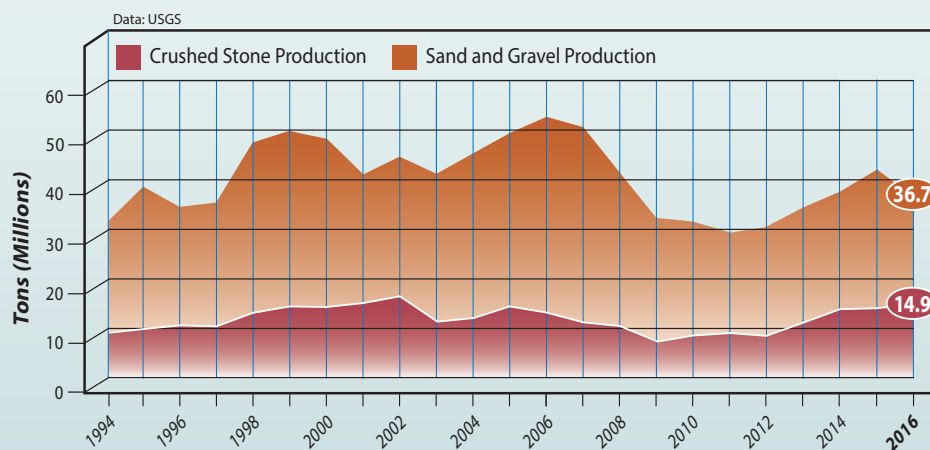


Figure 4-7. Aggregate production in Colorado, 1994–2016.

- Crushed stone production in 2016 was 14.9 million tons, an increase of 5% from the 14.2 million tons produced in 2015. The average price during 2016 for crushed stone aggregate was \$8.46 per ton, an increase of 5% from the 2015 value of \$8.06 per ton (**Figure 4-9**). The estimated total value of the 2016 crushed stone production was \$126 million, an increase of 9.6 % from the \$115 million value in 2015.

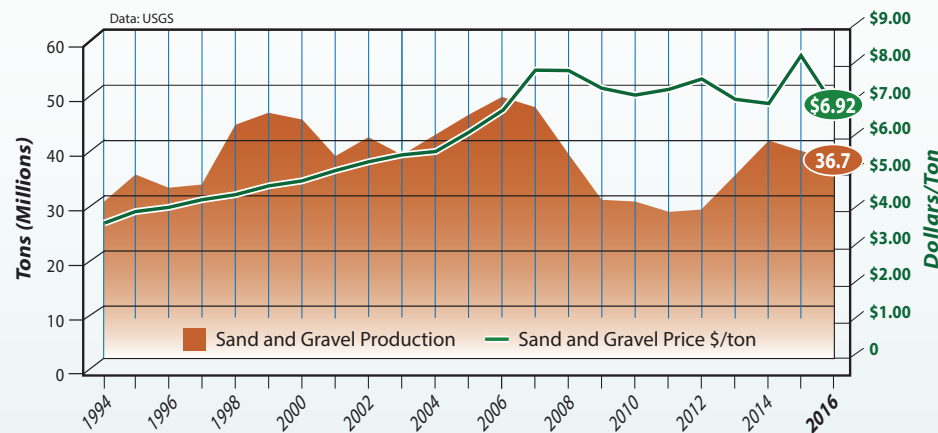


Figure 4-8. Price and production of sand and gravel aggregate in Colorado, 1994–2016.

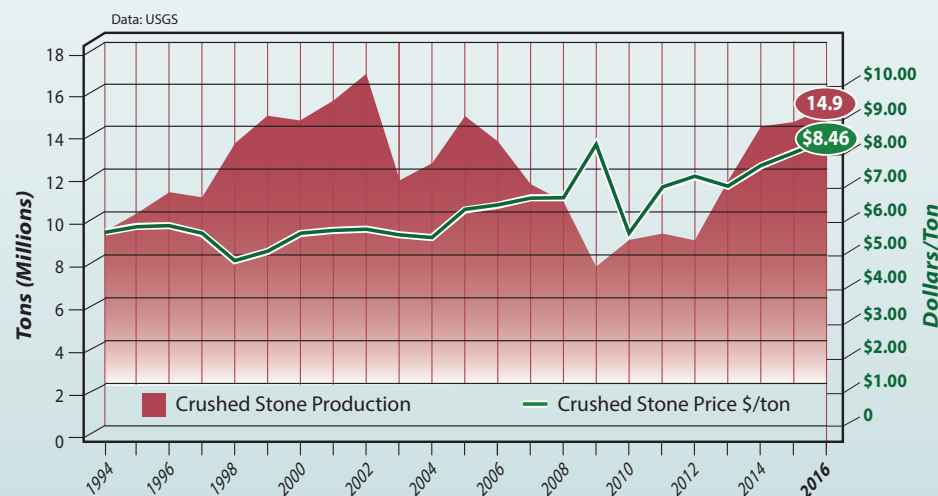


Figure 4-9. Price and production of crushed stone aggregate in Colorado, 1994–2016.

Walstrum aggregate quarry in Clear Creek County. Photo by Matt Morgan, CGS.



The combined value of all aggregate (sand and gravel, and crushed stone) production in 2016 was about \$380 million, a decrease of 12% from the 2015 value of \$430 million. Colorado uses a large amount of aggregate to build and maintain infrastructure. The cost of aggregate to the user is highly dependent on aggregate transportation costs. Locating quarries close to population centers helps lower overall costs. However, residential and commercial development near an aggregate source can make permitting a new or expanding quarry a challenge. The demand for aggregate is regional but land use planning/permitting for aggregate supplies is done on a local level. Balancing the need for readily available and reasonably priced aggregate with other regional, social, and environmental priorities is not an easy task for local governments. Recognizing the need to balance competing interests in urban areas, counties, with a population of least 65,000, must develop a master plan for the extraction of industrial mineral deposits. The intent of this 1973 state law is to allow for the extraction of aggregate, and other commercial mineral deposits, while protecting the environment and public safety.

To help local governments identify potential sources of sand, gravel and quarry aggregates, CGS created “Special Publication 5A and 5B, Sand Gravel and Quarry Aggregate Resources, Colorado Front Range Counties” (Schwochow and others, 1974). Digital versions of the aggregate resource maps can be found in CGS “OF-00-09 Atlas of Sand, Gravel, & Quarry Aggregate Resources, Colorado Front Range” (Cappa, 2000). CGS plans to update the maps and make them available to the public through an online map viewer

4.3 CEMENT

Portland cement in Colorado is used primarily in the production of concrete. Concrete consists of a mixture of aggregates and paste. Sand, gravel, or crushed

stone is mixed with water and cement. According to the Portland Cement Association, cement is created by heating lime, silica, alumina, iron, and other materials at high temperatures which creates small round pellets called clinkers that are ground, mixed with limestone and gypsum, and used to make concrete. Three portland cement plants operated in Colorado during 2016: Holcim (US), Inc. (Holcim) in Florence, the GCC of America plant in Pueblo, and the CEMEX plant near Lyons. GCC of America and CEMEX are Mexico-based multinational companies. Holcim (US) Inc. is a subsidiary of LafargeHolcim, a large multinational company based in Switzerland. All three mining companies are currently mining the Niobrara Formation as feed stock for their cement products. Like the aggregate business, the production of cement is largely tied to the construction industry. The USGS estimated Portland cement production (e.g. shipments from Colorado) in 2016 was 2.4 million tons, up from the 2.3 million tons in 2015. The average cement price in 2016 was \$100.70 per ton, a 5.2% increase from the 2015 value of \$95.71 per ton in 2015 (**Figure 4-10**).



Cemex plant operations outside Lyons, Boulder County.

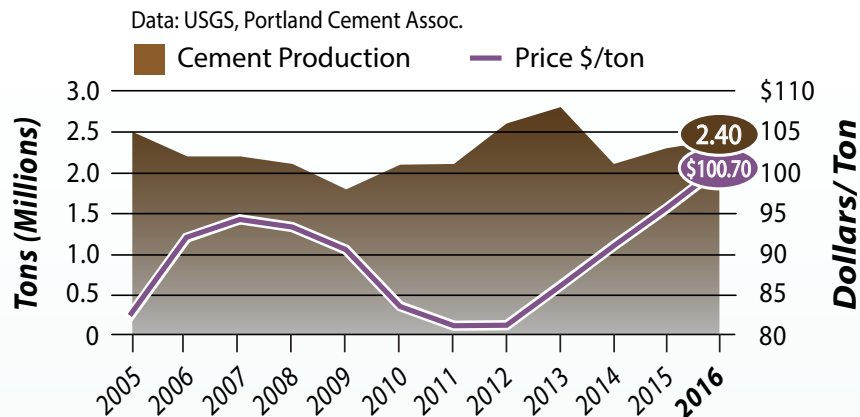
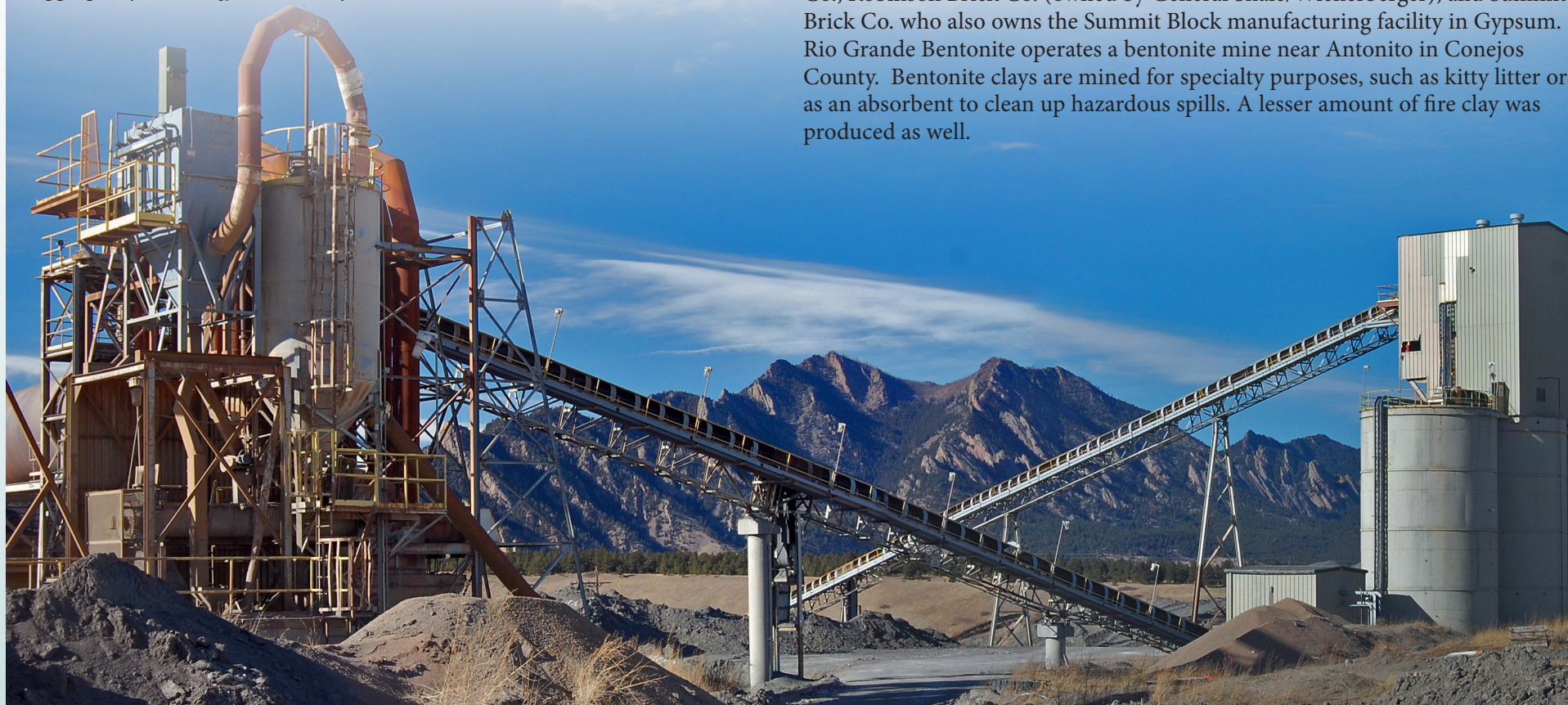


Figure 4-10. Price and production of cement in Colorado, 2005–2016.

Aggregate plant in Jefferson County.



4.4 CLAY AND SHALE

Common clay is mined primarily in eastern Colorado along the Front Range and is used mostly to make bricks and tiles. Higher quality clays have been mined from the claystone and shale deposits in the Dakota Group and the Dawson Arkose/Denver Formation and used in the manufacture of refractory ware (e.g. crucibles and high temperature fire bricks). Preliminary common clay and shale production was estimated at 251,000 tons in 2015 and 222,000 tons in 2016. Published production values were not available in early 2017. The estimated average price of common clay and shale was approximately \$11.79 per ton in both 2015 and 2016. The value of 2016 clay and shale production is estimated at \$2.6 million. As with other construction material, clay production has increased substantially since the recession of 2007–2009 (Figure 4-11).

In 2016, DRMS records indicate that there were 45 active permits for general clay. Three brick companies currently operate in the Denver area: Acme Brick Co., Robinson Brick Co. (owned by General Shale/Wienerberger), and Summit Brick Co. who also owns the Summit Block manufacturing facility in Gypsum. Rio Grande Bentonite operates a bentonite mine near Antonito in Conejos County. Bentonite clays are mined for specialty purposes, such as kitty litter or as an absorbent to clean up hazardous spills. A lesser amount of fire clay was produced as well.

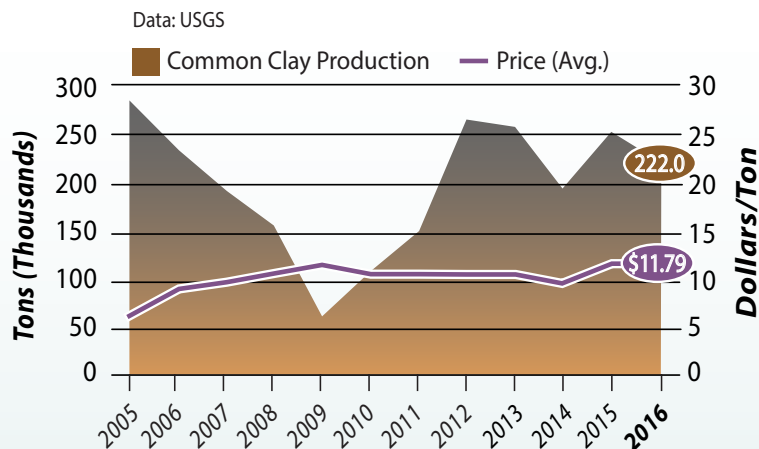


Figure 4-11. Estimated production and average price of common clay in Colorado, 2005–2016.

4.5 GYPSUM

Gypsum mined in Colorado is used for the production of wallboard, as an ingredient in cement production, as a soil conditioner, and for other industrial uses such as glass making and smelting. Production information from the USGS for Colorado gypsum manufacturers is not available due to proprietary reasons. In 2015, Colorado was ranked 8th in the U.S. in production of gypsum and was one of the top ten states accounting for 93% of the total crude gypsum domestic output.

American Gypsum Co. operates a large quarry and fabrication plant for wallboard in Eagle County, near the town of Gypsum. In recent years, the plant produced approximately 600 million square feet of wallboard. Gypsum is also mined by the Colorado Lien Company for the cement industry or for a soil amendment from the Munroe Quarry north of Fort Collins, Larimer County. Holcim (US) Inc., a cement manufacturer, operates the Coaldale quarry in Fremont County southeast of Salida. US Soil Conditioning Co. operates the Maverick Placer gypsum mine also east of Salida. GCC of America runs the Salt Canyon project quarry north of Florence in Fremont County.

4.6 SODIUM BICARBONATE (NAHCOLITE)

Sodium bicarbonate (more commonly known as baking soda) is primarily used in food preparation and baking, personal care products, pharmaceuticals, animal feed, agriculture water treatment, and other industrial applications. Natural Soda, Inc., owned by Energi Group, operates the world's only nahcolite solution mine in Rio Blanco County. Nahcolite is the naturally occurring mineral of sodium bicarbonate (NaHCO_3). High grade nahcolite (>80%) is

recovered from the Boise Bed in the Green River Formation of the Piceance Basin. Hot water is pumped down a well approximately 1,900 feet deep to dissolve the nahcolite. Other wells recover the sodium bicarbonate-enriched solution and pump it to the surface where the solution is allowed to cool and precipitate sodium bicarbonate. The precipitate is further dried and prepared to produce commercial grades of sodium bicarbonate. Natural Soda completed an expansion project in 2013 to double the mine's production capacity to 250,000 tons per year. Production in 2015 totaled 207,731 tons, a 13.6% increase from the 182,787 tons produced in 2014 (**Figure 4-12**). Production numbers for 2016 were not available at the time of this report.

4.7 SILICA

Sandstone is mined by Holcim (US) Inc. for use as a silica additive in their cement manufacturing plant in Florence. The sandstone is mined from the same area as the limestone and shale are mined to make the cement. CEMEX also mines sandstone as a cement additive at a mine in Boulder County. Well-rounded quartz sand from eolian deposits in the Colorado Springs area was mined by Colorado Silica Sand Co. in past years for silica sand. Most of this sand was used for filtration and water well packing purposes. Production information of industrial sand in Colorado was withheld by the USGS to avoid disclosing proprietary data. In 2016, the average national price for industrial silica sand and gravel reported by the USGS was \$42.29 per ton. Depending on the application and other factors, prices are highly variable.

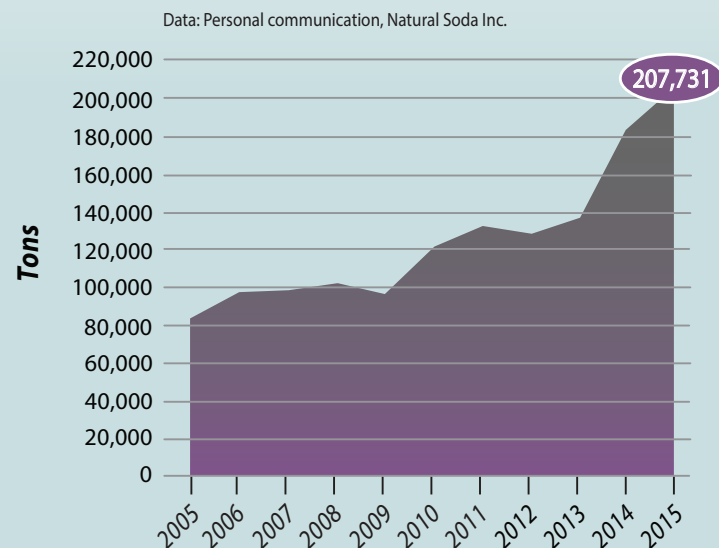
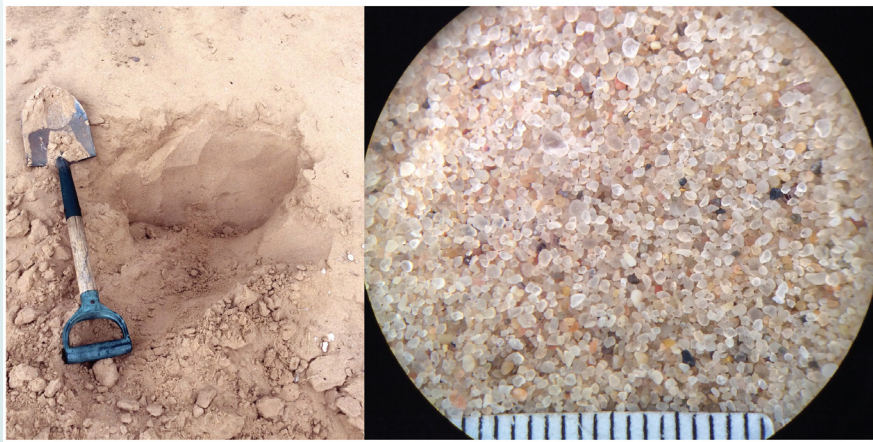


Figure 4-12. Sodium bicarbonate (nahcolite) production in Colorado, 2005–2015.

Hydraulic fracturing sand (also called “frac” or “proppant” sand) is used in the hydraulic fracturing process to prop open rock fractures and facilitate the flow of oil and gas to wells. The decline of drilling activity in recent years has resulted in lower demand for proppant sand however demand will likely increase in 2017 with increasing oil prices and drilling activities. According to the USGS, 72% of all silica sand usage in the U.S. in 2016 was for hydraulic fracturing and for well packing. The USGS reported that the prices for proppant sand were about \$48.25 per ton. However, prices for proppant sand are highly dependent on transportation costs, which are driving the current proppant sand mining increase near wellheads in the southern U.S. (e.g. Permian Basin). Most proppant sand is mined in the Midwest and Southern states. Several sandstone formations in Colorado could be candidates for proppant sand mining. The CGS initiated a field reconnaissance evaluation of surficial eolian sand and sandstone formations throughout the state for their potential suitability as proppant sand. The results from samples collected during this project will be published in mid 2018.



Potential Colorado frac sand location. Divisions on scale bar are 0.5 mm.

4.8 LIMESTONE, CALCIUM CARBONATE, AND LIME

Pete Lien & Sons mines high-purity limestone from deposits located in northern Colorado and southern Wyoming and grinds the rock into a calcium carbonate powder at their Livermore facility located in Larimer County. This material is used for a variety of purposes including a filler for roofing shingles, fire suppression in underground coal mines, calcium supplement for liquid animal feed, manufacture of pharmaceuticals, fertilizer, filler, drilling fluids, and as an additive in glass manufacturing. Colorado Lime Co., a wholly owned subsidiary of United States Lime & Minerals, Inc., operates the Monarch quarry on the east side of Monarch Pass west of Salida. At this time, only existing

stone stockpiles are being processed from the Monarch quarry. Facilities in Delta and Salida, process the high-purity limestone and produce ground calcium carbonate and screened limestone products for use mainly in coal mining and agriculture. Limestone and dolomite are also mined locally for crushed rock aggregate.

Lime is made by calcining (e.g. burning) high-purity limestone to form calcium oxide, commonly called quicklime. When water is mixed with lime, it forms hydrated or slaked lime (calcium hydroxide). Pete Lien & Sons produces hydrated lime at their Laporte plant near Fort Collins. The hydrated lime is used primarily in water and wastewater treatment, well drilling applications, asphalt concrete treatment for anti-strip purposes, soil amendment processing, and other environmental/agricultural applications. Western Sugar Cooperative Inc.'s Fort Morgan plant operates a lime kiln which supplies the quick lime (converted to milk-of-lime with the addition of sweeteners) and carbon dioxide off-gas for the sugar purification system. Milk-of-lime is used in sugar processing to raise the pH of the product and to precipitate out impurities. According to data provided by the USGS, lime sold for an average of \$113.67 per ton nationally in 2015, up 2.4% from the average price of \$111.04 in 2014. Data for 2016 were not available at the time of this report.

4.9 DIMENSION STONE AND DECORATIVE STONE

Dimension stone is any visually appealing rock that is quarried, cut, or shaped into useful forms. In Colorado, sandstone, granite, marble, rhyolite, and alabaster (a form of gypsum) are quarried for use as dimension stone. Dimension stone is used to construct buildings, wall cladding or veneer, monuments, floor tiles, walk ways (flagstone), landscaping features, and sculptures. Decorative stone is any type of rock that is used in its natural form for aesthetic purposes. It includes “river rock” (rounded cobbles), and “moss rock”, which is natural uncut boulders or cobbles with a thin veneer of colorful lichen (“moss”) in visually appealing patterns. In Colorado, various types of rock are mined locally for decorative use. **Figure 4-13** shows Colorado dimension stone production for the period from 2005-2015 based on USGS data.

Average annual prices and production of dimension stone are highly variable from year to year. Color, grain structure, and finish contribute to the dimension stone price and market. According to USGS estimates, Colorado produced 22,388 tons of dimension stone in 2015 worth about \$9.57 million. Colorado data for 2016 were unavailable at the time of this report. The average 2015 price for dimension stone was \$158.76 per ton, an 8% decrease from 2014 based on USGS estimates. In 2016, Colorado was a minor producer while Texas, Indiana, Massachusetts, Wisconsin, and Georgia accounted for about 64% of U.S. production.

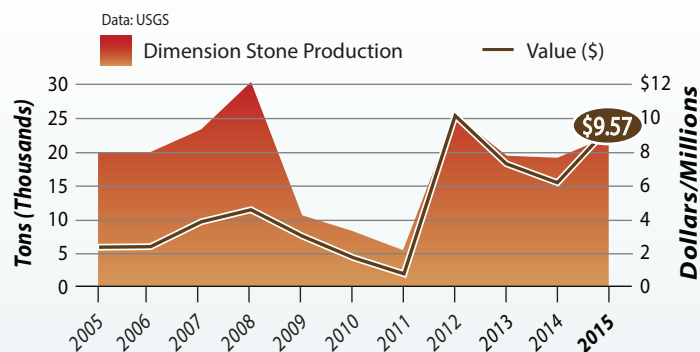


Figure 4-13. Production and product value of dimension stone in Colorado, 2005–2015.

Estimated dimension stone production in the U.S. decreased from 2.9 million tons in 2015 to an estimated 2.7 million tons in 2016. The majority of rock types sold in the U.S. in 2016 by descending value included limestone, granite, miscellaneous stone, sandstone, marble, and slate. Colorado has many dimension stone and decorative stone producers. Some of these companies, along with a listing of their more significant products, are summarized below:

Arkins Park Stone - Sandstone used for landscaping, building/home veneers, and rip-rap;

Colorado Alabaster Supply - Alabaster for sculpting;

Colorado Flagstone - Quartzite (hard sandstone) for building stone, veneers, landscaping, rip-rap, and flagstone applications;

Colorado Rose Red Inc. - Granite dimension stone used for building stone, monuments, memorials, counter tops, landscape boulders, pavers, veneers (cladding), aggregate, and signs;

Colorado Rose Sandstone - Sandstone for building/home veneers, landscaping, pavers, curbstones, capstones, flagstone, and retaining walls

Colorado Stone Quarries - Yule Marble dimension stone for memorials and building veneers;

Loukonen Bros. Stone - Sandstone for flagstone, stepping stone, wall rock, cut stone, boulders, and cut stone;;

Moffat Limestone Company - Limestone for stone cut veneers, counter tops, boulders, and cut rock slabs;

Monarch Limestone Company Inc. - Dimension stone for building



Lyons Sandstone awaits use as demension stone at Loukonen Bros. stockpiles.

veneers, landscaping flagstone, decorative moss rock, and river rock;

Siloam Stone - Sandstone used for landscaping, building/home veneers, retaining walls, rip rap, moss rock, field stone, memorials, and monuments;

Stone Wholesale - Sandstone for building/home veneers, decorative moss rock, and landscaping.

5.0 PEAT

Peat is a natural material that consists of partially decayed and disintegrated plant material. It is mined for use in mixed fertilizers, potting soils, plant nurseries, golf course amendments, a filtration medium, and can be used as an energy source. Colorado is a minor producer of peat and most deposits occur at high elevations in wetlands areas (or areas that were formerly wetlands during wetter climates) near river or creek valleys. There are two active peat mining permits for operations located in Teller and Alamosa counties. The USGS estimated that the value of peat production in the conterminous U.S. was \$12.4 million in 2016. Estimated consumption in the U.S. totaled 1.63 million tons in 2016. Minnesota and Florida are the leading producing states and most peat consumed in the U.S. is imported from Canada.

5.1 GEM AND SPECIMEN MINERALS

Because of its diverse geological environments, Colorado is home to a variety of gem and specimen minerals. These include diamonds derived from kimberlite pipes in the Stateline district of Larimer County, aquamarine found in granite on Mount Antero in Chaffee County, amazonite in several areas within the Pikes Peak granitic batholith west of Colorado Springs, and rhodochrosite (Colorado's State Mineral) which is found in several places but most notably at the inactive Sweet Home Mine near Fairplay in Park County.



Mount Antero from the Arkansas River Valley in Chaffee County. Gem prospects are found high on the southwest slopes.

INDUSTRIAL GASES (NON-ENERGY)

5.2 CARBON DIOXIDE

Naturally occurring carbon dioxide gas (CO₂) was produced in 2016 primarily from three areas in Colorado: McElmo Dome in Montezuma County, Doe Canyon Deep in Dolores County, and the Sheep Mountain Field in Huerfano County. McCallum Field in Jackson County and the Rangely Field in Rio Blanco County also produce CO₂. Kinder Morgan's McElmo Dome and Doe Canyon Deep units are the largest producers in Colorado. CO₂ is produced from wells in a similar way to natural gas production. The CO₂ is mostly used in enhanced oil recovery (EOR) in New Mexico and Texas. Enhanced oil recovery is the implementation of various techniques for increasing the amount of crude oil that can be extracted from an oil field. Enhanced oil recovery is also called improved oil recovery or tertiary recovery (as opposed to primary and secondary recovery). CO₂ is used to extend the life of a well after the initial pressure in the well decreases. Other uses for CO₂ include welding gases, the manufacture of dry ice, and in the food and beverage industry. In 2016, Colorado produced an estimated 444 Bcf at an estimated average price of \$1.75 per Mcf for an estimated value of \$778 million. **Figure 4-14** shows Colorado's CO₂ production for the period 1994-2016.

5.3 HELIUM

Helium has numerous uses such as metallurgy, fiber optics, semiconductor manufacturing, magnetic resonance imaging (MRI), lifting high-altitude scientific research balloons, blimps and party balloons, breathing atmospheres for deep diving, unique blood gas medical mixtures, analytical chemistry, pressurizing and purging pipes and other critical equipment, leak detection, and other advanced applications. Grade-A helium has been produced by DCP Midstream LLC at the Ladder Creek gas plant facility located in Cheyenne Wells, Cheyenne County in southeastern Colorado. The gross capacity of the Ladder Creek facility is 40 million cubic feet per day (MMcf/d). In 2015, Air Products and Chemicals, Inc. (Air Products) built a helium production facility in Doe Canyon. Most of the helium is extracted from a gas stream composed primarily of carbon dioxide. The plant has a capacity of about 230 million standard cubic feet per year. IACX Energy, a midstream company, has reportedly agreed with a local producer to install helium recovery units in the Badger Wash area in Mesa County. The price for private industry grade-A helium as reported by the USGS, was about \$200 per Mcf.

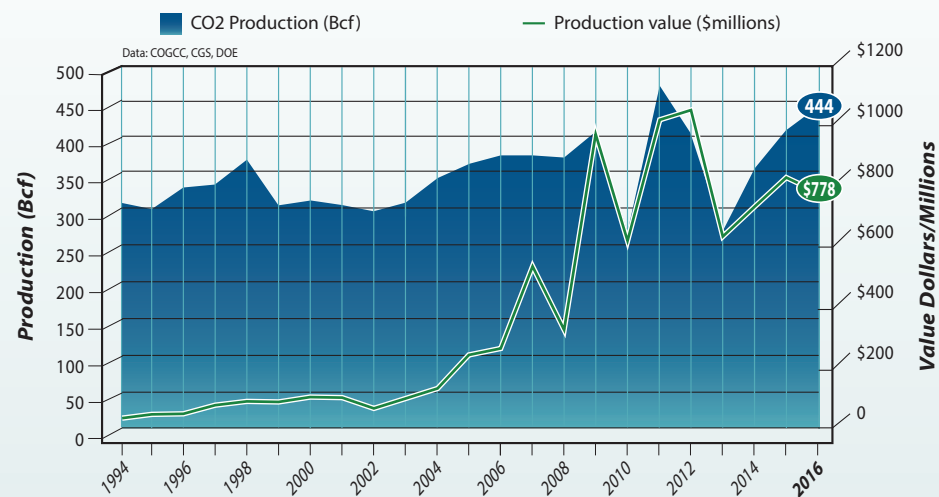


Figure 4-14. CO₂ production and estimated production value in Colorado, 1994–2016.

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