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The Effect of Coal Industry of Southern Indiana: A Look at the Evolution of Safety, Health, and Environmental Practices and Concerns

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ABSTRACT

Coal mining in the United States is currently and extremely hot topic and will continue to be for many years. For many years, this industry has been a way of life for many families. That truly represents the state of Indiana. Situated over one of the largest coal basin in the country, Indiana has been a top ten coal producing state for years. While this industry is relied on by millions, it doesn't come without hazard. The health and safety of the individuals that work in these mines are two factors that have seen immense change since the ounce of coal was recovered. From age requirements to required inspections and coal dust thresholds to enhanced protections, the landscape of this industry is ever changing. A range of protocols have been implemented to manage the effects of the mining process on the surrounding environment. Land reclamation projects in Indiana have seen numerous regional awards, while helping re-establish natural ecosystems to these lands.

INTRODUCTION

The coal industry in the United States of America has been a staple for many communities for over many years. However, many do not understand the amount of time, resources, and risks involved in the coal mining industry. A densely vegetated swamp from millions of years ago is now utilized to provide power to much of the modern world.

While the goal has always remained the same, the action plan has changed over the years. New methods were developed as a result of the invention of new machinery. Protections were added for both the health and safety of mine workers. Regulations were enacted to protect the environment that is needed to sustain life.

Although there a push to shift towards more renewable, green resources, that shift will be gradual at best. The American dependency on coal is strong and difficult to shake. With centuries worth of coal reserves still buried beneath the surface, coal will be around for the long haul.

COAL FORMATION AND VARIATIONS

Coal, classified as an organic sedimentary rock, is vastly different than other sedimentary rocks. As the classification suggests, coal is made of primarily organic, typically plant, material. In order for coal to form, certain conditions must be met. First, the availability of massive quantities of plant material. Second, the proper environment must be present. These first two criterion seemingly go hand in hand. The ideal environment for coal formation is a swamp. According to National Geographic (2012), "a swamp is an area of land permanently saturated, or filled, with water." Millions of years ago as plant material would die it would fall and accumulate on the swamp floor, typically underwater. While this material would partially decay, full oxidation was generally not possible. Due to most swamps being stagnant bodies of water, the amount of free oxygen within the water is minimal.

With the lack of an oxygen rich environment certain types of bacteria would work to breakdown this material. In doing so, oxygen and hydrogen gases were released. The release of these gases results in an increased concentration of carbon. Also released by this process is certain types of acids. As the concentration of these acids increase, the bacteria are killed off resulting in partially decomposed material. It is at this point that the beginning stages are coal are recognized. The remaining material after the decomposition process is called peat. This is "a soft brown material in which plant structures are still easily recognized (Lutgens & Tarbuck, 2009 p. 148)." While not technically classified as coal, without peat coal will not form. Although not a true coal rock, peat can be burned for fuel once dried out as was the case in ancient Rome (Plummer et al., 2010). Figure 1 (below) helps illustrate the following processes to transform peat into coal rock.

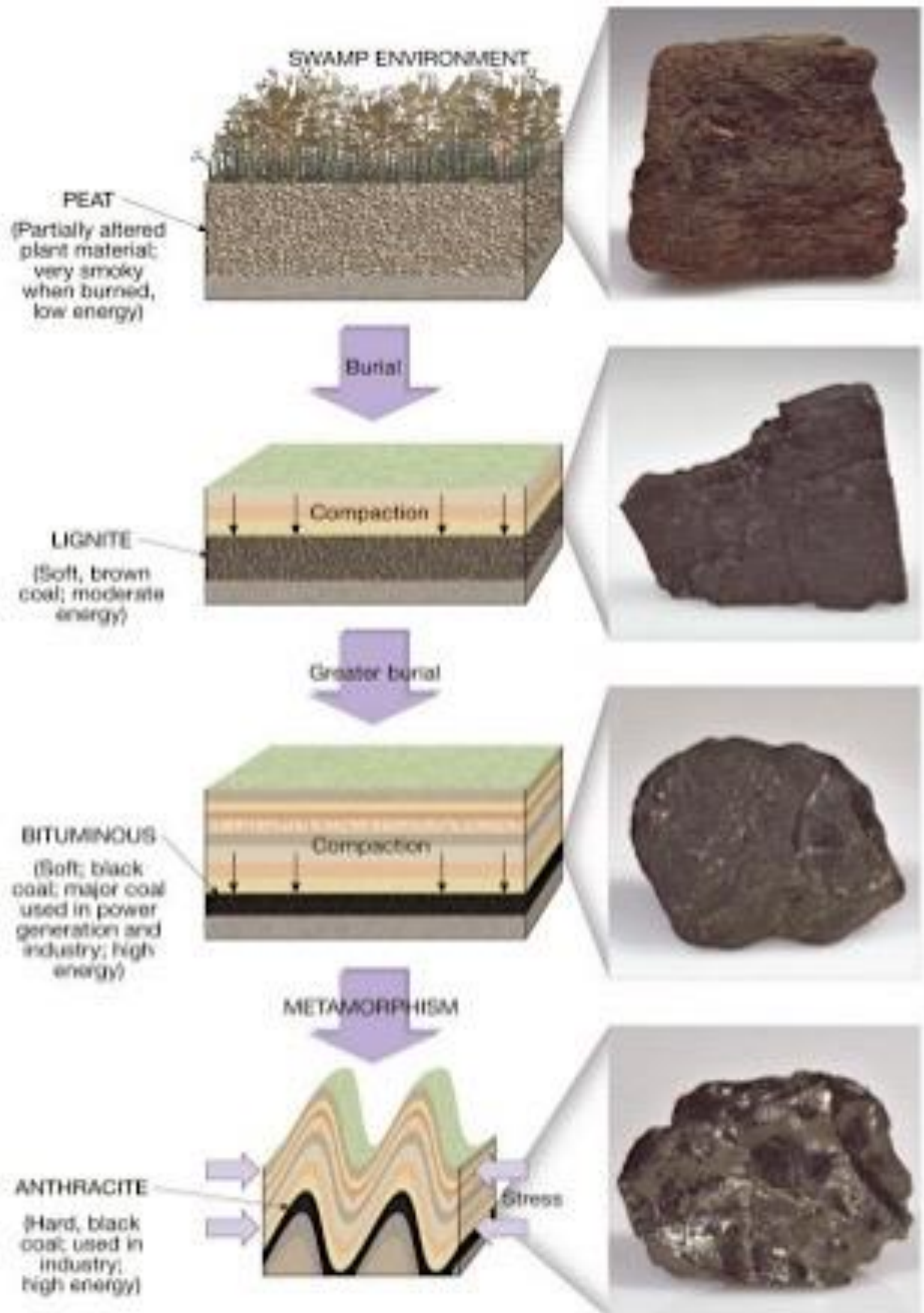


Figure 1. Successive Stages in Coal Formation, (Lutgens & Tarbuck, 2009).

To turn peat into a form of coal, compaction is required. As the material is compressed by burial of subsequent layers of organic material and other strata, the peat material will slowly change to lignite, often called brown coal. With a 45% water content (Plummer et al., 2010), lignite will hold its shape until it dries out. When it does dry out, it will crumble to pieces. At this stage, pieces of wood from the original plant material can still be identified. A limiting factor for lignite to be used as fuel is that it can spontaneously combust when exposed to oxidizing conditions.

With further burial the lignite will also start to increase in temperature. This combination of increased pressure and temperature induces chemical reactions that turn this soft brown coal into actual coal rock. Through these chemical reactions water and other volatiles (organic gases) are pressed out resulting in a higher content of fixed carbon. Fixed carbon refers to the amount of "solid combustible material left after water, volatiles, and ash (noncombustible solids) are removed (Plummer et al., 2010)." The higher content of fixed carbon, the more desirable the coal due to its potential heat value.

With further compression and chemical reactions, lignite is transformed into subbituminous and bituminous coal. These two types of coal are generally very similar in appearance, but differ in their composition. Subbituminous coal has higher quantities of water and volatiles, resulting in a lower fixed carbon percentage than bituminous coal. These coal types also vary in their heat value. The approximate heat value of coal is measured in BTUs, or British Thermal Units. "One BTU is equivalent to 1,055 joules", the scientific unit of energy (Plummer et al., 2010). The approximate heat value of subbituminous coal is 10,000 BTUs. This is nearly the base heat value of bituminous coal, which has a range of 10,500 to 15,00 BTUs. At this point in the compression process, scientists believe that the bituminous coal bed that has formed is nearly 1/10 the size of the peat layer it started out as (Lutgens & Tarbuck, 2009).. This means what started out as, for example, 10 inches of organic material would only produce a one-inch seam of coal.

Unlike lignite, subbituminous, and bituminous coal layers, the final coal variation is classified as a metamorphic rock due to different processes involved in its transformation. In addition to heat and pressure, folding and deformation processes are applied. These added forces create anthracite, or hard coal. Whereas bituminous coals have a very dull black appearance, anthracite has a glossy black presentation. Anthracite is considered the highest quality of coal due to its low content of water and volatiles and high content of fixed carbon. Table 1, below, shows a comparison of each type of coal and the factors that rank them.

Table 1	**Varieties (Ranks) of Coal**				
	Color	Water Content (%)	Other Volatiles (%)[2]	Fixed Carbon (%)[3]	Approximate Heat Value[4]
Peat[1]	Brown	75	10	15	Varies
Lignite	Brown to brownish-black	45	25	30	7,000
Subbituminous coal	Black	25	35	40	10,000
Bituminous coal (soft coal)	Black	5 to 15	20 to 30	45 to 86	10,500 to 15,000
Anthracite (hard coal)	Black	5 to 10	5	86 to 98	14,000 to 15, 000

1. Peat is not truly coal, but may be thought of as “pre-coal.”
2. “Volatiles” are other organic gases
3. “Fixed carbon” means solid combustible material left after water, volatiles, and ash (noncombustible solids) are removed.
4. BTUs, British Thermal Units, of heat per pound of dry coal

(Plummer et al., 2010 p. 547)

The map labeled Figure 2, courtesy of the United States Geological Survey, illustrates the known coal fields of the contiguous United States. The country is divided into six provinces: Easter, Gulf, Interior, Northern Great Plains, Rock Mountain, and Pacific Coast. These boundaries are notated by the dashed yellow lines. Each type of coal is represented by two colors. The darker shade for each color "represents areas known to contain coal beds that are of commercial value (Tully, 1996)." The lighter shade for each color shows areas where the value of coal is unknown. There are three reasons they are noted this way, according to Tully. First, the beds may be irregular in shape or very thin, which offers negligible value. Second, the quality of the coal is poor. Third, thickness and/or quality information is non-existent or weak (Tully, 1996).

Lignite is represented by the yellow and gold shades that can be seen in the states near the Gulf of Mexico extending north into the Western Tennessee and Kentucky areas, as well as in North Dakota and Montana. The green shades represent areas of subbituminous coal, which is located exclusively the western region of the United States; stretching from the border Canada to Mexico. Bituminous coal is separated into two categories; medium to high volatile, represented by the grey and teal shades, and low volatile, represented by the pink shades. These areas lie in the Appalachian Mountains, from Iowa to Oklahoma, and nearly the entirety of Illinois. Lastly, anthracite is depicted by the shades of orange. These coal beds predominantly in Eastern Pennsylvania, with a small section showing in Arkansas (Tully, 1996).

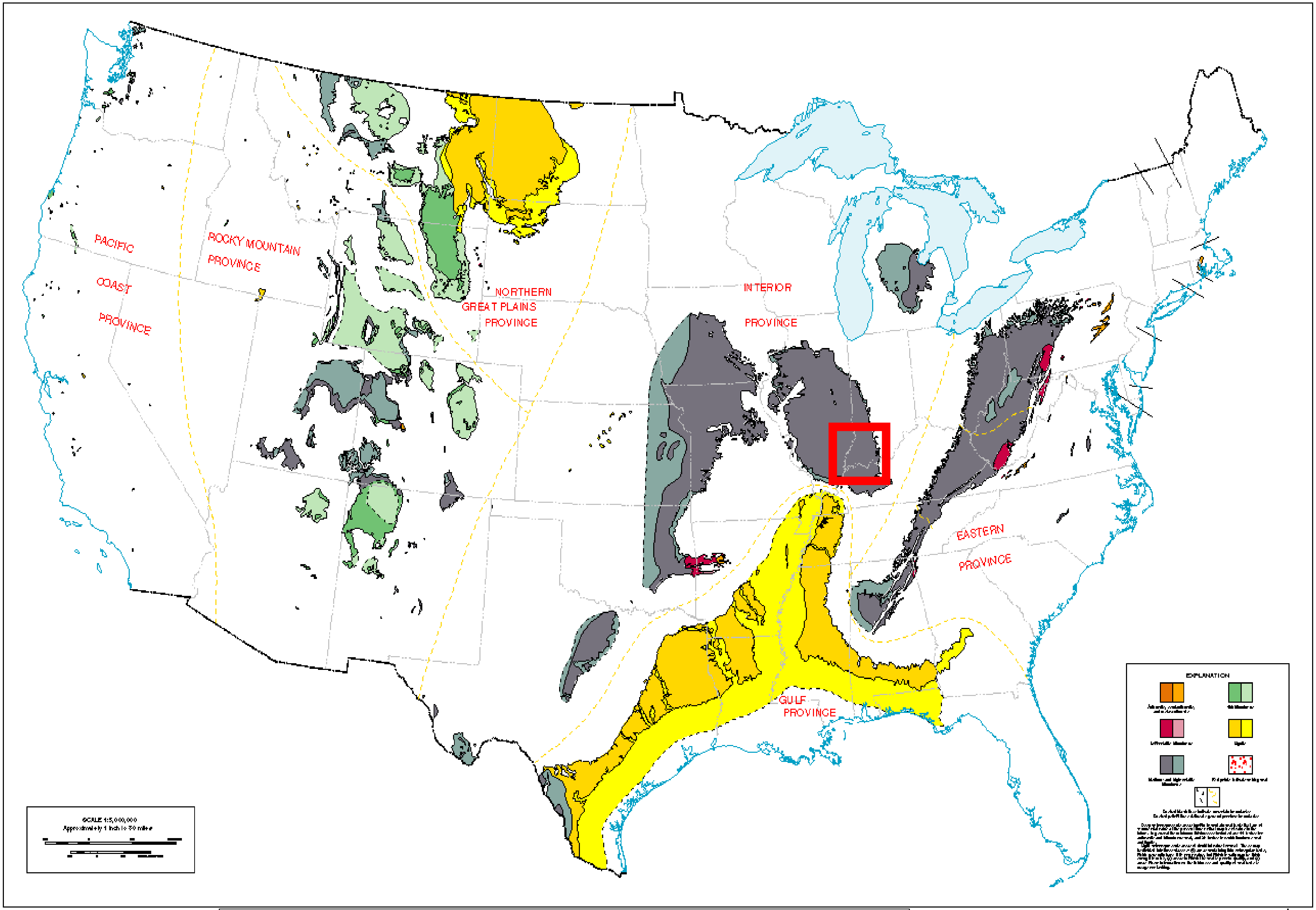


Figure 2. Coal Fields of the Conterminous United States, (Tully, 1996).

The red square on the map lies in the southern most region of what is called the Illinois Basin and outlines the area of focus within this document. The Illinois Basin dates back to the Pennsylvanian subperiod of the Carboniferous period, approximately 323.2 million to 298.9 million years ago (National Park Service, 2020). This time period predates dinosaurs by nearly 70 million years at the least, who first emerged roughly 230 million years ago. This period was characterized by extensive forests which created the massive amounts organic matter needed to create these coal beds.

MINING PROCESSES

Coal mining processes may vary slightly from location to location, but all can be divided into two classifications, underground mining and surface mining. When deciding which path to take, the characteristics of the coal seam must be taken into consideration. According to the World Coal Association, "the quality of a coal deposit is determined by:

- Types of vegetation from which the coal originated
- Depths of burial
- Temperature and pressures at those depths
- Length of time the coal has been forming in the deposit (World Coal Association, 2020)."

These factors must be weighed along with the economic factor – which process is the most economically efficient?

Just as the name suggests, underground mining processes take place deep under the surface, at depths of at least two hundred feet. This mining type is used to retrieve coal deposits that are encased within layers of sedimentary rock. To reach coal beds at these great depths, vertical shafts are cut into the Earth. Pulley systems are erected over these shafts and fitted with elevators, typically two. One elevator is for crew access and the other for coal removal. After the vertical shafts have been established, tunnels are created in a horizontal direction away from the main shafts and towards the coal seams. In some cases where the horizontal coal seam is visible above ground, a vertical shaft is not necessary.

Within the underground mining classification there are two different techniques that are used. The first is room-and-pillar mining. Figure 3 helps illustrates the room-and-pillar mining process. Room-and-pillar mining consists of a network of “rooms” being cut into the coal seam. These rooms leave “pillars” that are utilized to support the mine roof. These pillars that remain can account for 40% of the entire coal seam (World Coal Association, 2020).

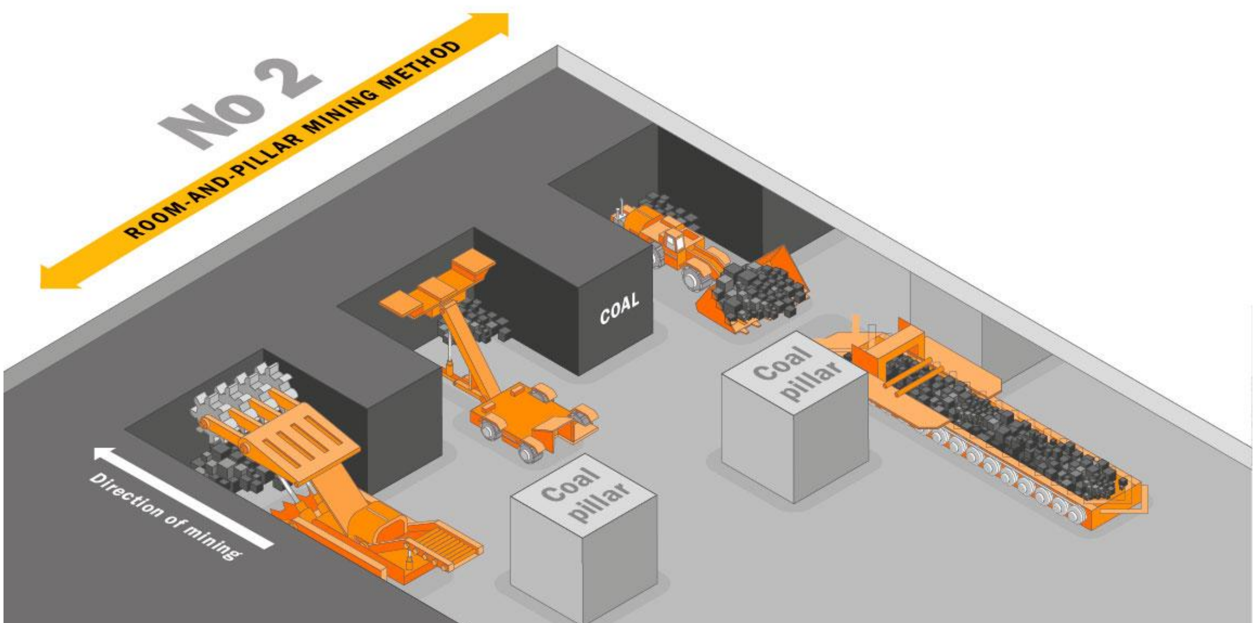


Figure 3. Room-and-Pillar Mining (EVRAZ, *Room-and-Pillar Mining* 2017)

The other method of underground mining is called longwall mining. This method of mining involves mining directly through the coal seam by removing the "face" with mechanical shearers. Below the shearers is a collection conveyor that feeds the coal to a grinder that breaks the coal into manageable sized pieces in preparation for extraction. As the face of the coal seam is cut back mechanical supports are put in place to hold up the roof of the seam. As the mining process progresses, the supports continue along and the roof collapses behind. According to the World Coal Association this method is extremely efficient, extracting over 75% of the coal deposit (World Coal Association, 2020). Figure 4 below illustrates the longwall mining method.

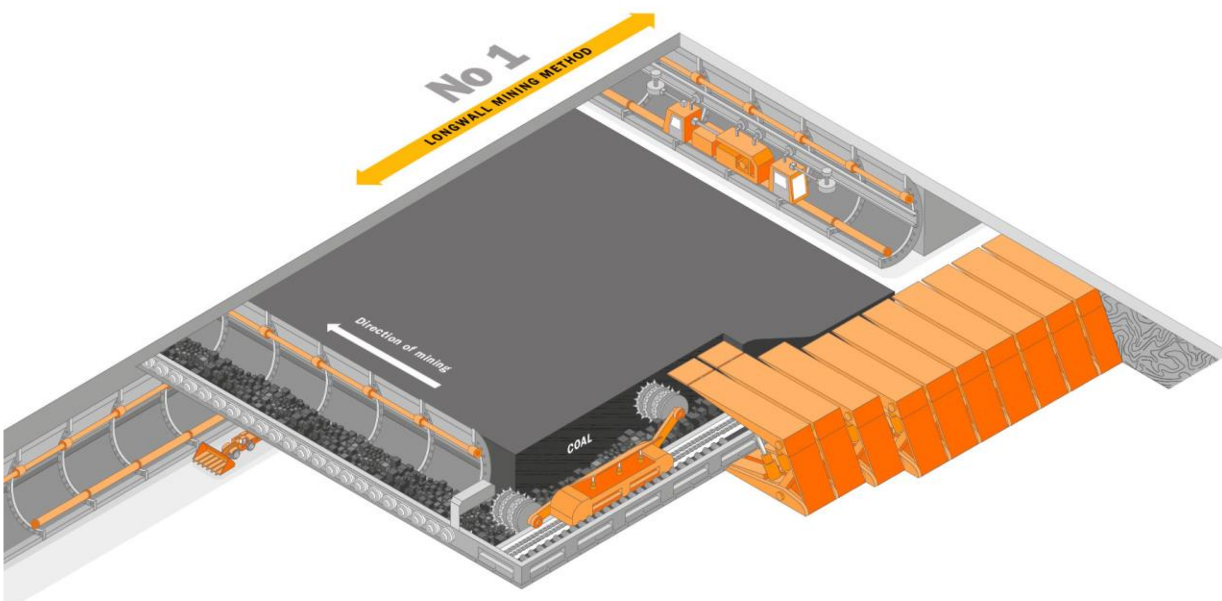


Figure 4. Longwall Mining (EVRAZ, *Longwall Mining* 2017)

In some cases the coal that remains from the pillars can be retrieved later in a process called retreat mining. In retreat mining, the pillars that were in place to hold up the roof are systematically removed, intentionally allowing the roof to cave in. This process can be extremely dangerous if not planned thoroughly. According to The Washington Post, in an article published in 2007, “between 1992 and 2001, 100 miners died in roof collapses, 27 of them during retreat mining (Borenstein, 2007).”

The second classification of mining is surface mining, sometimes referred to as strip mining. Surface mining is utilized when the coal deposits are buried near the surface, typically less than two hundred feet. This form of mining covers expansive areas of land that are generally flat and contain very large, thick seams of coal. In order to move the potentially hundreds of feet of overburden, the layers of rock and soil between the surface and the coal seam, this type of mining requires massive equipment and a lot of it. Some common pieces of machinery used are large trucks, excavators, power shovels, and draglines (World Coal Association, 2020). Figure 5 shows and example of a large dragline that has been retired from the Squaw Creek Coal Company in Lynville, Indiana. While the surface mining method may present to be more costly upfront, the efficiency seems to far outweighs that concern. According to the World Coal Association, surface mining methods can retrieve 90% or more of the coal deposit.

Figure 5. Retired dragline from the Squaw Creek Coal Company in Lynville, Indiana. (Saltzman, 2012)

During the beginning stages of surface mining, the topsoil and subsoil layers are carefully removed and set aside to be replaced at the end of the mining process. Any layers of rock that lie on top of the coal are broken apart with the help of explosives and then removed by the dragline. After reaching the coal seam, the coal is systematically drilled and fractured to

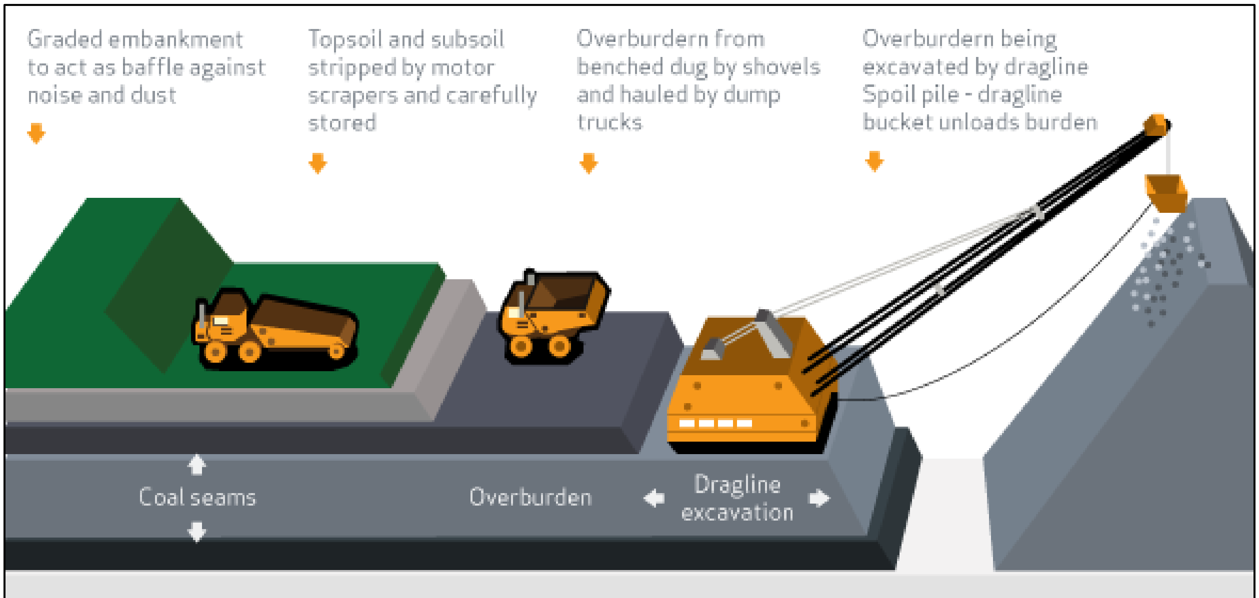


Figure 6. Surface Mining process. (World Coal Association, 2020)

before loading onto conveyors or trucks for removal. From this point, the coal either travels to the location that it will be used or to a plan that prepares the coal for its final destination (World Coal Association, 2020). Figure 6 illustrates the general process of surface mining.

PRODUCTION AND CONSUMPTION

Since the Industrial Revolution, coal has been a staple for energy and steel production. As the discussion on climate change intensifies, the number of facilities that are making the switch to more sustainable, renewable resources also grows. This change is apparent in the Annual Coal Report found in the United States Energy Information Administration’s records.

In 2019 the total United States coal consumption 586,539 thousand short tons or 1,173,078,000,000 pounds. This is a 14.8% decrease from 2018 in which 688,105 thousand short tons or 1,376,210,000,000 pounds were consumed. Of the 2019 total, 91.8% of the total, approximately 538,601 thousand short tons, was used for electric power. Other industrial uses came in at nearly 5% with 29,095 thousand short tons of coal. Coking coal, a specific type of coal that is used in steel production, came in next at 3%. The final category looked at was Commercial and Institutional usage, coming in at 0.12%. This data set also shows that 42 states and the District of Columbia saw a decrease in consumption between 2018 and 2019 (United States Energy Information Administration, 2020 Table 26).

As for coal production, the United States also saw a decrease of 6.6% between 2018 and 2019. While not as large as the decrease in consumption it is consistent with the downward trend in production since 2008. Based on the “Coal Production, 1949-2019” data set in the United States Energy Information Administration’s 2019 Annual Coal Report, production in 2008 was the highest of the 50 year period at 1,171,808,669 short tons. Comparatively, production in 2019 was 706,309,263 short tons (United States Energy Information Administration, 2020 Table ES1).

INDIANA COAL PRODUCTION AND CONSUMPTION

Sitting in the southeast region of the Illinois Basin, Southern Indiana has had a long history with coal mining and coal consumption. In Southern Indiana, coal was first discovered along the banks of the Wabash River in 1736. In the late 1830s, the first formal coal mine opened under the American Cannel Coal Company of Cannelton and was located in Perry county. By 1840, Indiana produced 9,700 tons of coal per year between Perry and Warrick counties. At the end of World War I, over 30,000,000 tons of coal were produced per year in Indiana. In the years after World War 1, production would begin to decline. In the 1940s, after World War II, surface mining replaced underground mining as the preferred method. The creation of the excavation machinery capable of large-scale projects like this allowed for the surge that led to surface mining being responsible for over 80 percent of Indiana's annual coal production by 1965. Although underground mining saw a resurgence in the late 1980s, surface mining continues to account for almost 70% of Indiana's total coal production (Indiana Geological & Water Survey).

The map in Figure 8 shows mines by method in Indiana overtop the coal reserve basin in the area. This map, published in 2015 by InContext from Indiana University's Kelley School of Business, includes both active and inactive mines. All coal deposits in the state are located

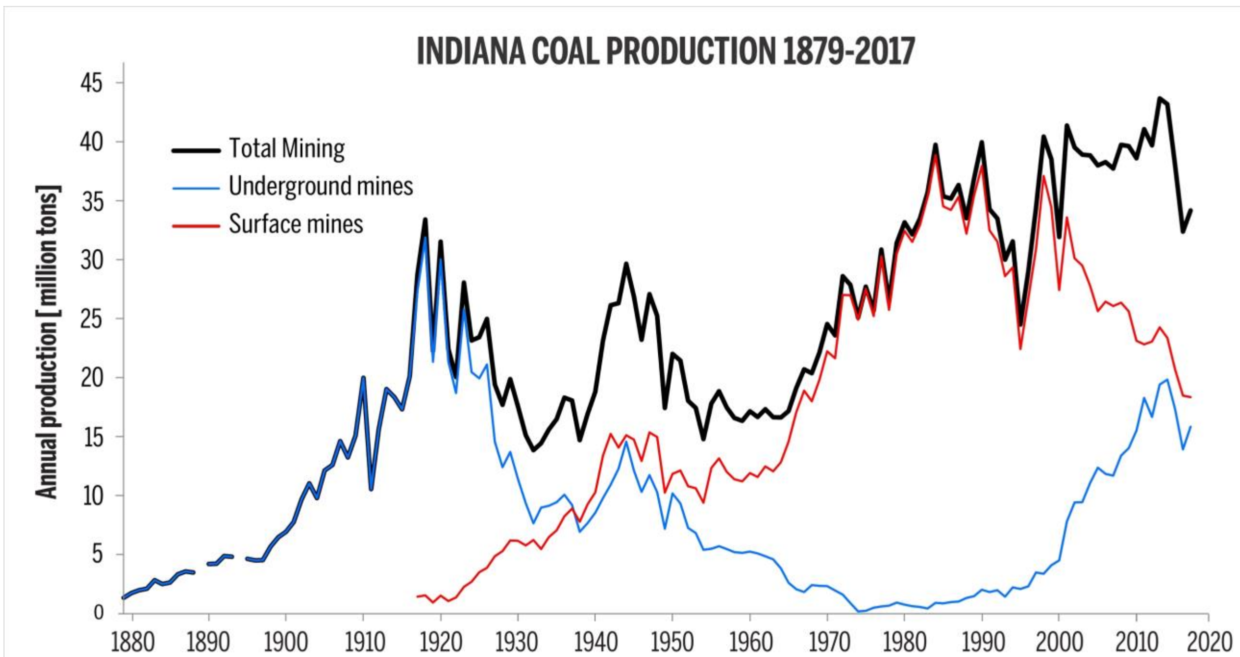


Figure 7. Indiana Coal Production 1879 to 2017 by mining method. (Indiana Geological and Water Survey)

within the area shown, resulting in highly localized industry. Currently, Indiana sits on a reserve of nearly 57 billion tons of untouched coal. The Indiana Geological & Water Survey at Indiana University estimates that 17 billion tons of this coal could be retrieved with available technology and that this reserve could last longer than 500 years if current rates of production hold. Of what is accessible at present time 88% would utilize underground methods and 12% utilizing a surface mining approach (Indiana Geological & Water Survey).

In 2019, Indiana was the third largest consumer of coal in the United States at 36.7 million short tons. Only North Dakota and Texas consumed more coal in 2019; nearly 40 million short tons and over 60 million short tons respectively. Indiana's total consumption accounted for 6.5% of the United States total. Since the United States Energy Information Administration began tracking state-level data in 1960, Indiana has utilized coal as the primary energy source. In 2018 coal consumption made up 35% of the state's total energy consumption. Only six other states saw a higher percentage. The primary use of coal in Indiana is to fuel eight of the states ten biggest power plants, which accounted for 84% of the consumption in 2019. After energy production, a

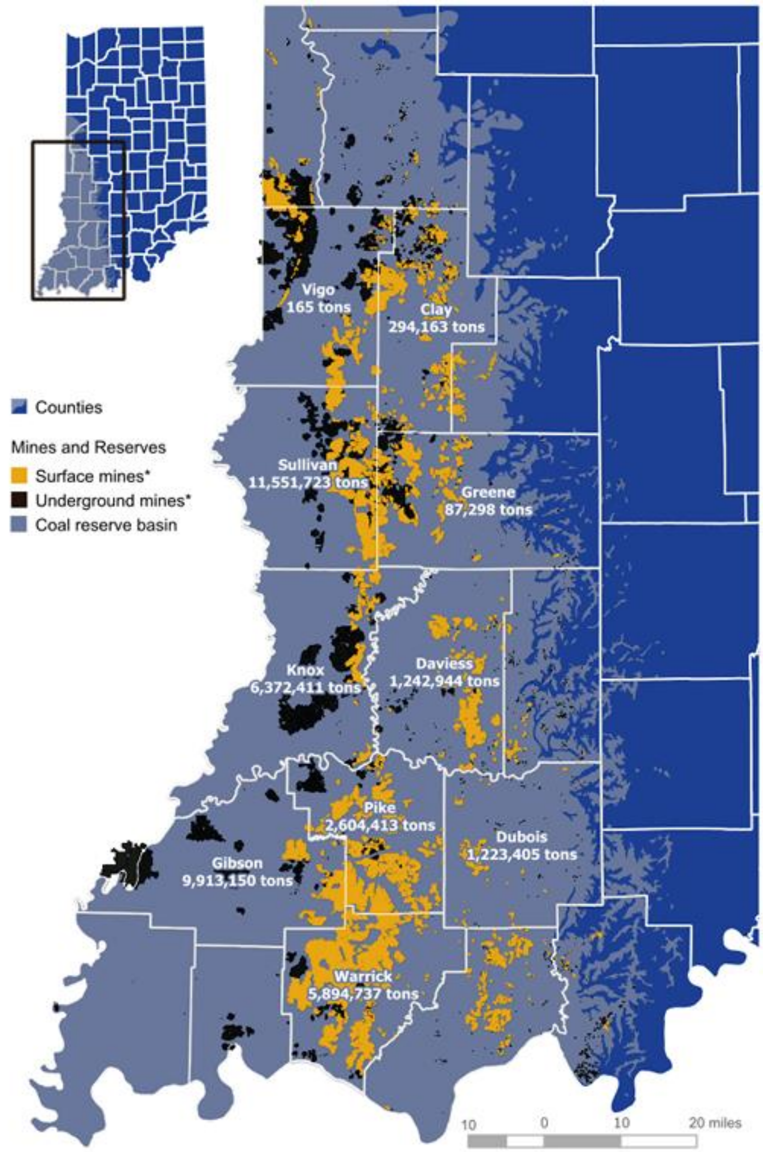


Figure 8. Indiana coal mines and coal bed.
*Includes active and closed mines.
(Evans, *Coal Production by county, 2014* 2015)

majority of the rest of Indiana's coal consumption is attributed to steel manufacturing. In 2019, only two states used more coal in the industrial sector than Indiana, those being North Dakota and Pennsylvania (Marohl, 2020).

In 2019, Indiana was the seventh largest producer of coal in the United States at 31,559 thousand short tons (United States Energy Information Administration, 2020 Table 1). In Table 2 below, Indiana's coal producing counties are shown with the yearly production total in thousands of tons between 2005 and 2015 (Evans, 2015). Even though Indiana is listed as a top coal producing state, the production rate does not measure up to the consumption rate. Nearly all of the coal that is brought in to the state to make up the deficit comes from Illinois, Kentucky, West Virginia, and Wyoming (Marohl, 2020). According to Thea Evans, approximately 40% of Indiana's coal for consumption is imported (Evans, 2015).

Table 2: Coal Production by County (thousands of tons)

County	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Sullivan	84	172	972	2,054	2,780	5,962	9,936	10,880	12,152	11,552
Gibson	15,176	15,690	14,898	15,403	12,919	11,562	10,583	9,546	10,672	9,913
Knox	4,076	5,100	4,869	5,264	5,045	4,761	5,044	4,543	5,461	6,372
Warrick	1,288	1,187	1,403	1,352	2,399	2,279	3,332	4,330	4,930	5,895
Pike	4,854	4,507	3,934	3,660	3,929	4,281	3,949	3,406	3,066	2,604
Daviess	3,537	3,334	3,451	3,544	3,492	2,812	2,688	2,326	2,058	1,243
Dubois	0	75	641	838	1,124	1,204	1,128	867	1,160	1,223
Clay	1,378	815	549	602	710	597	539	18	78	294
Greene	3	0	0	0	0	0	31	13	21	87
Vigo	3,846	3,835	3,514	3,330	3,558	1,562	36	90	22	<1
Spencer	217	0	0	0	0	0	0	0	0	0
Total	**34,460**	**34,716**	**34,231**	**36,047**	**35,996**	**35,020**	**37,266**	**36,019**	**39,620**	**39,184**

Table 2. Coal Production by Indiana County, 2005 – 2014.
Source: InContext (Evans, 2015)

Although Indiana is consistently a top ten coal producing state in the country, its impact on the state economy is fairly minimal. According to Evans, "the mining industry, excluding oil and gas, has long comprised less than one percent of Indiana's total real gross domestic product (Evans, 2015)." The coal industry's impact on the statewide economy in 2012 was less than 0.6 percent of the GDP (Evans, 2015). However, in mining counties such as Sullivan and Pike where mining production has either been fairly consistent or increasing of the years, the impact on the local economy is significant. In 2013, the employment rate for residents in both of these counties within the coal industry was greater than 15%. The state average at the time was 0.13% (Evans, 2015).

SAFETY PRACTICES AND REGULATIONS

The health and safety of the dedicated men and women in this industry is something that can be severely impacted by a single poorly positioned charge blast or something as small as an overly concentrated amount of suspended coal dust. Throughout the evolution of this industry its processes and safeguards have been tested time and time again. These tests and set-backs, along with the shear uniqueness of this industry, called for a specialized organization that would oversee the development and implementation of new safety and health procedures. In 1891, the United States Federal government passed the first piece of legislation aimed at improving the safety of underground coal mines. This first statute, only enforceable in territories of the United States, set minimum ventilation benchmarks and made it illegal to hire anyone under the age of 12.

In 1910 the Bureau of Mines was created as a division within the Department of the Interior. The primary agenda of this agency was to conduct research and investigate incidents, but did not provide the ability to conduct inspections. That authority was not given to the Bureau of Mines until 1941. The first set of safety protocols were not introduced until 1947. The passage of Public Law 80-328 allowed for these standards to be enacted, however, there were no enforcement requirements and therefore expired after one year. The passing of the Federal Coal Mine Safety Act of 1952, while only applying to underground mines and those that employed more than 15 people, provided the first set of substantial measures to help protect these individuals. The primary focus with this Act was preventing major incidents by instituting the following:

- “Required annual inspections in certain underground coal mines;

- Limited enforcement authority given to the Bureau of Mines, including power to issue violation notices and imminent danger withdrawal orders;
- Mandatory safety standards for underground coal mines, with more stringent standards for "gassy" mines;
- Assessment of civil penalties against mine operators for noncompliance with withdrawal orders or for refusing to give inspectors access to mine property (United States Department of Labor, *MSHA History*)."

In 1966, the Federal Coal Mine Safety Act of 1952 was expanded in many different facets. First, it now included those smaller underground mines that were previously exempt. Second, it provided the ability the Federal government with the ability to serve withdrawal orders for deliberately neglecting to comply with the set standards. Third, training and education programs were enhanced.

The Federal Coal Mine Health and Safety Act of 1969, often just called the Coal Act, was one of the most overarching and thorough pieces of legislation passed aimed at improving work conditions. Some of the most notable items to come from this ground breaking Act include:

- "Four annual inspections required at all underground coal mines;
- Two annual inspections required at all surface coal mine;
- Mandatory fines for all violations;
- Criminal penalties for knowing and willful violations;
- Individual State enforcement plans discontinued;
- Safety standards for all coal mines strengthened and health standards adopted;

- Specific procedures created for developing improved mandatory safety and health standards;
- Training grant program instituted;
- Miners given the right to request a Federal inspection;
- Miners disabled by black lung disease provided benefits (United States Department of Labor, *MSHA History*)."

In 1973, the Mining Enforcement and Safety Administration, or MESA, was created by the Secretary of the Interior. The creation of this new agency allowed for the government to separate the safety and health that now fell under MESA from the mineral resource development and research conducted by the Bureau of Mines. Through the passage of the Federal Mine Safety and Health Act of 1977, more often referred to as the Mine Act, a new regulatory committee was established. The Mine Safety & Health Administration, or MSHA; an entity of the U.S. Department of Labor took over responsibilities from the Department of the Interior to enforce safety regulations. While MSHA, the Mine Act also created an independent organization whose sole purpose is to examine the actions of enforcement for MSHA. "Key components of the Mine Act include:

- Four annual inspections required at all underground mines;
- Two annual inspections required at all surface mines;
- Strengthened and expanded rights for miners;
- Enhanced protection of miners from retaliation for exercising such rights;
- Mandatory miner training provisions established;

- Mine rescue teams required for all underground mines (United States Department of Labor, *MSHA History*)."

In addition to the above regulations, the Mine Act also created the Federal Mine Safety and Health Review Commission. This commission was created to act as an independent party when reviewing enforcement actions made by the Mine Safety and Health Administration. An amendment of the 1977 Federal Mine Safety and Health Act was passed in 2006 that required the following:

- "Mine-specific emergency response plans in underground coal mines;
- New regulations regarding mine rescue teams and sealing of abandoned areas;
- Prompt notification of mine accidents;
- Enhanced civil penalties (United States Department of Labor, *MSHA History*)."

Table 3 below compiles the changes in regulations as new acts were passed in the national legislature and presents them in a comparative format.

Table 3. *Key Regulatory Factors by Major Coal Mine Legislation*

	Age Restriction	Incident Research & Investigation	Training Programs	Application to Surface Mines	Application to Underground Mines	Annual Inspections	Miner Rights and Protections	Incident Response and Rescue Teams	Black Lung Benefits	Willful Safety Violation Penalties	Minimum Safety Standards	MSHA Notification of Accidents	Civil Penalties
1891	X (>12 yrs)												
1910	X	X											
1941	X	X				X							
1952	X	X			X (>15 employees)	X					X		X
1966	X	X	X		X	X					X		X
1969	X	X	X	X	X	X (4 underground, 2 surface)	X		X	X	X		X
1973	X	X	X	X	X	X (4 underground, 2 surface)	X		X	X	X		X
1977	X	X	X	X	X	X (4 underground, 2 surface)	X	X	X	X	X		X
2006	X	X	X	X	X	X	X	X	X	X	X	X	X

Source: Mine Safety and Health Administration

Each year the Mine Safety and Health Administration publishes statistics from inspections, injuries, and fatalities. These statistics are based on the inspections performed each year and by injuries or fatalities that are reported. Table 4 takes a look at those statistics from 2015 to 2019. As a whole, the injury rates and fatality rates are fairly consistent throughout the five years presented. An obvious goal is for both of these rates to be zero, especially the fatality rate. While any work related fatality is tragic, these numbers are a far cry from many years ago. According to the Mine Safety and Health Administrations report *Coal Fatalities for 1900 Through 2019*, until 1948 fatalities were in the thousands each year with 1907 being the deadliest at 3,242 (Mine Safety and Health Administration, 2020).

Table 4. Mine Safety and Health Statistics 2015 to 2019

Calendar Year	**2015**	**2016**	**2017**	**2018**	**2019**
Number of Mines	1,457	1,287	1,216	1,191	1,137
Number of Miners	102,867	81,880	82,932	82,853	81,468
Fatalities	12	8	15	12	12
Fatal Injury Rate	0.0131	0.0115	0.02	0.0155	0.0159
All Injury Rate	2.93	2.91	3.19	2.88	2.92
Coal Production[1]	897	728	775	756	706

Source: Mine Safety and Health Administration
[1]*In millions of tons*

While 2020 statistics will not be available until well into 2021, the Mine Safety and Health Administration does provide a running fatality report for the year. As of October 27 there have been five coal mining fatalities this year ((*Fatality Reports* 2020). If this trend keeps on track, 2020 could see the lowest number of fatalities related to coal mining in history.

HEALTH SECTION

While many industries have their own hazards related to health and safety, the coal mining industry has arguably some of the most severe hazards that can have long lasting, often lifelong, effects. Recognizing the severe risks involved in this industry in particular, an intense focus on the health and safety of these workers began. Although there are many different health complications that can come from working in this industry, few are as well-known or discussed as coal workers pneumoconiosis. According to the American Lung Association, "an estimated 16% of coal workers are affected" by coal workers pneumoconiosis (American Lung Association, 2020).

Coal workers pneumoconiosis (CWP), also known as Black Lung Disease, is a pulmonary disease caused by breathing in coal dust over a prolonged period of time. For many individuals, symptoms of CWP don't develop for many years after their first exposure. When inhaled, the dust travels throughout the patients airway and deposits in the lungs producing dust covered macrophages. The lungs try to rid themselves of this foreign material which leads to inflammation. This inflammation results in scar tissue forming. The scar tissue that forms is what doctors are look for when diagnosing CWP. Based on the amount of scarring found in the CT scan or chest X-ray, the diagnosis can be classified as either simple or complicated pneumoconiosis. Simple pneumoconiosis is represented by smaller areas of scar tissue on the lungs. Complicated pneumoconiosis, or progressive massive fibrosis, presents severe, large areas of scarring (American Lung Association, 2020).

The following images in Figure 9 depict what is seen when diagnosing coal workers pneumoconiosis. In the set of x-rays below, obtained through Radiopedia, the left x-ray shows the image produced when looking at a normal, healthy chest x-ray. The dark areas to the left and right of the spine indicate clear lungs without scar tissue. The right x-ray shows the image produced by a patient with progressive massive fibrosis, or complicated pneumoconiosis. The polar opposite is very apparent in this image. The cloudy areas to either side of the spine represent the scar tissue that has developed from the inflammation caused by the inhalation of coal dust.

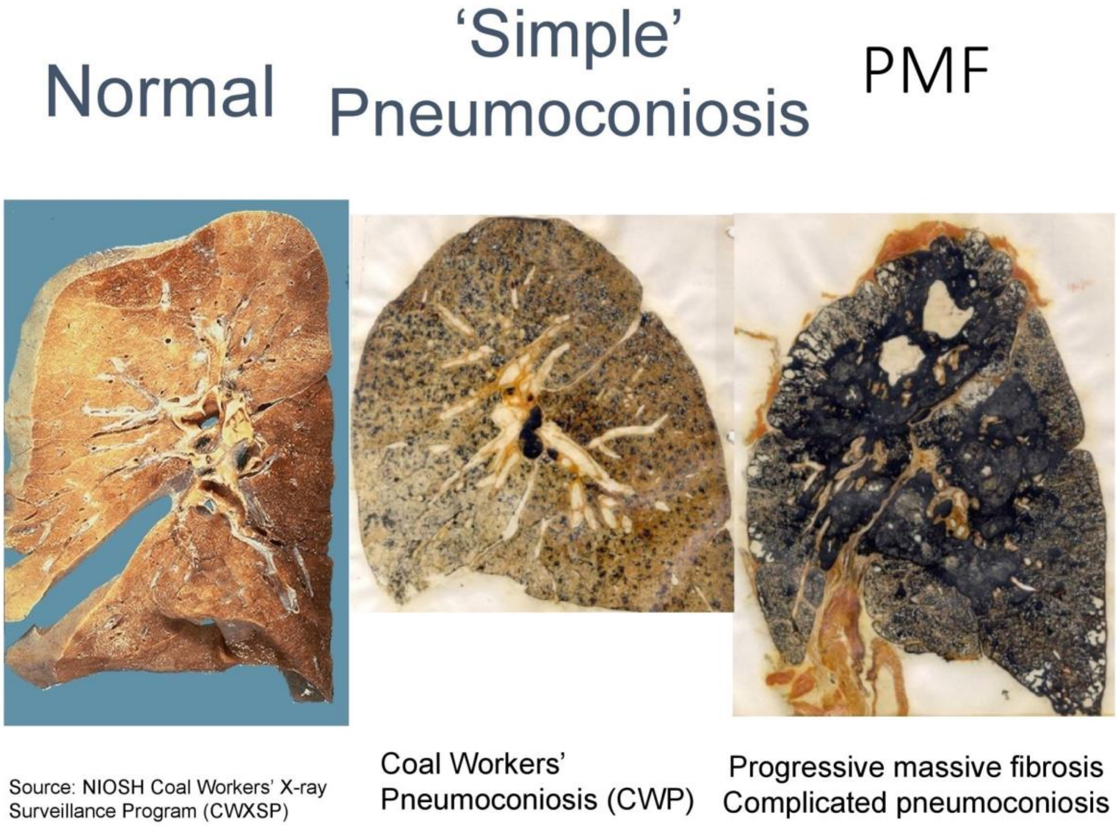
Figure 9.

(Gaillard, *Normal chest x-ray*)

(Murphy & Gaillard, *Progressive massive fibrosis*)

Figure 10, below, is of a PowerPoint slide from presentation by the National Institute of Occupational Safety and Health (NIOSH) showing the progression of coal workers pneumoconiosis in the human lung. The far left image, like the first x-ray, shows that of an actual normal, healthy lung. The middle image shows a more mild/moderate, in comparison, case of CWP or simple pneumoconiosis. The black spots are signs of coal dust deposits and scaring. The third image depicts an extremely advanced case of CWP, which at this severity is considered Passive Massive Fibrosis, or complicated pneumoconiosis.

Figure 10.



(*Progression of CWP*, 2018)

Symptoms associated with coal worker's pneumoconiosis include shortness of breath, cough, chest tightness, and coughing up black sputum (mucus). While the individual may notice these symptoms more frequently after high energy activities, with time, the disease will progress and result in symptoms being noticed during periods of rest (American Lung Association, 2020). Cases of simple pneumoconiosis often present more subtle symptoms in the individual. Complicated pneumoconiosis cases, however, result in more severe symptoms and can lead to an increased risk of developing chronic obstructive pulmonary disease (COPD). No matter the severity of the diagnosis, breathing abilities are negatively affected.

Although there is no cure for coal worker's pneumoconiosis, it can be treated to help provide a better quality of life for the individual by slowing the progression and minimizing the symptoms. After determining the extent of the disease, the doctors can then develop a treatment plan for the individual. According to Johns Hopkins Medicine, this plan commonly includes the following (Johns Hopkins Medicine, 2020):

- Not smoking
- Avoiding all dust exposure
- Using supplemental oxygen
- Taking medications called bronchodilators that open lung passages

While these items are the common issued items and may not be needed continuously, the goal is to slow the progression. For example, an individual may not need supplemental oxygen when cooking a meal but will during or after some form of highly physical activity such as exercising.

In the most severe of cases coal workers pneumoconiosis, a lung transplant may be needed. In a study conducted by David J. Blackley, Cara N. Halldin, and A. Scott Laney for the Respiratory Health Division of the National Institute for Occupational Safety and Health, available data is showing an continued increase in commonality of lung transplants due to CWP since 1996 when the first transplant for this disease was performed (Blackley et al., 2018). A lung transplant can be talked about in two forms; either single or bilateral. A single lung transplant is just as it sounds, a single lung is replaced. A bilateral transplant is the replacement of both lungs in the same procedure. At the time that this study was conducted, the average cost of a bilateral transplant was $1.2 million in the United States. This cost not only included the procedure, but the "period including 1 month before transplantation, through 6 months afterwards (Blackley et al., 2018)."

With the implementation of the Federal Coal Mine Health and Safety Act of 1969, the Coal Workers' Health Surveillance Program (CWHSP) was established. This purpose of this program was to provide underground miners with access to free chest x-rays periodically in hopes of mitigating any current cases of coal workers pneumoconiosis. If certain signs of CWP were present during these exams, the affected miner was transferred to a work area with low dust to help prevent the further development of the disease. After the enactment of this legislation, the percentage of occurrence of CWP in miners dropped from 11.2% at the end of 1974 to 2.0% at the end of 1999. After reaching a historic low, the prevalence climbed to 3.3% at the end of 2006 (Suarthana et al., 2011). While participation in Coal Workers' Health Surveillance Program is voluntary, the National Institute for Occupational Safety and Health wanted to increase the usage of this program in order to help reduce the number of cases. To help, mobile examination units were set up at the mine sites.

In this article from *Occupational and Environmental* Medicine, researchers pulled information based on miner age, length of employment, coal type, mine size by number of miners, mine location, and if available, x-ray readings, when compiling their data. All data obtained was filtered based on the following limiting factors:

- Miners aged 16 and older
- Mine seam height

- Districts (District 1 was excluded due to low number of participants)

At the end of this process, 12,408 miner remained to be utilized in this analysis.

After testing, the results showed that an increased number of cases came from the central Appalachia region. A few of the factors that aided in this were the number of hours worked were higher in this area than in others, and the coal seam heights were lower with the average at around 60 inches. However, it is worth noting that the average concentration of coal dust in the central Appalachia area was lower averages than other areas (Suarthana et al., 2011).

The concentration of dust in underground mines averaged 6 mg/m^3 prior to the 1969 Act being implemented. When this article was published in May of 2011, the compliance limit was 2 mg/m^3 (Suarthana et al., 2011). According to the Mine Safety and Health Administration, as of 2016 there have been over 76,000 deaths due to coal workers pneumoconiosis and over 45 billion dollars in compensation from the federal government since 1968. In an effort to halt the surge in cases of CWP, beginning August 1, 2016, the Mine Safety and Health Administration put new limits on respirable dust into effect. All underground and surface mines must have coal mine dust concentrations that are below 1.5 mg/m^3 (United States Department of Labor, 2016).

In an interview by NPR in 2018, the National Institute for Occupational Safety and Health (NIOSH) released that they had discovered the largest regional grouping of progressive massive fibrosis ever recorded. In a study completed between 2013 and 2017, a total of 416 new cases were confirmed by the National Institute of Occupational Safety and Health across three clinics in the central Appalachia region. These clinics, ran by Stone Mountain Health

Services, treat individuals from key states in the region; Kentucky, Virginia, and West Virginia. Ron Carson, director of the black lung program for Stone Mountain, shed light on the severity of the surge that is being seen. In 1990 when Carson began to implement the program at these clinics, doctors would see five to seven cases, on average, of progressive massive fibrosis a year. Jump ahead to 2018, Carson said they are seeing those numbers every few weeks. Between the end of the NIOSH study and the interview with NPR, Carson and the team involved with the program he oversees saw and additional 154 new cases (Berkes & Lancianese, 2018).

With the implementation of the Federal Coal Mine Health and Safety act of 1969, the Division of Coal Mine Workers' Compensation, or the Federal Black Lung Program, was established. Through the Black Lung Disability Trust Fund, benefit payments and other eligible reasons for compensation are paid out. Revenue is generated for this fund by an excise tax that is imposed on all coal that is produced and sold within the United States. According to Szymendera and Sherlock, 2018 coal excise tax rates for surface and underground-mined coal were $0.55 and $1.10 per ton, respectively; with a max of 4.4% of the total price. In 2019, tax rates dropped to $0.50 for underground and $0.25 for surface, with a 2% max of the total. In the instance of a financial shortfall, the Fund borrows from the United States Treasury's general fund (Szymendera & Sherlock, 2019).

Under the Federal Black Lung Program, benefits are to be paid out first by the last operator to employ the miner. When an operator is acquired by another company, the new company, or successor operator, is responsible for fulfilling payment claims of the original operator. In the event that the operator shutters or is unable to make the payments, the claims are then paid out of the federal fund. Eligibility for benefits as a miner is contingent on full disability status due to pneumoconiosis as a result of coal mining. In the event of the miner's death, the survivors may be eligible for benefits if pneumoconiosis from coal mining was the cause of death. Pneumoconiosis, when discussing eligibility of benefits, is defined as "a chronic dust disease of the lung and its sequelae, including respiratory and pulmonary impairments, arising out of coal mine employment," according to the Black Lung Benefits Act (Szmyendera & Sherlock, 2019). Although not a form of pneumoconiosis, chronic obstructive pulmonary disease (COPD), and other respiratory disease, is covered under this program. Individuals with these conditions can also be eligible for benefits, provided they are the result of being a coal mine employee.

Through this program, miners can be eligible for two types of benefits; medical or disability. Miners eligible for medical benefits receive medical coverage at no cost to them and, typically, see their preferred medical provider. Disability benefits are paid out based on a set rate of 37.5% of the pay rate of federal employee at the GS-2, Step 1 level. Table 3 shows the benefit amounts from 2019 and the change in the basic benefit rate based on the number of dependents.

Table 3. Monthly Black Lung Benefit Amounts for 2019

Category	Monthly Benefit Amount	Basic Benefit Rate (%)
Claimant with no dependents	$660.10	37.5
Claimant with one dependent	$990.10	150
Claimant with two dependents	$1,155.10	175
Claimant with three or more dependents	$1,320.10	200

(Szymendera & Sherlock, 2019)

While being a completely preventable occupational disease, coal workers pneumoconiosis claims the lives of many American workers each year. In a study looking at years of potential life lost compared to life expectancy, researchers found an average of 8.8 years lost for individuals under 65 years of age. Those over 65 years of age had an average of 7.3 years lost. These statistics were based off data from 1999 to 2016. In 1999 the total number of deaths related to coal workers pneumoconiosis was 409. This number decreased sharply from 1999 to 2008, then gradually continued to decline to 112 in 2016 (Mazurek et al., 2018).

ENVIRONMENTAL IMPACTS AND CONCERNS

After the cessation of mining in an area there are two things that often remain. The first is expansive open pits that are hundreds of feet deep as a result of surface mining processes. This method leads to the destruction of the natural landscape and ecosystem in the area. On the flip side, underground mining leaves behind hidden dangers. The large open tunnels well below the Earth's surface over time weaken and subsidence occurs. Subsidence is often a costly fix that is passed on to the owner of the land at the time.

The year of 1977 saw another expansive piece of legislation passed, and for the first time, focusing on the surface mining. The Surface Mining Control and Reclamation Act of 1977 (SMCRA), originally slated to be a temporary program, set forth a regulation program for mine land reclamation operations throughout the country. The goal of this national program was to be a sort of launchpad for state governments to build their own plan and take primary responsibility of regulations and enforcement, sometimes referred to as primacy. In order to achieve primacy, a program must be developed by the State that meets the set benchmarks and be as effective, or more, than the federal regulations provided by the Surface Mining Control and Reclamation Act of 1977. To be approved, the State must also provide evidence that is has the capabilities to execute the developed plan in all legal, financial, and administrative capacities. After approval by the United States Secretary of the Interior, the State takes control and authority of all coal mining and exploration within its region. At current time, only twenty four states have achieved primacy.

Alabama	Alaska	Arkansas	Colorado
Illinois	Indiana	Iowa	Kansas
Kentucky	Louisiana	Maryland	Mississippi
Missouri	Montana	New Mexico	North Dakota
Ohio	Oklahoma	Pennsylvania	Texas
Utah	Virginia	West Virginia	Wyoming

While sweeping federal regulations were not passed until 1977, many individual states began passing their own regulations for mining practices and the reclamation of abandoned mines. Pennsylvania passed their first set of laws in 1968. Many of the issues that Pennsylvania faced were all due to one particular hazard of abandoned mines, acid mine drainage. Acid mine drainage occurs when "iron sulfide (found in coal) is exposed to water and air, and then separates into iron and sulfur, producing sulfuric acid (Testa 48)." If this drainage is contained in a pond or reservoir of some type, it is much easier to manage and correct. Pennsylvania's issues were much more severe than that. The drainage from many of the mines was draining into the major rivers of that area. According to Testa, "The U.S. Geological Survey estimated that the costs for cleaning these watersheds were between $5 billion and $15 billion (Testa 48)."

Another state that began passing reclamation laws prior to 1977 is Indiana. The state passed its first piece of legislation in 1941, nearly 25 years prior to any federal regulations. Like Pennsylvania, Indiana also had to deal with the many challenges of acid mine drainage. The Indiana Division of Reclamation treated this situation in very different way than Pennsylvania. Instead of pooling the water into a pond or reservoir and then removing it, Indiana's Division of Reclamation built a man-made stream and used earthen materials to filter the water naturally. One of the water systems that the state has been working on is the South Fork Patoka River.

According to Testa, “Water samples taken from the river in 1966 had a heavily acidic pH of 2.8; samples from 2009 had a pH of 7.71 (Testa 51).” After many years of work and effort, some sites have made a recovery and many native wildlife species have moved back into the area, including the endangered river otter species that resides in the state.

The process of repairing the previously mined land to a state similar to its original landscape before mining began is referred to as land reclamation. This means the reclaimed land must meet all standards of safety, health, and environmental specification as set by law. This concept of land reclamation is fairly new in the grand scheme of coal mining and is the end stage for abandoned, typically surface mined, sites in the United States. The purpose of this reclamation process is to help rid the area of potential hazards that are present in these areas and to restore the land back to a natural setting that will promote wildlife expansion back into the area.

In an effort to help fund reclamation efforts, federal fees were established and placed on each ton of coal that is recovered. As stated above, the Surface Mine Control and Reclamation Act was originally intended to be a temporary program. Because of this, the authority to collect these fees, after the original fifteen years set by the initial legislation expired, has needed to be extended. An extension has been approved through additional legislation seven times since 1977, with the current extension expiring in 2021. Beginning in 2013 the following fees were assessed (*Reclaiming Abandoned Mine Lands* 2020):

- Surface Mined Coal - $0.28 per ton;
- Underground Mined Coal – $0.12 per ton;
- Any Mined Lignite – $0.08 per ton

The fees collected are deposited directly into the Abandoned Mine Land Fund. The Abandoned Mine Land Fund provides financial support through grants for reclamation projects. As of September 30, 2019, the total amount that had been collected, as well as earned interest, was $11.496 billion. Here is what the allocation of the Abandoned Mine Land Fund looks like as of that date (*Reclaiming Abandoned Mine Lands* 2020):

- Abandoned Mine Land Grants - $5.935 billion;
- United Mine Workers of America Health and Retirement Funds - $1.511 billion;
- Office of Surface Mining Reclamation and Enforcement Operation and Abandoned Mine Land Emergencies – $1.816 billion;
- Unappropriated Remaining Balance – $2.233 billion

Along with setting a fee collection framework, the Surface Mine Control and Reclamation Act of 1977 identified a set of standards that must be met when applying for a mining permit. This Act requires all companies to have a comprehensive plan before being approved for the permit. This plan must include a detailed description on how the company intends to properly reclaim the land. Also included in the plan for rehabilitation should be the following items:

- "description of the mining operation;
- Proposed life of the mine;
- information to demonstrate that reclamation can be accomplished;
- type of mining process and technique;
- direction of mining;
- access roads;
- facilities for coal processing;

- coal processing waste disposal sites;
- structures;
- water impoundments and land uses;
- stream diversions;
- water and air pollution control facilities;
- overburden and topsoil handling storage areas (*Citizen's Guide to Coal Mining and Reclamation in Indiana* 2007).

In Indiana, the Division of Reclamation oversees the Abandoned Land Mine Program. This office is an entity within the Department of Natural Resources and is responsible for the reclamation projects within the state. This organization has overseen many different projects and received numerous accolades at the regional and national level for their work. In September of 2020, a project of the Indiana Division of Reclamation received a regional award from the Office of Surface Mining Reclamation and Enforcement for their work in Pike County Indiana. According to the press release by the Indiana Department of Natural Resources, Indiana has taken on many projects since 1982 that has resulted in the restoration of nearly 10,000 acres of Abandoned Mine Land (Indiana Department of Natural Resources, 2020).

As mentioned earlier, subsidence is large concern within the reclamation world. What drives a large part of this concern is that while mines now are able to be mapped with extreme accuracy, it is extremely difficult to identify where all previous mining locations are due to a lack of surveying at the time. This is made even more difficult by the fact that these were, by majority, underground mines. In a subsidence event, the once stable bedrock over top an underground mine gives way due to a gradual weakening of the support structures left behind.

In many cases these supports are the "pillars" left from room-and-pillar mining practices. Being that today's mining technology is much more advanced than many years ago, the focus for restoration is directed entirely at old abandoned mines.

In Southern Indiana, where underground mining was the predominant method for many years, subsidence events are a major concern. As the pillars left in the mine shafts underground start to erode away issues like the ones depicted in Figure 11 A-C shows an example of a subsidence event in Warrick County, Indiana. This home, which has since been demolished, was built in a subdivision that lies entirely over an old mine shaft. Figure 11D shows a map of the subdivision with the yellow triangle indicating the location of this residence and the blue shading representing known underground mine locations. This instance of a subsidence event is not all that surprising. According to Nathan Blackford, "Warrick County is considered one of the four most active subsidence areas in Indiana (Blackford, 2012)."

Figure 11 A, B, & C. A residence that has experienced a subsidence event. (Blackford, 2012)

Figure 11 D. A map of the Quail Crossing subdivision in Warrick County, Indiana. (*Source: Indiana Department of Natural Resources Coal Mine Information System*)

In the time since the passing of the Surface Mine Control and Reclamation Act of 1977, there has been great progress made in securing and eliminating hazards that have been left behind by years of coal mining practices. According to a statement published by the United States Department of the Interior on June 7, 2017, the accomplishments of the Abandoned Mine Land Program are listed as thus;

- “Closure of over 43,000 abandoned underground mine shafts and openings;
- Eliminated over 950 miles of dangerous highwalls;
- Abated over 3,700 dangerous water bodies;
- Eliminated over 129,000 acres of dangerous spoils and embankments;
- Restored 35,000 acres of streams and land;
- Replaced infrastructure for over 53,000 polluted water supplies (Owens, 2017).”

CONCLUSION

The world of coal is one that can be explored over and over and still find something new each time. This industry is an ever changing and evolving piece to the puzzle of human life. While the trend is appearing to move towards more renewable resources, the dependency on coal in the United States is still holding strong. For many, this small black rock of carbon provides the power needed in everyday life. This small rock that took hundreds of millions of years to create combusts and provides energy for a microscopic portion of that time.

An industry that once had a yearly fatality total of over 3,000 is now much safer after the enactment of several pieces of legislation that had the life's of the coal mine workforce in its best interest. The health and safety of these individuals is one that will be studied for years to come, for both the good and bad. Although the dial for cases of coal workers pneumoconiosis is trending upwards, there is hope that this disease will be brought back under control.

An industry that once took the land that was mined for granted is now working to repair the ecosystems that were destroyed. Coal may not be the go to choice in the future, but it will keep the lights on for now.

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