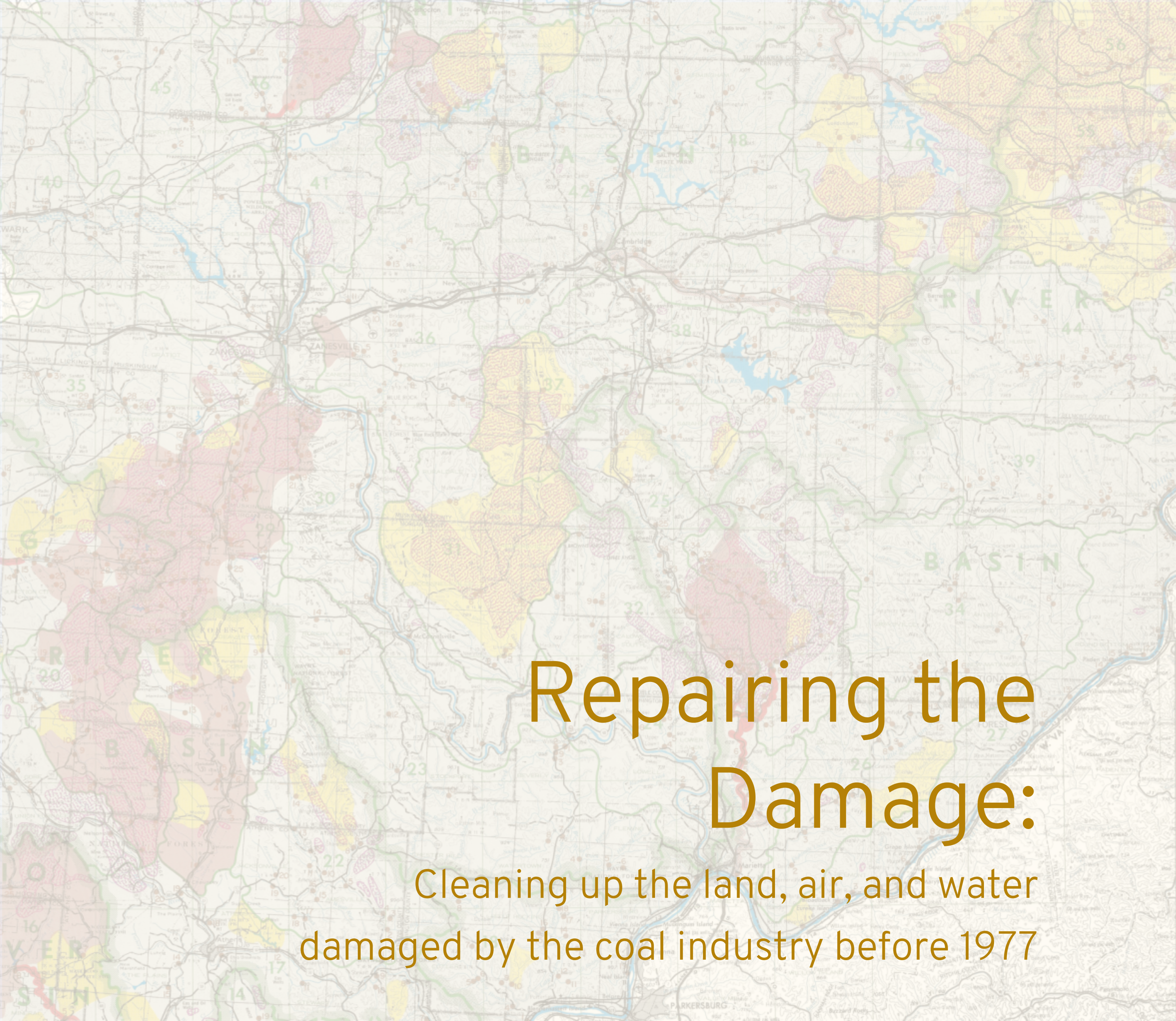

Repairing the Damage:

Cleaning up the land, air, and water damaged by the coal industry before 1977

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Eric Dixon

Ohio River Valley Institute

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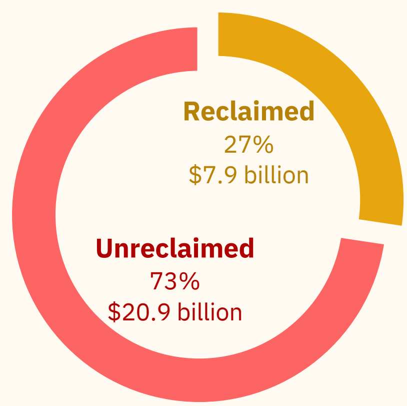
Executive Summary

For more than 200 years, the coal industry extracted billions of tons of coal in the US, damaging thousands of acres of land and water and leaving much of it unreclaimed.[1] In this report, I demonstrate why it is critical to address the damaged sites that remain: they threaten the injury and death of residents, deter development, harm local ecosystems, and contribute to climate change. I also estimate the cost of cleaning up the remaining damage and project future reclamation program revenues. I estimate the number of jobs required to repair this damage and investigate the pay of common reclamation occupations. I close the report with a series of policy recommendations.

In 1977 Congress created the Abandoned Mine Land (AML) program to repair the damage of the coal industry prior to the genesis of the AML program. Since 1977, 978,000 acres and $7.9 billion worth of this damage has been cleaned up (see figure 1).[2] The AML program has remained severely underfunded relative to the massive backlog of unreclaimed damage: in more than four decades, the program has cleaned up only 27% of total damage as of 2020.[3] Congress chose at multiple junctures to keep AML fee levels low, rather than prioritize the cleanup of extensive damage to the land, air, and water of rural, persistently poor communities.[4] Now, the coal industry is rapidly declining and with it the ability to finance the AML program through fees on coal production.

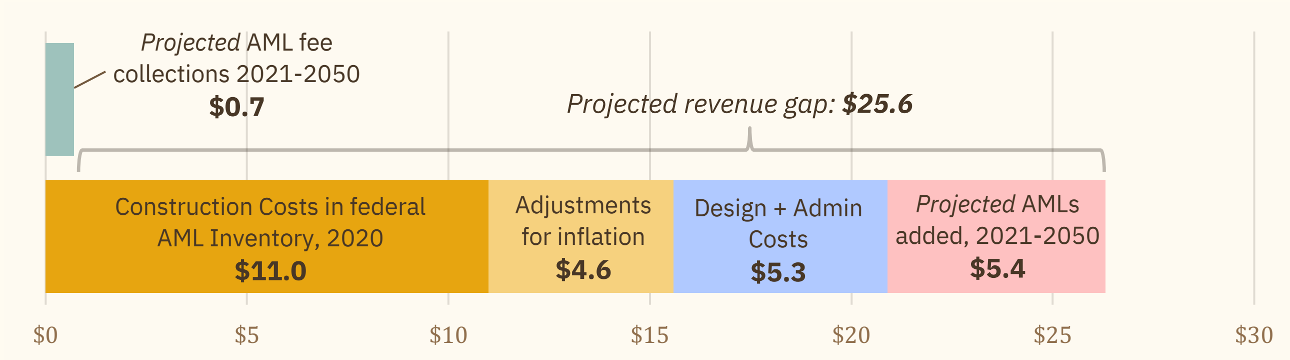
Figure 1. Cost to address damage from AMLs, 2020



I estimate that there are $20.9 billion in unreclaimed AMLs remaining, as of 2020 (medium scenario estimate).[5] This estimate is much larger than the $11.0 billion in costs listed in the federal AML inventory because I A) use a method based on more recent average cost estimates and adjust for inflation, and B) include design and administration costs (not just construction costs, as in the federal inventory). As more AMLs are discovered or deteriorate amidst impacts from climate change, I project that $5.4 billion in unreclaimed AML costs will be added to the inventory over the next 30 years, bringing the total unreclaimed cost to $26.3 billion by 2050 (medium scenario).[6] See figure 2 for these cost estimates.

The program already faces a funding shortfall relative to expected reclamation costs. If the current AML fee levels are reauthorized through 2050, I project an estimated $0.7 billion in 2021-2050 collections, meaning the AML program's revenue gap will balloon to an estimated $25.6 billion by 2050 (medium scenario).[7]

Figure 2. Unreclaimed AML costs and projected AML fee collections, billions (medium scenario)



Key Findings

- Only 27% of total AML damage has been repaired (by 2020 cost), and more than 850,000 standardized acres of damage remain.
- The estimated cost to reclaim all unrepaired AMLs is $18.3 to $24.4 billion as of 2020 (low and high scenarios)—significantly higher than the $11.0 billion in unreclaimed construction costs in the federal AML inventory. Unreclaimed costs will likely grow to $21.0 to $33.6 billion by 2050.
- 84% of remaining damage is concentrated in the 7 Appalachian states of PA, WV, OH, KY, AL, VA, and TN. PA alone contains 41% of remaining damage and WV holds 24% (by 2020 cost). 5.5 million people in Appalachia live within 1 mile of an AML site, including 1 in 3 West Virginians.
- Surface-mined AMLs can produce greater runoff and carry sediment that clogs waterways, increasing flooding. AMLs continue to clog 5,500 miles of streams—enough to stretch across the continental US. Flooding will likely exacerbate as peak rainfall increases with climate change in areas like Appalachia.
- AMLs discharge at least 320,000 gallons of water pollution per minute—enough to fill an Olympic swimming pool every 2 minutes.
- AML mine fires emit CO_2, and abandoned underground mines leak CH_4 –emissions that are currently unregulated and could be considerable sources of greenhouse gas (GGH) emissions. Abandoned coal mines are the 11th largest source of CH_4 emissions in the US, and there remain at least 7,000 acres of AML mine fires that will cost more than $1 billion to remediate.
- If 25% of unreclaimed AML acreage were reforested, forests could potentially sequester 232,000 metric tons of CO_2 annually—about as much as is emitted from powering 40,000 homes for a year.
- If we clean up half of remaining AML damage in 10 years ($1.3 billion per year), it would support 6,909 direct jobs for 2021-30: 3,178 construction jobs with $30 assumed hourly gross pay, 3,317 design jobs with state/tribal agencies, and 484 federal administration jobs (medium scenario). An estimated 10,384 induced and indirect jobs—or, 17, 293 total jobs—would be supported. Cleaning up all AMLs ($26.3 billion) would support an estimated 138,024 direct job-years and 344,403 total job-years.
- Common AML construction occupations include Construction Laborers and Operating Engineers, whose median hourly pay in AML states is around $17.60 and $22.87, respectively. Many of these workers are likely paid above a poverty wage but below a living wage. Some of these jobs are unionized, but the extent of union density is unclear and likely varies widely by state.

Policy recommendations

The longer that Congress allows thousands of acres of AML-damaged land and water to linger, the more these sites threaten coalfield communities, downstream residents, and the planet.[8] The need to repair mine-scarred damage is urgent. It will require drastic increases in the scale of funding as well as ambitious changes to policy.

Poverty has persisted for decades in many coal areas, where economic distress can be sharp—including for the many coal workers already laid off en masse and the many more expected to be jobless in coming years.[9] The misery that accompanies economic distress continues to be borne disproportionately by women, by people of color, and by young people: unemployment and poverty rates are higher among these groups in AML counties.

Amidst these intersecting crises, policymakers should consider the program as part of a massive national economic mobilization to address climate change and inequality. To approach the AML program with a myopic focus on making AMLs safer—though important—is to ignore the opportunity presented by the location, size, and nature of mine reclamation to address larger crises. As a federally funded program with jobs potential in rural coal communities, the program is uniquely positioned to help address inequality, economic distress, and environmental harm facing former coal regions and the planet. Policymakers should consider the following actions:

1. Ensure reclamation workers are paid a living wage, build power in AML workplaces, and prioritize firms owned broadly and/or by historically disadvantaged groups.

Policies include: Davis-Bacon wage regulations and a living wage floor, project labor agreements, local and targeted hire provisions, apprenticeship requirements, aggregating contracts to make them more viable for union contractors, prioritizing certain types (broadly-owned or historically disadvantaged) of firms, and more.

2. Create a public reclamation jobs program under a Civilian Climate Corps (CCC) to ensure jobs are accessible among those most in need and in rural coal communities.

A public reclamation jobs program within the CCC could fundamentally change the impact of the AML program, transforming it into a program that creates thousands of well-paying jobs that are accessible to those who need them most in some of the poorest communities in the country—at an investment scale that could raise the bar for wages and benefits, safety, and reclamation techniques in those rural construction markets in general.

The program could have two employment tracks: one could provide one-year job terms, require no previous background in construction, and include training and skills development (modeled after a past CCC mine reclamation program in OH); the second track could provide permanent reclamation positions for more experienced workers (modeled after current in-house crews at the PA AML agency). It is critical that the agency provide hiring preferences and/or set-asides for former coal workers, people of color, women, formerly incarcerated workers, and those recovering from substance abuse.

3. Strengthen mine reclamation to incorporate ecological health, prioritize reforestation and abating GGH emissions, and bring more land into public and local stewardship.

Under current law, to "reclaim" an AML is only to remove its immediate danger to humans. Policymakers should update AML reclamation to incorporate enironmental health as well. This could be accomplished by requiring reforestation on applicable sites and/or by prioritizing AMLs that emit greenhouse gases, such as mine fires and underground AMLs. Where applicable, reforestation presents many benefits: it 1) sequesters carbon, 2) cleans water discharge that can be polluted by coal deposits, 3) reduces water runoff (and lowers flood risk), and 4) increases native wildlife habitat and biodiversity.

The CCC should use AML reclamation as a legal mechanism to bring more land under public and local stewardship – especially in cases with absentee or corporate land-owners and where owners are tax delinquent. The CCC could purchase impacted land, reclaim it, and then either put it into public stewardship or the stewardship of local land trusts or non-profits.

4. Support mine reclamation training and research program(s).

A big uptick in reclamation will likely increase the demand for reclamation jobs. Congress should fund OSMRE to support reclamation workforce training and research program(s)– in partnership with AML agencies, higher education, and unions – to train this next generation of workers.

5. Update the federal AML inventory and strengthen data collection and reporting.

In order to gather a more accurate assessment of remaining AML damage, Congress should fund OSMRE, states, and tribes to lead a holistic update of the AML inventory to be completed in 3 years. Data collection should be strengthened to include GGH emissions, payroll data, and more.

6. Double AML fee levels and extend collections through 2050.

Current fee levels have an effective fee rate of 0.6%, nearly half the 1.08% effective rate when the fees were created in 1977. Doubling fee levels would raise the effective rate to 1.2% and generate an estimated $1.1 to $5.9 billion in collections by 2050 (low and high scenarios).

7. Appropriate $13 billion in AML reclamation over the next 10 years. In 3-5 years, once the inventory is updated and more precise remaining AML costs are available, then appropriate more funding to complete (nearly) all remaining AML cleanup by 2050.

A $13 billion appropriation for AML cleanup would address half of remaining AML damage according to best estimates based on current (incomplete) data. Frontloading AML reclamation would repair AML damage whose impacts worsen over time and would immediately ramp up job creation. It would support 6,909 direct jobs per year, 2021-2030. With an updated inventory, Congress should then appropriate more funding for 2031-50. A significant portion of the AML Fund should be retained after 2050 to fund the ongoing costs for acid mine drainage (AMD) treatment systems and for future AML problems, which are likely to arise as sites deteriorate.

Community Context

Massive recent job loss has sharpened the pains of persistent poverty, racial and gender inequality, and absentee land ownership in coal regions.

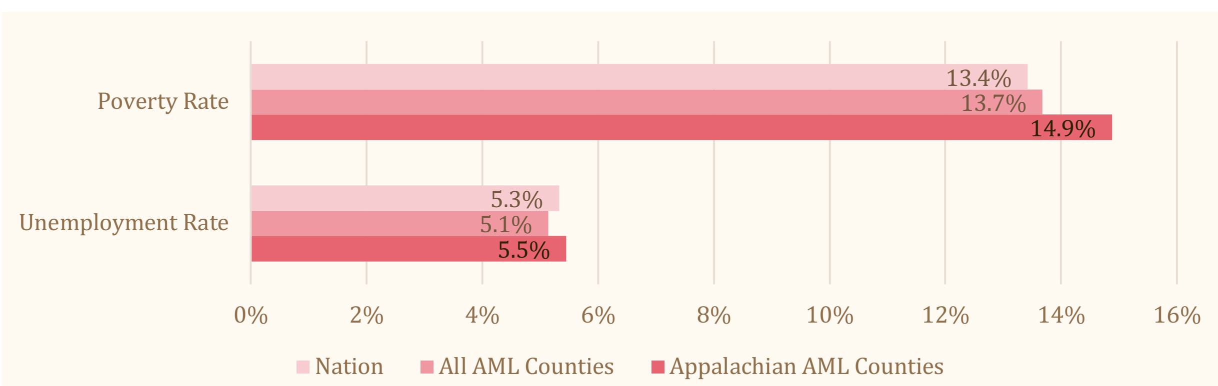
Unemployment and poverty in Appalachian AML counties –which contain 84% of remaining AML damage—are higher than both the nation and their respective states. Abandoned coal mines are located predominantly in rural communities that are the frontline for a confluence of economic, social, public health, and environmental crises. Many rural communities in coal regions –particularly in Appalachia – have experienced persistent economic distress and poverty for decades.[10]

The poverty rate in 2019 was higher in counties with AML damage relative to national average (figure 3). It was worse in Appalachian AML counties, where the poverty rate was 1.5 percentage points higher than the nation.

Despite massive growth in coal production over the past half century, coal jobs have been steadily declining since a peak in 1923: even when the coal industry was growing, employment in many coal communities was often shrinking.[11] Since the Great Recession and the decline of the coal industry over the past decade, many of these coal communities have declined even further. From 2011 to 2020, 55% of the country's coal jobs have been lost.[12] Joblessness in Appalachian AML counties – where coal job loss has been severe – was 0.4 percentage points higher in 2019 than the national average. While unemployment in AML counties overall was slightly lower than the national average, this is explained in part by a labor force participation rate that was 1.7 percentage points lower than the nation.

If we compare Appalachian AML counties to their state averages, we see a similar trend: in all 7 Appalachian states but Alabama and Pennsylvania, AML counties had higher unemployment and poverty rates than the state on average.

Figure 3. Poverty rate and unemployment rate, 2019



The opioid crisis has struck many communities in coal regions especially hard, leaving thousands struggling to recover from substance abuse without the proper support and a stigma that can make it difficult to find work. The fall in coal jobs will likely continue as we shift toward a clean energy economy. While the jobs have left, much of the land remains in the hands of absentee owners.[13] The little coal that remains in production contributes to the changing of our climate—as does the methane leaking from abandoned mines.

Within AML counties, people of color, women, young people, and those without a college degree have disproportionately high indicators of economic distress.

People of color in coal regions, like in other parts of the US, have experienced a long history of racism, from the criminal justice system to the economy, where racial gaps persist.[14] Black coal miners were often the "last hired, and first fired" in the mines, and the share of miners who are Black is now a fraction of historic levels.[15] Within AML counties, the unemployment rate *and* the poverty rate is higher for all races/ethnicities than for the white population (except for the Asian unemployment rate) (figures 4 and 5).

Women have historically borne the brunt of unpaid care work in the US, dedicating hours of weekly work to the home but not participating in the formal economy at the same rates as men.[16] This trend is now finally shifting, but women in coal states continue to face a pay gap.[17] In AML counties in 2019, women had a lower rate of joblessness (figure 4), but this is because their participation rate in the formal labor force is still 9.5 percentage points lower than for men. Women in AML counties are poor at a rate 2.5 percentage points higher than for men (figure 5).

Young people and those with less formal schooling also disproportionately face economic distress. Young people had a 4.7 percentage point higher poverty rate than people age 18-64 in AML counties in 2019. People with High School degree were in poverty at a rate 9.6 percentage points higher than people with a bachelor's degree.

Figure 4. Unemployment rate by gender and race, AML counties, 2019

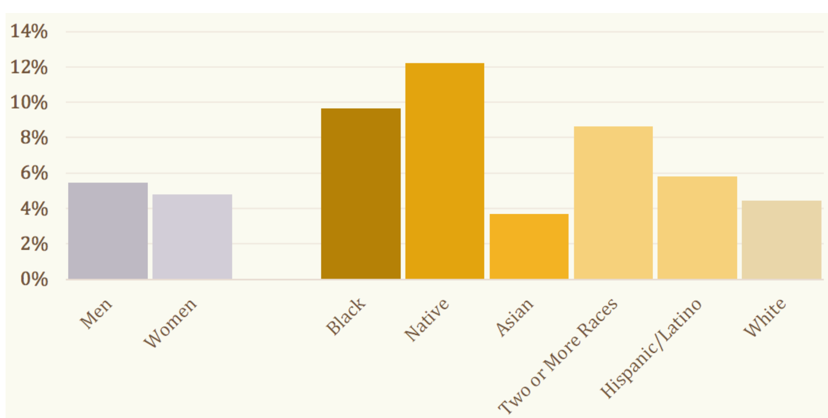
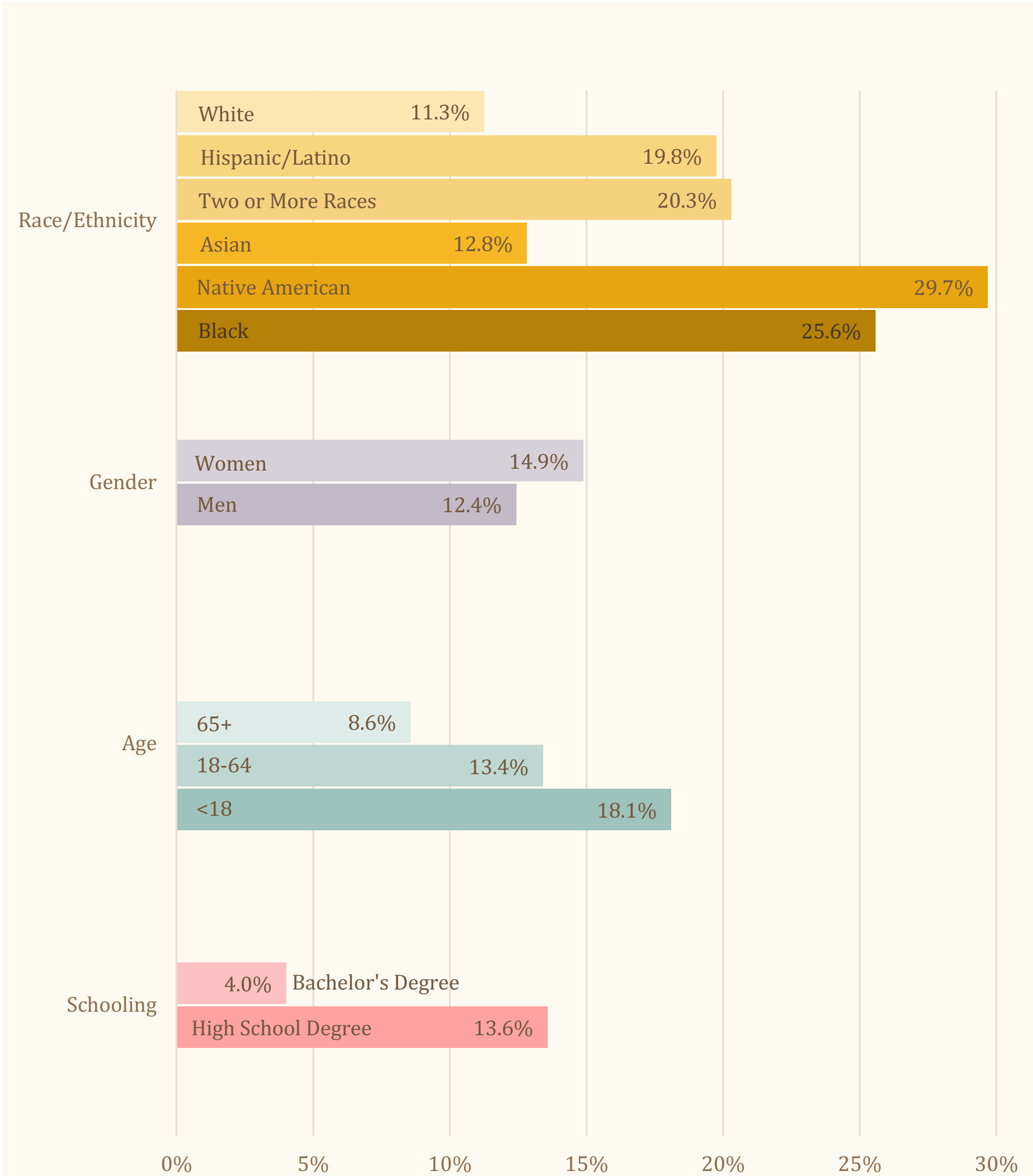


Figure 5. Poverty rate by race/ethnicity, gender, age, and schooling, AML counties, 2019



AMLs 101

What are abandoned mine lands (AMLs)?
Coal AMLs are the land, water, and air damaged by pre-1977 coal extraction.

For over 250 years coal provided cheap heat and electricity that powered the American economy. The historical benefit of coal is undeniable, yet it has not come without great costs. Before coal can be burned for energy it must be extracted from the earth, a process that necessarily damages and pollutes land, water, and air.[18] Since the country's first coal mine opened in 1736, the coal industry has extracted *billions of tons* of coal. [19] During this long history, the industry routinely abandoned mines—and the damage of that mining—once coal was extracted. [20]

According to a study from the US Department of the Interior, by the mid-1960s more than 60% of the land surface-mined for coal in Appalachia was not reclaimed or was reclaimed inadequately and mining had left about 20,000 miles of highwalls.[21] Another study found that by the late 1970s, around 2.3 million acres had been surface mined in Appalachia—mostly for coal.[22] A 1965 study found "that more than 60% of 318 sampled Appalachian coalfield streams were affected by mining-origin sulfate, acidity, and other pollutants."[23]

The accumulation of abandoned mines was made possible by the lack of any federal system to repair the damage caused by coal mining. Many mining states had passed reclamation requirements by the 1970s, but they were so weak that the Asst. Attorney General of Pennsylvania characterized their impacts as "disastrous consequences resulting from historic failure."[24] Congress finally passed the Surface Mining Control and Reclamation Act (SMCRA) in 1977 and with it created the Abandoned Mine Land (AML) program to repair the damage of the coal industry prior to 1977.

Coal AMLs include not only abandoned mines themselves, but damage from coal extraction and processing, such as polluted streams, coal loading facilities, and methane leaking from abandoned mines. AMLs include 30 different Problem Types (PTs) (figure 6). Group A problems are typically closer in proximity to humans and pose a greater immediate danger, but Group A and B AMLs both represent significant AML damage to land, air, and water.[25]

Figure 6. Reclaimed & Unreclaimed AML Acres and Costs, by Type[26]

GPRA is a standardized acre measurement calculated by federal officials in order to develop a common unit to compare problem types with different standard units (miles, feet, acre, etc.)

			Acres			Units	Costs	
	Type	Unit	Reclaimed acres (GPRA) Source: eAMLIS	Unreclaimed acres (GPRA) eAMLIS	% of total unreclaimed acres eAMLIS	Unreclaimed units eAMLIS	Median cost per unit IMCC/NAAMLP	% of total unreclaimed cost (medium scenario, 2020)
GROUP A	Clogged Streams	Miles	13,405	27,539	3.2%	5505	$333,118	11.8%
	Clogged Stream Lands	Acres	42,489	39,942	4.7%	28090	$20,599	3.7%
	Dangerous Highwalls	Feet	85,349	111,309	13.0%	7375488	$147	7.0%
	Dangerous Impoundments	Count	14,171	7,625	0.9%	1523	$24,324	0.2%
	Dangerous Piles and Embankments	Acres	30,448	21,161	2.5%	21129	$25,332	3.4%
	Dangerous Slides	Acres	5,699	2,379	0.3%	2399	$163,331	2.5%
	Gases: Hazardous/Explosive	Count	88	12	0.0%	12	$19,547	0.0%
	Hazardous Equipment and Facilities	Count	1,310	345	0.0%	3388	$5,000	0.1%
	Hazardous Water Bodies	Count	12,287	9,178	1.1%	1831	$46,657	0.5%
	Industrial/Residential Waste	Acres	1,888	1,023	0.1%	996	$15,217	0.1%
	Portals	Count	2,390	1,253	0.1%	11965	$6,108	0.5%
	Polluted Water: Agricultural & Industrial	Count	2,981	12,504	1.5%	2501	$20,791	0.3%
	Subsidence	Acres	10,529	12,909	1.5%	12911	$42,215	3.5%
	Surface Burning	Acres	2,251	434	0.1%	434	$52,739	0.1%
	Underground Mine Fires	Acres	9,466	6,495	0.8%	6494	$112,946	4.7%
	Vertical Openings	Count	3,861	782	0.1%	7693	$3,289	0.2%
GROUP B	Polluted Water: Human Consumption	Count	286,510	27,055	3.2%	3123		28.4%
	Bench	Acres	828	6,044	0.7%	6044		0.2%
	Equipment Facility	Count	98	139	0.0%	1394		0.1%
	Gobs	Acres	10,481	6,663	0.8%	6698		0.8%
	Haul Road	Acres	4,444	2,693	0.3%	2694		0.1%
	High Wall	Feet	7,104	120,636	14.1%	8444668		12.1%
	Industrial/Residential Waste	Acres	379	239	0.0%	244		0.0%
	Mine Opening	Count	148	1,125	0.1%	3017		0.1%
	Other		4,331	2,376	0.3%	13666		0.6%
	Pits	Acres	10,396	5,884	0.7%	5854		0.5%
	Slump	Acres	1,024	2,203	0.3%	2207		1.1%
	Slurry	Acres	3,163	826	0.1%	825		0.1%
	Spoil Area	Acres	108,491	138,566	16.2%	138534		8.1%
	Water Problems	Gallons/Min	302,480	284,087	33.3%	320783		9.1%
	Total		978,489	853,426	100.0%			100.0%

Impacts

Why are AMLs a problem?

Human safety: AMLs threaten the lives and health of residents.

Over just the past couple decades, at least 24 people have died as a result of AMLs.[27] Most are drownings or fatalities caused by falling debris from highwalls. Since the AML program started, reclamation has protected 7.2 million people from injury or death, according to OSMRE.[28] In Appalachia, about 5.5 million people live within 1 mile of an AML site (reclaimed or unreclaimed) —about 1 in 10 people.[29]

In addition to immediate danger, environmental problems from AMLs—especially water pollution and mine fires—may also contribute to long-term negative health impacts of local residents.[30] For example, underground mine fires can smolder for decades, leaving physical hazards and emitting toxins likely to cause adverse respiratory and cardiovascular impacts and even increased mortality.[31]

Local economies: AMLs deter local development.

Many AMLs are located in rural communities that have experienced persistent poverty for decades (see above for more on economic distress in AML counties). AMLs likely deter growth in these communities, even if they were not the original cause.[32] When a community does not have clean water, for example, or a coal waste pile sits in the middle of town, it can be difficult to pursue new community projects or start new small businesses. The North Branch of the Potomac River, for example, once ran orange from AML pollution, but after being cleaned up now supports a thriving boating and angling industry.[33]

Environment: AMLs harm the local environment and contribute to climate change.[34]

AMLs can cause a diversity of local environmental damage that includes 1) destruction of wildlife habitat, 2) severe flooding, 3) water pollution such as acid mine drainage, as well as global impacts like 4) greenhouse gas emissions from mine fires and methane leaks from underground mines.

— Loss of biodiversity and wildlife habitat

Damage from AMLs have lowered the biodiversity of terrestrial wildlife and plant communities in impacted areas, due in part to loss of habitat.[35] The flora and fauna of Appalachian forest ecosystems are among the most biodiverse and most threatened in the world.[36] Plant diversity and productivity on many landscapes impacted by AMLs are lower due to "coarse texture, compaction, poor water-holding capacity, low fertility, and in some cases high acidity."[37] Many of these landscapes now lack large trees, and non-native species are common. According to the Appalachian Regional Reforestation Initiative, "most native Appalachian wildlife species require primarily forested habitats," yet outslopes, highwalls, acid mining drainage, and other damage from mining has had severe negative impacts on these forests and on native wildlife.[38]

— Increased risk of flooding

A) Higher water runoff from land with fewer trees and compacted soil and B) streams clogged by erosion from mines can both increase local flooding—which may be exacerbated by climate change.

The loss of forests and poor vegetation on mined landscapes can lead to erosion, carrying exposed minerals and sediment from the mine site to waterways and clogging the stream—which can damage aquatic life and contribute to flooding.[39]

There remain more than 5,500 miles of streams clogged by damage from AMLs and more than 28,000 acres of Clogged Stream Lands, according to the federal AML inventory.[40] Clogged streams, coupled with increased water runoff from mine sites, can increase local flooding.[41] Regarding mining's impact on stream flow, the state geologist of Kentucky explains, "If you were to pick a really general conclusion, in broad terms, mining results in an increase in peak discharges during storms." [42] For example, a 2009 flash flood in Central Appalachia was due in part to a 51% increase in stream flow from mining; in other court proceedings, scientists have argued that mined areas produce more runoff.[43]

Much of the increase in runoff likely comes from active mines or surface mines after 1977, yet deforestation and other damage from pre-1977 surface mining likely contributes to increased flooding. [44] As the climate changes, these floods in mining areas are likely to become more common, and the damage to human lives and property can be severe.[45] For example, in Kentucky flooding killed 41 people and cost about $40 million in annual losses over the past 11 years.[46] Related AML problems like landslides and mine blowouts will likely also become more common as flooding increases.[47]

As the climate shifts, coal regions such as Appalachia will likely see more rainfall—probably from larger storms with higher peak precipitation.[48] Nine watersheds in Appalachia could see stream flows increase by 15-25% by 2040 due to climate change.[49] One analysis estimates that heavy rainfall events have already increased in these areas over the past 50 years.[50] A recent analysis estimates that home flood risk in Central Appalachia is much higher than previous government estimates which did not adequately account for a changing climate—and this flood risk is expected to rise in the coming decades. [51]

Box 1. AML Damage in Appalachian States

Because the vast majority of coal mining in the US prior to 1977 occurred in Appalachia, the vast majority of unreclaimed damage is in the seven Appalachian states of Alabama, Kentucky, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia. These Appalachian states make up 82.4% of unreclaimed acres in the federal inventory and 84.2% of unreclaimed costs (see figure 7). Damage is concentrated in Pennsylvania and West Virginia in particular: roughly half of unreclaimed acres and two-thirds of unreclaimed costs are in these two states. For comparison, no other state or state tribe has a share of unreclaimed acres or costs that is even in the double digits. Wages of common AML reclamation occupations in Appalachian states tend to make below the national average, with the exception of Pennsylvania and Ohio (figures 13 and 14).

Appalachian states make up **84.2%** of unreclaimed AML costs

Figure 7. Unreclaimed acres & costs, Appalachian States[52]

		Alabama	Kentucky	Ohio	Pennsylvania	Tennessee	Virginia	West Virginia	All other States & Tribes	Nation
Nearby Population	**Population** who live within 1 mile of an AML	387,115	407,905	949,284	2,723,932	75,037	117,161	809,850		
	% of State Population (2010 Census)	7.49%	8.59%	7.60%	17.66%	1.17%	1.44%	30.41%		
Acres	**Unreclaimed Acres** (GPRA)	73,216	34,402	69,219	288,090	14,426	50,399	173,797	149,844	853,393
	%	8.6%	4.0%	8.1%	33.8%	1.7%	5.9%	20.4%	17.6%	100%
Costs	**Unreclaimed Costs** (2020, medium scenario)	$886,826,834	$1,187,928,910	$978,372,500	$8,512,460,705	$126,073,441	$809,135,948	$5,090,972,801	$3,305,588,292	$20,897,359,430
	%	4.2%	5.7%	4.7%	40.7%	0.6%	3.9%	24.4%	15.8%	100%
Top 5 Common Problem Types (by GPRA)		Spoil Area	Clogged Stream Lands	Clogged Stream Lands	Water Problems	Spoil Area	Highwall	Highwall		
		Highwall	Polluted Water: Human Consumption	Spoil Area	Dangerous Highwall	Highwall	Polluted Water: Human Consumption	Dangerous Highwall		
		Dangerous Highwall	Spoil Area	Dangerous Highwall	Spoil Area	Bench	Clogged Stream Lands	Water Problems		
		Dangerous Piles & Embankment	Subsidence	Water Problems	Dangerous Piles and Embankments	Pits	Dangerous Highwall	Clogged Stream		
		Water Problems	Bench	Highwall	Highwall	Dangerous Piles & Embankments	Bench	Polluted Water: Human Consumption		

— Acid mine drainage (AMD)

AMD lowers aquatic diversity and density, and has impacts far downstream. The Appalachian region is home to high aquatic wildlife diversity: the rate of fish species endemic to Appalachia is higher than anywhere else in North America; the region is one of two "hotspots" globally for crawdad diversity; biodiversity of salamanders and amphibians is exceptionally high; and the region holds the majority of mussel diversity.[53] Yet, damage from AMLs can yield acid mine drainage (AMD) in waterways that significantly damages aquatic habitat and wildlife, reducing biodiversity and density.[54] These and other AMD impacts "can have ecological consequences extending far downstream," explain Kruse Daniels et al.[55]

AMD refers to water that has a pH less than 6.0 and high levels of metals and sulfate. [56] Coal and surrounding mineral deposits often contain pyrite and other metal sulfides.[57] When mining exposes these to air and water, they react and form "sulfate, dissolved iron, and other products." [58] AMD-impacted streams often have "high sulfate and conductivity, and elevated acidity, iron, aluminum, manganese and trace metals...that include copper, zinc, selenium, and arsenic." [59] In Appalachia, AMD is most common north of southern West Virginia in areas that have both high sulfur content and low "buffering capacity to neutralize acidic discharges." [60]

AMD can significantly damage aquatic wildlife, which in turn "extend to disturbance of aquatic food chains, both locally and downstream of AMD inputs." [61] In Pennsylvania where AMD is widespread, streams have been measured with impairments "that would exceed in-stream water quality and/or drinking water standards if released without treatment." [62] AMD can lower the density and diversity of fish (i.e. Brook Trout) and macroinvertebrates (i.e. mussels, crawdads, and insects like mayflies and dragonflies), which in turn reduce their ability to decompose organic material and slows the cycling of nutrients in the ecosystem. [63] One study found that an AMD-impacted stream had a 76-96% lower density of macroinvertebrates and reduction of species richness by 58% relative to a reference stream.[64]

Half of the Salamander species in Appalachian mining regions "have some kind of conservation concern," for example, yet one study found that salamander abundance was lower in in AMD-impacted streams relative to reference streams.[65] Another study investigated the impacts of the two-week failure of an AMD-treatment system and found that after just this temporary lack of treatment fish and macroinvertebrate metrics had reverted to pre-treatment levels (similar to a severe drought year) for about 6 miles downstream, and fish metrics did not improve for 2 years. [66] Critically, evidence suggests that AMD can have *watershed-scale* impacts on fish and other aquatic life, extending far beyond the stream directly receiving mine runoff.[67]

Some studies have shown that, as pyritic minerals exposed by mining are depleted, the impact of AMD on water discharge can improve over time.[68] Though this improvement varies drastically by site, and other studies have shown that waterways impacted from mining that occurred decades ago remain acidified.[69]

AMD impacted at least 11,000 miles of streams prior to 1977, meaning AMD-impaired streams could stretch across the continental US more than four times.[70] It is difficult to know the remaining extent of AMD impacts—and the *severity* of each of those stream miles—from pre-1977 mining. According to the inventory, there remain more than 5,500 instances of unaddressed polluted water caused by AML damage, and AML Water Problems yield greater than 320,000 gallons per minute.[71]

A variety of active and passive treatment systems have been developed to treat AMD-impacted water discharge.[72] Over the past decades treatment systems have been installed across the country, many of which are effective at "neutralizing acidity and raising pH and, in many cases, have enabled some recovery of biological communities"—though treated streams rarely recover to pre-AMD levels and often have altered biological communities.[73] AMD treatment systems require ongoing operations and maintenance, and there remain many miles of streams impaired by AMD from pre-1977 mining.

— Greenhouse gas emissions (GGH)

CH_4 leaking from abandoned underground mines and CO_2 from coal mine fires are unregulated and could be considerable sources of GGH emissions. All abandoned coal mines (including those abandoned after 1977) were the 11th largest source of methane emissions in the US in 2018, contributing 6.2 MMT of CO_2 equivalent (about 1% of total CH_4 emissions), according to the EPA.[74] New research suggests that CH_4 emissions from active and abandoned coal mines are significantly higher—in some cases up to 50% higher—than previous estimates.[75] It is difficult to determine precisely what share of CH_4-leaking abandoned mines were abandoned prior to 1977, but one estimate suggests that at least 200 AMLs release methane.[76]

Mine fires release greenhouse gases CO_2 and CH_4, as well as pollutants such as Hg, CO, nitrogen oxides, sulfur dioxide, and other toxic substances into air breathed by nearby residents – but these pollutants are not regulated.[77] Leftover coal debris in underground mines or coal waste on the surface can self-ignite or be ignited by lightning, wildfires, or human activity.[78] Often, low levels of oxygen in the mine cause the fire to smolder, slowly releasing pollutants and, in some cases, shifting the geologic conditions of the mine and causing more subsidence. For example, a mine fire has been burning below the town of Centralia, Pennsylvania since 1962; nearly all residents of the town relocated due to the hazards from the fire.[79]

There are nearly 7,000 acres of these unaddressed fires in the AML inventory, though this is likely an undercount given that fires have not historically been added to the inventory until they become emergencies.[80] According to the US Geological Survey, current data is insufficient to provide specific emission levels from coal fires but CO_2 and CH_4 emissions could be significant.[81]

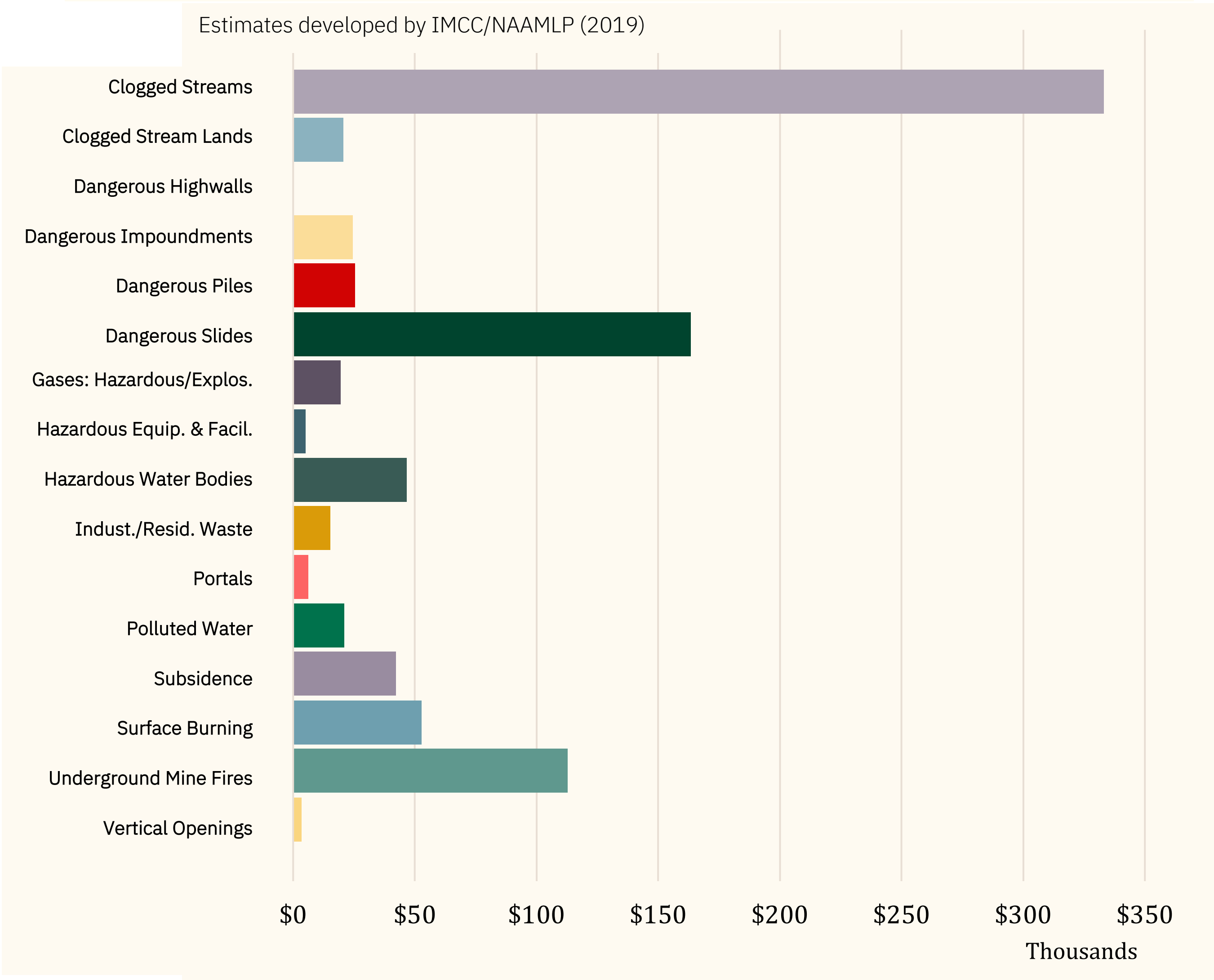
Though fires on AMLs are concentrated in Pennsylvania and West Virginia, they occur throughout the country and can be extremely difficult and costly to extinguish.[82] As of 2020, it will cost about $1 billion to address all AML Underground Mine Fires (medium scenario)—though we have good reason to believe actual costs of remaining underground fires is billions of dollars higher.[83] AMLs with Surface Burning will cost about $30 million to address (medium scenario).[84]

Cost estimates of repairing AML damage

How much does it cost to repair damage from an AML?

The AML program is federally funded and administered with significant authority delegated to states and tribes.[85] In general terms, federal administration is handled by the Office of Surface Mining Reclamation and Enforcement (OSMRE) (which oversees the state/tribal reclamation programs, collects and distributes funding, supports research, provides training), state/tribal administration and design of projects is handled by state and tribal AML agencies (which select, design, and inspect reclamation projects within their boundaries), and construction is handled by private firms. Reclamation—and costs—vary dramatically depending on what type of AML is being reclaimed. Figures 6 and 8 illustrate broad variability in reclamation costs.

Figure 8. Median construction cost to reclaim (per unit), by problem type[86]



While the reclamation process can vary widely by problem type, there are some common steps: fielding calls from landowners about damaged land, assessing whether land or water damage is caused by an AML, adding it to the federal inventory, designing an engineering plan for the project, ensuring the plan satisfies relevant environmental regulations and permits, working with the landowner to incorporate their interests in the design and to access the land, securing an Authorization to Proceed (ATP) from OSMRE, bidding the project publicly to construction firms, completing the construction phase, and inspecting the project.[87] It is not uncommon for projects to take 1-5 years from the first to last steps.[88]

How much will it cost to clean up all AMLs, as of 2020?

It will cost an estimated $20.9 billion to clean up all of the unreclaimed AMLs, as of 2020 (medium scenario). Figure 9 estimates low, medium, and high scenarios for the costs to clean up unreclaimed AMLs as of 2020. An accompanying Technical Note outlines the assumptions and details of these scenarios. Estimates are much larger than the $11.0 billion unreclaimed AML costs listed in the federal AML inventory because of three key reasons:

1. Estimates in the federal inventory reflect only construction costs, not design or administration costs.[89] According to official data from OSMRE, construction costs are only around 75% of total reclamation costs.[90]

2. Estimates in the federal inventory can be decades old and are not updated for inflation. In general, prices in the construction industry have risen over time and cost estimates in the inventory have not updated for these changes; actual costs may exceed these estimates. Some old estimates may not reflect newer reclamation techniques and costs that have changed over time—some of which may be lower.[91]

Figure 9. Reclamation cost of unreclaimed damage from AMLs (billions, 2020$)

Estimates for Group A AMLs are based on median cost estimates from 2019 IMCC/NAAMLP report.[92] Group B estimates are based on unreclaimed total costs in eAMLIS (10.19.20) and are inflation-adjusted assuming newest (low scenario) and oldest (high scenario) possible date for each AML. Group B medium scenario estimates are an average of low and high estimates. High scenario assumes 5% rise in construction costs from wage-push price increases. See Technical Note for details.

		LOW	MEDIUM	HIGH
As of 2020	Construction Costs	13.6	15.6	18.4
	Design Costs	3.2	3.7	4.2
	Administration Costs	1.4	1.6	1.8
	TOTAL COSTS	18.3	**20.9**	24.4
2021-2050 *Projected*	Construction Costs	2.0	4.0	7.0
	Design Costs	0.5	1.0	1.6
	Administration Costs	0.2	0.4	0.6
	TOTAL COSTS	2.7	**5.4**	9.2
As of 2050 *Projected*	Construction Costs	15.6	19.6	25.4
	Design Costs	3.8	4.7	5.8
	Administration Costs	1.6	2.0	2.4
	TOTAL COSTS	21.0	**26.3**	33.6

How much will it cost to clean up all AMLs, as of 2050?

There are many AMLs in the field that are not included in the AML inventory. This is a key third reason why the costs in the inventory do not represent the total unreclaimed AML costs and why we can expect more AMLs to be added to the inventory in the future:

3. The federal inventory does not include all of the unreclaimed AMLs in the field. AML problems continue to be added to the inventory annually. It is commonly understood among AML experts that the federal inventory does not include all AML problems, though it is impossible—without further inventorying work—to assess the extent of unreclaimed AMLs in the field. There are two key drivers:

a. Current policy disincentivizes state and tribal agencies from inventorying AMLs. State and tribal agencies are not provided funding for updating their AML inventories. Given the massive pool of unreclaimed AMLs, states and tribes understandably focus their limited resources on reclamation and rarely proactively inventory new sites. Further, because AML funding can only be used on "high priority" AMLs (those posing immediate danger to humans), states and tribes are disincentivized from inventorying the thousands of "low priority" AMLs.[93] These "low priority" AMLs, which include serious problems like water pollution, are even less likely to be accurately represented in the inventory.

b. AMLs can worsen over time through erosion or changing conditions, thus increasing the costs of AMLs already listed in the inventory or causing an AML to be reclaimed multiple times. The deterioration of AMLs may increase as a changing climate leads to increased flooding in areas like Appalachia.[94]

The directors of multiple AML programs agree that eAMLIS does not include all of the AMLs in their respective states, and some also warn of the difficulty of achieving a "complete" inventory, given the likelihood of AML problems to deteriorate and the ongoing costs of AMLs, such as in the case of long-term treatment needed for AMD.[95] For a brief history of the AML inventory—incl. the initial push to create an (incomplete) inventory, the exclusion of some sites from the list historically, lack of funding for inventorying efforts, and more—see box 2.

As landowners call AML agencies about damaged land or water or as humans move closer to AMLs, AML problems are passively but continually added to the inventory ("discovered"). Figure 9 provides projections for how many AMLs will be discovered over the next thirty years. These projections are based on the annual rate of AMLs added to the inventory from 2010-2019, with the low scenario assuming this rate of AML discovery will decline faster and the high scenario assuming it will grow initially and then decline quickly. Under the medium scenario, a projected $5.4 billion worth of unreclaimed AMLs will be added to the inventory between now and 2050. Adding this to the unreclaimed AML cost in 2020 yields an estimated unreclaimed AML cost of $26.3 billion in 2050.

Box 2. A brief history of the federal AML inventory, "eAMLIS"

Early in the program's history, states/tribes devoted considerable resources toward building an AML inventory. This initial inventory lacked many AMLs in the field and—without funding dedicated for this purpose—states/tribe have had limited capacity to inventory sites since this initial phase. Even with more resources, an inherent difficultly in cataloging AMLs is that they are not static: the inventory will likely never be "finished" because AMLs continue to deteriorate and some require ongoing remediation.[96]

For most states/tribes, initial inventorying efforts—though incomplete—established a backlog of AML problems that quickly exceeded their funding, disincentivizing them from continuing to spend limited resources on improving their inventory. In Pennsylvania, for example, officials focused on building the state's inventory in the 1980s but shifted those resources toward reclamation and have not dedicated significant resources toward inventorying new sites since this initial phase.

AML policy intentionally prioritizes the reclamation and inventorying efforts of "high priority" AMLs, so the process that created the inventory has been biased against the inclusion of allegedly "low priority" AMLs. In order for a reclamation project to be funded, damaged land must be A) caused by pre-1977 coal mining or processing, and B) a threat to human health or safety ("high priority"). SMCRA makes a distinction between "high priority" and "low priority" AML problems—the former are AMLs that represent a threat to human health or safety, while the latter do not.[97] What constitutes "threat to human health or safety" has traditionally been defined by the AML's proximity to humans, so "low priority" problems are AMLs that allegedly aren't close enough to humans to threaten their safety or health. Though, this phrase is a misnomer: "low priority" AMLs are damaged land, air, and water that present significant environmental problems and may well threaten human health in the long-term, even if they do not represent the urgency of other AML problems. For example, the problem type "Water Pollution" is considered "low-priority."

OSMRE has changed the definition of what qualifies as a "high priority" AML throughout the program's history, at times artificially lowering the official inventory of AMLs by purging allegedly "low priority" sites from the system. In the 1990s, OSMRE officials used aerial inspection to review the "high priority" AMLs that states and tribes had added to the inventory. Based on these aerial inspections, OSMRE determined that hundreds of AMLs in the inventory were not close enough to human populations to be considered "high priority" or were too costly to remain in the inventory, and were removed, or "scrubbed," from the system. This effort, known as "the scrub" yielded a much smaller federal AML inventory, providing the appearance of less work to do. In reality, AML problems had just been struck from the official list.

In West Virginia, for example, $2 billion worth of unreclaimed highwalls were purged from the inventory, and OSMRE also forced the removal of any AML problem with an estimated cost of $500,000 or above.[98] OSMRE barred another $1 billion of underground mine fire projects from the inventory because they were deemed unlikely to become reclamation projects or represented costs that were too significant.[99]

Since the 1990s, humans have moved closer to many AMLs, re-qualifying them as "high priority" and re-adding them to the inventory, and recently OSMRE has provided new flexibility to states/tribes in classifying AMLs. Over time, some AML problems have been re-added to the AML inventory, as human activity has moved closer to them through residential and commercial growth, ATV use, and other development.[100] State and tribal officials have argued that states have the authority to determine what should be in the federal inventory for their states/tribes. Recently, OSMRE has agreed, giving the green light for states/tribes to add "scrubbed" AML problems to the inventory.[101]

In West Virginia, AML staff have recently evaluated 285 of these old AML sites, updating the cost estimates for those deemed applicable and adding them back to the inventory.[102] There are another 556 of highwall sites like this to evaluate – and that is just in one state, for one problem type. West Virginia also has ongoing efforts to re-include underground mine fire projects and to update outdated cost estimates of various types of projects.

Recent changes in OSMRE's authorizing states to add these back has been important, but it is unclear to what extent other states/tribes are adding "scrubbed" AMLs back to the inventory. And this only addresses the AML problems that were "scrubbed" in the 1990s. It does not include the likely thousands of other sites that exist in the field but have never been added to the inventory or have not yet degraded to the point of gathering the attention of residents.

It is impossible to know the full extent of the AMLs that are not currently captured by the inventory. The actual unreclaimed AML cost may be larger than these estimates—we simply will not have a better grasp of the universe of unreclaimed AMLs without more inventorying work. These projections are based on historic AML discovery, which reflects agencies' *passively* adding AMLs to the inventory as they've moved forward on projects—not what could be added to the inventory annually if agencies *actively* pursued inventory efforts.

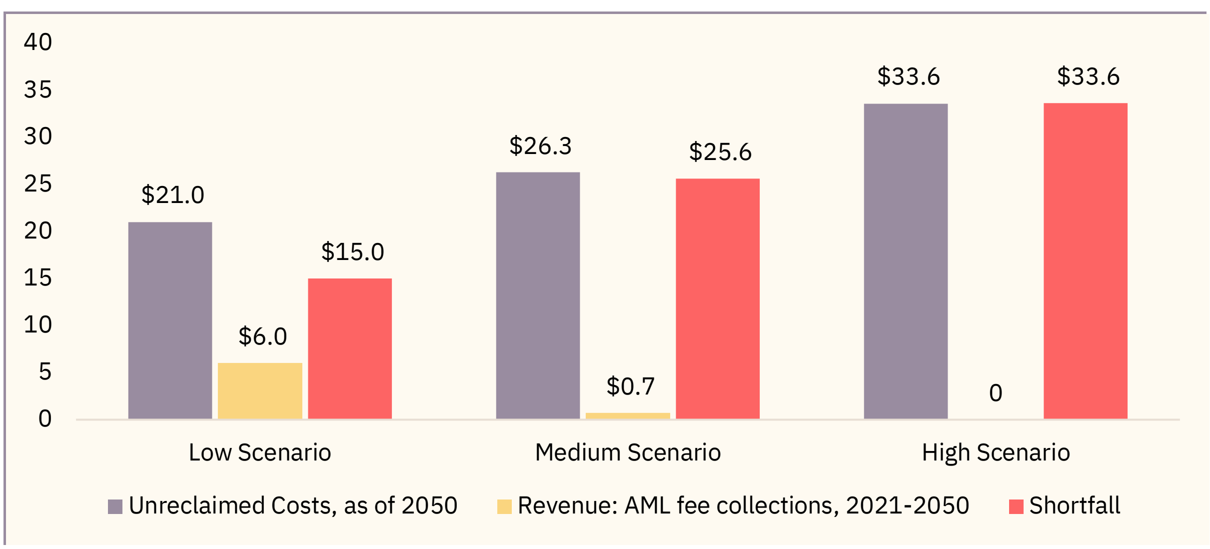
The cost estimates in figures 2 and 9 adjust for various deficiencies and biases of the federal inventory and provide what I hope are more reasonable estimates of what it will take to clean up all AMLs as of 2020 and 2050. My cost estimates differ from the $11.0 billion in the inventory in the following ways. First, I adjust for changes in prices by using a method based on more recent average cost estimates (for Group A PTs) and adjusting for inflation (for Group B PTs); this adds $4.6 billion (medium scenario). Second, I estimate design and administration costs (based historic data of these costs relative to AML construction costs), which adds $5.3 billion (medium). Third, I project how many unreclaimed AMLs will be added to the inventory from 2021-2050, which adds $5.4 billion (medium). See Technical Note for details about data sources, assumptions, and calculations.

Actual costs may end up being higher—even the high scenario estimates do not include what may be required to treat long-term AMD, and these estimates are ultimately rooted in the universe of AMLs listed in the inventory and how quickly the program has (relatively passively) added those AMLs in recent decades. We may well discover more damage than these projections suggest. Yet, they demonstrate that costs will, at least, be much larger than the official figure.

How large is the AML program's funding shortfall?

To provide some reference for the massive backlog of unreclaimed damage, we've only reclaimed about 978,000 acres of AMLs since the program started in 1977, at a cost of $7.9 billion (2020$).[103] Though important work, this represents only 27% of the $28.8 billion worth of all AMLs discovered as of 2020 (medium scenario). Under current policy, tens of billions of dollars of AML problems will be left unreclaimed in 2050, even after accounting for future AML fee collections. Assuming a projected $0.7 billion in AML fee collections from 2021-2050 (assumes current fee levels on all coal production through 2035, then only on metallurgical coal through 2050), there will be an estimated $25.6 billion shortfall in unreclaimed cleanup costs versus AML fees (medium scenario).[104] Figure 10 provides low, medium, and high estimates for the projected revenue gap. As described above, actual AML costs may be higher, in which these gaps could increase.

Figure 10. Unreclaimed AML costs, revenue, and funding shortfall, 2050 (billions, 2020$)[105]



Labor

How many direct jobs are supported/created by AML cleanup?

Remediating AML damage removes threats to humans and to the planet. It also generates economic activity in impacted states and communities. Many workers—with a range of skills and qualifications—are necessary for AML cleanup, from government engineers, scientists, and managers who design, administer, and research AML reclamation, to machinery operators, clerical staff, and tree planters who execute reclamation construction. How many jobs would be created by more cleanup, and what would they pay?

Cleaning up all outstanding damage would create/support between 103,913 job-years (low scenario estimate) and 170,153 job-years (high scenario estimate).

Reclaiming *half* of the $26.3 billion in unreclaimed damage (medium scenario) *in the next decade* would create/support an estimated 6,909 direct jobs annually for 10 years: 3,286 jobs at state/tribal agencies, 478 jobs at OSMRE, and 3,114 construction jobs. This assumes OSMRE is annually funded at $112.5 million to administer the AML program ($1.1 billion over 10 years, exclusive of the $26.3 billion reclamation cost). Figure 11 provides low, medium, and high job estimates, using different assumptions regarding pay levels and other variables.

The remaining half of unreclaimed damage (according to our current estimate) could be cleaned up between 2031-2050, perhaps by phasing down the annual volume of reclamation over time. Figure 12 provides direct jobs estimates assuming 50% of unreclaimed costs are reclaimed in 2021-2030, 33% in 2031-2040, and 17% in 2041-2050. Such a cleanup timeline could balance the need to address damage as quickly as possible, the challenge in drastically scaling up the AML program, and the programmatic need to provide planning and funding certainty beyond the immediate term. Long-term certainty can be key for workers and administrators and can ensure we continue to have a strong AML program in coming decades amidst uncertainty regarding the full extent of damage and to what degree climate change might worsen existing damage.

Though these jobs projections assume reclamation of half of (currently estimated) AMLs by 2030 and all by 2050, the cleanup schedule could vary–such as by distributing reclamation equally over 30 years rather than phasing down over time. Different cleanup schedules will impact how many directs jobs are created/supported annually.

Figure 11. Direct jobs estimates, 2021-2030

Assumes half of unreclaimed AML damage (projected 2050) is cleaned up in the next decade, where reclamation is distributed equally across 10 years: $1.0 billion (low), $1.3 billion (medium), and $1.5 billion (high) annually. Assumes payroll is 15% (low), 20% (medium), and 30% (high) of construction costs; assumes a 5% wage-push construction cost increase in the high scenario. Assumes 2.5 state/tribal jobs is supported by every $1 million in AML grants, which is the state/tribal median according to official 2019 reports to OSMRE. Assumes 4.25 OSMRE jobs is supported by every $1 million in AML discretionary funding, which is the 2009, 2010, 2019, and 2020 average according to official OSMRE annual reports. Assumes $75M (low), $112.5M (medium), and $150M (high) in annual AML discretionary funding is provided to OSMRE. See Technical Note for details.

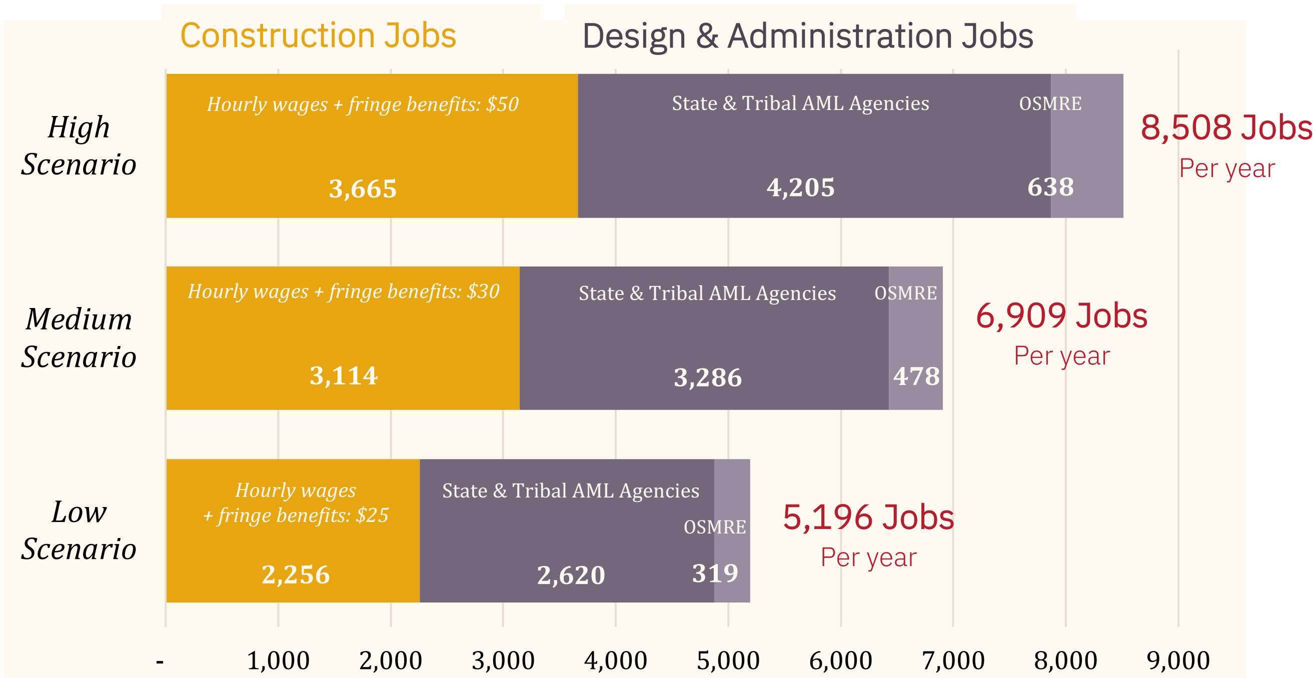


Figure 12. Direct jobs estimates, 2021-2050[106]

Assumes 50% of unreclaimed damage (2050) is reclaimed in 2021-30, 33% in 2031-40, and 17% in 2041-2050

			LOW	MEDIUM	HIGH
JOBS (2021-30)	Construction		2,256	3,144	3,665
	Design, Inspection, Admin	State/tribal	2,620	3,286	4,205
		OSMRE	319	478	638
	Total	Per year, 2021-2030	5,196	**6,909**	8,508
JOBS (2031-40)	Construction		1,504	2,096	2,443
	Design, Inspection, Admin	State/tribal	1,747	2,191	2,803
		OSMRE	212	319	425
	Total	Per year, 2031-2040	3,464	**4,606**	5,672
JOBS (2041-50)	Construction		752	1,048	1,222
	Design, Inspection, Admin	State/tribal	873	1,095	1,402
		OSMRE	106	159	212
	Total	Per year, 2041-2050	1,732	**2,303**	2,836

How does AML cleanup impact the broader economy?

In addition to direct jobs doing AML reclamation, more cleanup would support jobs along the AML value chain and would increase regional output. Spending on heavy machinery necessary for reclamation would likely rise—and jobs needed to manufacture heavy machinery along with it. A similar impact could be expected with other inputs, such as seeds, saplings, fertilizer, fuel, and gravel. And more spending would circulate in regional economies, as workers spent their wages on goods and services in surrounding communities.

Using IMPLAN U.S. input/output tables, Pollin et al. estimate that $1 million in spending on AML reclamation supported 2.9 indirect jobs and 5 induced jobs in 2018.[107] According to the spending levels proposed in figure 12 ($1.3 billion annually for first 10 years), 10,384 induced and indirect jobs would be supported annually for 2021-2030. Combining this with the 6,909 in direct jobs (medium scenario), 17,293 total jobs would be supported/created annually for 2021-2030.

Spending $26.3 billion to address *all* estimated remaining AML costs (medium scenario, 2050) would create/support an estimated 138,024 direct job-years and 344,403 total job-years.

Further research into the job quality (wages, fringe benefits, union density, etc.) for the indirect and induced jobs supported by AML spending is needed. An assessment of the common occupations and typical wage levels of direct AML construction jobs are explored below.

How much are AML construction workers paid?

Many AML construction jobs fall under two BLS Standard Occupational Categories: Construction Laborers (i.e. “Laborers”; SOC Code472061), and B) Operating Engineers (i.e. “Operators”; SOC Code472073). Specific occupations within these categories are explored in box 3.

Construction job estimates assume average hourly gross pay of $30.00 ($20.24 in wages + $9.76 in fringe benefits) for the medium scenario – this is the author’s best approximation of median pay among AML construction workers under current labor regulations, market conditions, and rates of unionization.[108] Lacking wage data on AML workers specifically, this approximation is based on BLS data for Laborers and Operators generally and adjusted to account for AML work.[109]

The low scenario uses $25.00 per hour in gross pay and assumes that unionization or prevailing wage laws are weakened in AML states/tribes or that the $30.00 approximation is too high based on unlikely but possible scenarios.[110] The high scenario uses $50.00 per hour and assumes that prevailing wage laws are strengthened significantly and that unionization rates rise among Laborers and Operators in AML states and tribes. See Technical Note for details related to all three scenarios.

Most staff of construction firms doing AML reclamation are hourly construction workers—but not all. These firms also employ "professional" staff (licensed engineers, environmental scientists, etc.) who are typically compensated as salaried staff, and hourly clerical or administrative staff, neither of whom are necessarily assigned specific reclamation projects in the same way as Laborers or Operators but whose work is no less critical for reclamation projects. These jobs comprise part of AML construction jobs, but for lack of data I do not incorporate "professional" staff salaries and clerical/administrative wages into estimated average hourly wage. Presumably, most AML construction payroll supports Laborer and Operator occupations, so average wage is based on these.

How many AML jobs are supported at federal, state, and tribal agencies?

In addition to construction jobs, AML reclamation supports design and administration jobs at state/tribal and federal agencies. State/tribal AML staff are typically salaried positions funded through federal AML grants to states and tribes, sourced from AML fees and the federal Treasury. State and tribal AML workers perform many tasks, including: fielding reclamation requests, inspecting reclamation projects, working with landowners on realty issues, administering and managing the state/tribal AML program, and, perhaps most critically, design engineering for reclamation plans.

Based on the average number of FTEs supported by $1 million in AML funding across the 28 state/tribal AML programs, cleaning up half of unreclaimed AML damage would support/create 3,286 FTEs at state/tribal agencies over the next decade.[111]

Federal AML staff at OSMRE are typically salaried positions funded through annual discretionary appropriations from Congress.[112] Federal staff administer, inspect, train, and research mine reclamation.

Based on the average number of FTEs supported by $1 million in AML discretionary funding, proposed cleanup would support/create 478 FTEs at OSMRE offices across the country from 2021-2030.[113] This assumes that OSMRE receives $112.5 million in AML discretionary funding annually (medium scenario), which is 2.6 times 2009-10 levels ($44M avg.) and 4.5 times 2019-2020 levels ($25M avg.).[114] For reference, proposed annual AML cleanup is 3.9 times 2009-10 levels ($231M avg.) and 5.7 times 2019-20 levels ($334M avg.) respectively.[115] See Technical Note for details about OSMRE funding levels under various scenarios and cleanup timelines.[116]

Box. 3. Common occupations and wages among AML Workers in Ohio

Construction Laborers and Operating Engineers are the two common occupational categories of AML construction workers. Specific occupations within these categories range from flaggers to operators of heavy machinery like excavators; many of the most common occupations are listed in figure 12. Wages for AML construction-related occupations vary by occupation, with Operators generally making more than Laborers.

In Ohio, the state requires AML contractors to pay a prevailing minimum wage that varies by occupation. These occupation-specific wage levels are the average wage among all Ohio AML projects in the past three years and are adjusted every three years. Figure 12 outlines the minimum wage levels for various occupations, from $17.39 for Watchmen to $27.46 for Crane Operators. Note that these figures are wages only, not gross hourly pay (they exclude any fringe benefits).

Figure 13. Common AML Reclamation Occupations in Ohio[117]

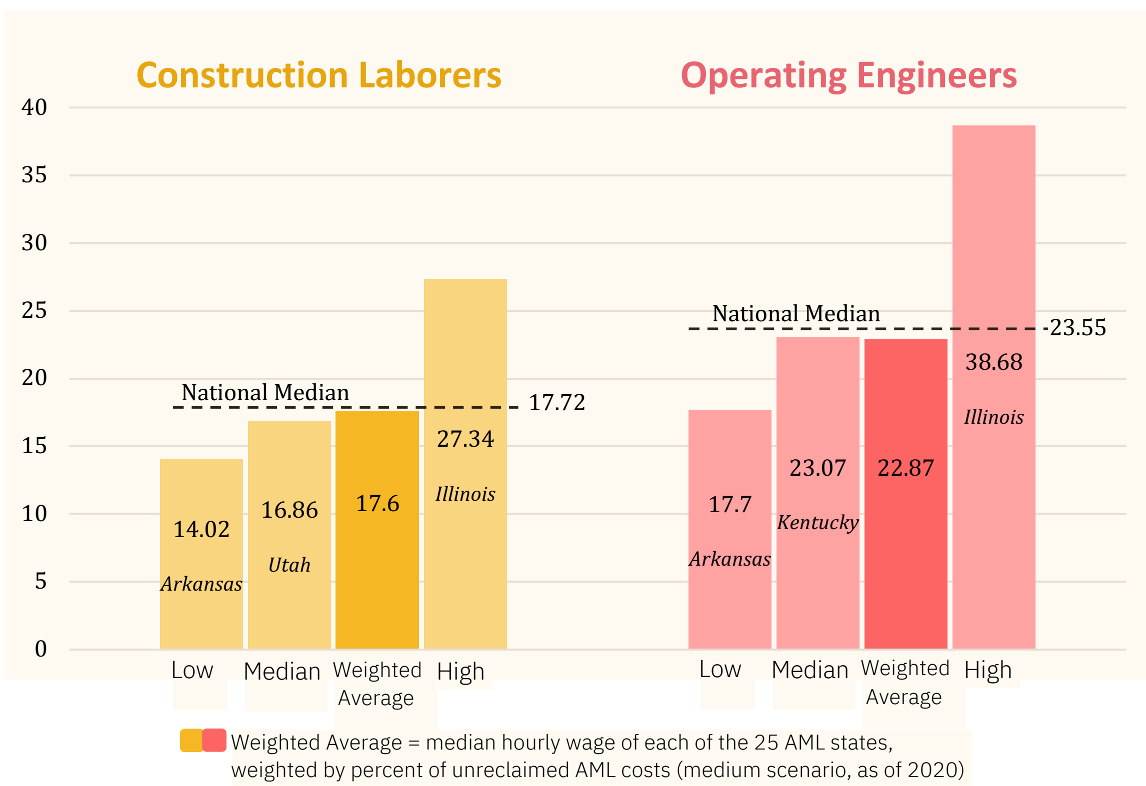
Hourly or Salaried	Category	Occupation	*Required AML Wage Rate in Ohio*
Common Hourly Occupations	**Construction Laborer**	Flagger	
		Watchman	*$17.39*
		Laborer	*$18.85*
		Grade Checker	*$18.44*
		Pipe Layer	*$19.71*
		Blaster	*$21.83*
	Operating Engineer & Equipment Operator	Operator of Power Tools	*$18.09*
		Jackhammer Operator	*$18.32*
		Drill Rig	*$25.37*
		Two Axle Truck	*$21.41*
		Tandem and Tri-Axle Truck	*$21.43*
		Five Axle and Over Truck	*$23.65*
		Bulldozer	*$25.24*
		Excavator	*$25.70*
		Trench Machine	*$23.17*
		Farm-Type Tractor	*$19.94*
		Grader	*$23.26*
		Seeding and Mulching Machine	*$22.09*
		Crane	*$27.46*
		Compactor	*$21.44*
		Loader	*$23.81*
		Backhoe	*$23.70*
	Mechanic	Power Tools	*$22.50*
		Tractors, Small Equipment	*$23.26*
		Trucks	*$24.30*
	Administration	Clerical/Administration Worker	
Common Salaried Occupations		Surveyor	
		Geologist	
		Biologist	
		Engineer	
		Real Estate Expert	
		Inspector	

What are the average wages for common AML occupations, like Laborers and Operators?

The wage levels among these occupations among AML workers varies by state and tribe—in some cases considerably. The mean hourly wages of Laborers and Operators in all industries (not AML-specific) in Ohio are in the top 20% of the 25 states with AML, so we can expect that AML Laborers and Operators are likely lower in most other AML states relative to Ohio.

According to 2019 BLS data, the national median wage is $17.72 for Laborers and $23.55 Operators across all industries (not-AML-specific), see figure 13. Median wages range from a low of Laborers in Arkansas, who make $14.02 per hour, to Operators in Illinois, who make a $38.68 per hour. If you take the median hourly wage in each AML states and weight it by the state's percent of unreclaimed AML costs, then Laborers are paid a weighted average of $17.60 and Operators are paid a weighted average of $22.87. This does not provide median wages for AML construction workers specifically, but it does provide a reasonable estimate for Laborer and Operators generally across the 25 AML states. I use a wage level directly in the middle of these two weighted averages ($20.24) as the basis of my medium scenario gross pay assumption and add assumed fringe benefits of $9.76 (32.5% of pay) to get to the $30.00 assumed pay level noted above.[118]

Figure 14. Median Wage of Laborers & Operators Among 25 AML States, All Industries[119]

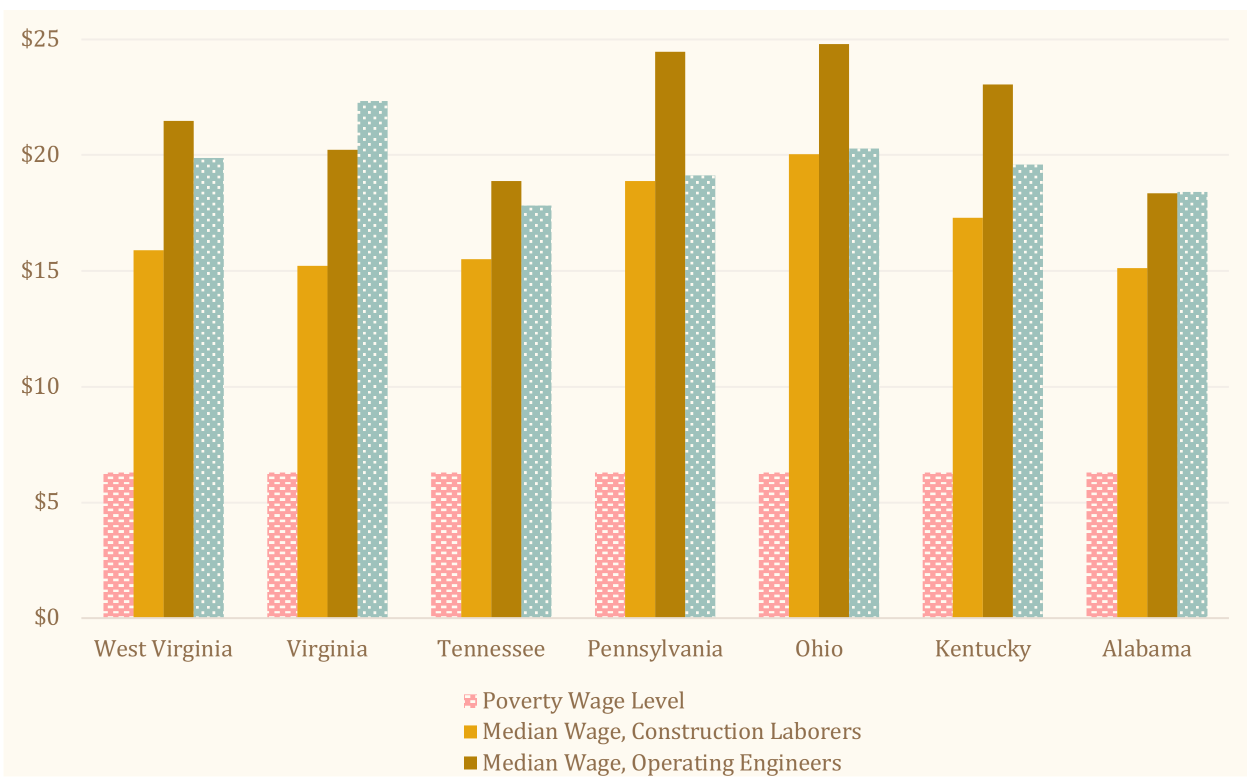


Laborers and Operators are paid an above-poverty wage but not a living wage

In general, construction occupations common among AML projects provide enough income to keep a family out of poverty but not enough to provide a living wage, though there are some exceptions. Assuming both parents are working in a family of four, the median wage for Laborers would only provide a living wage in a handful of states, according to the MIT Living Wage Calculator.[120] The median wage for Operators does provide a living wage in 19 AML states. But that's only for Operators making the *median* wage or higher—Operators making a wage that's closer to the lower end of the distribution don't make a living wage.[121]

Both Laborers and Operators—even the lowest paid Laborers and Operators—are paid wages that lift them above the federal poverty threshold.[122] The exception is for the lowest paid Laborers in families with only one adult working—Laborers in this case make a poverty wage only in 7 AML states. These living wage and poverty wage assessments use wage data for Laborers and Operators in general (not AML workers specifically), so the specific wages for AML workers could vary. For example, the lowest required wage for AML workers in Ohio is $17.39, which is almost $5 higher than the lowest wage for Laborers in all industries in Ohio—likely explained in part by the compression of wages among Ohio construction workers doing in the AML industry in particular.[123] Still, it is reasonable to assume that the general pattern that these occupations don't provide a living wage but do provide a poverty wage apply to AML construction workers.

Figure 15. Median wages of Laborers & Operators compared with living & poverty wages, Appalachian states[124]



What skills are required for AML work, and are they union jobs?

Skills and training for Laborer and Operator occupations vary, with Operator occupations generally requiring more technical knowledge and experience operating machinery—including experience operating specific machines. Many coal-related occupations share skills required for Laborer and Operator occupations—including experience with heavy machinery. While coal workers possess many of the skills needed for AML work, in general Laborer and Operator occupations are also jobs that are relatively more accessible for other community members, including those without secondary education or professional degrees.

Though the extent of union density among Laborers and Operators doing AML reclamation is unclear, some AML workers are unionized—including in states like Illinois and Pennsylvania by the Laborers' International Union of North America (LiUNA) and International Union of Operating Engineers (IUOE). In Illinois where a state prevailing wage law has been in place for decades, it is likely that a majority of AML firms are union.[125]

In some cases, these unions provide apprenticeship programs for their member Laborers or Operators. In other cases, Laborers or Operators are provided on-the-job training by private employers or through vocational or community college training programs.

In addition to the construction occupations, professional scientists and engineers, as well as experts in real estate issues and surveyors are also key AML occupations employed by either contractors or AML agencies (see figure 12).

Policy Recommendations

The fundamental idea behind the AML program – that the coal industry must pay to clean up its long history of pollution and damage – is an essential and somewhat radical one. It carries with it the idea that corporations—no matter how wealthy—cannot evade responsibility to the environment and to some of the poorest communities among us. But the promise of that idea has been betrayed many times, as Congress chose not levy fees on the coal industry that were high enough to actually clean up all of the mess. Now the coal industry is on its last legs. Even if the fees were increased and assessed for the next 30 years, it is too late for this shrinking industry to provide enough AML fees to clean up the massive remaining damage. Because of the lack of will to hold the coal industry accountable historically, tens of billions of dollars will likely need to be found elsewhere to clean up the mess.

The longer that Congress allows thousands of acres of AML-damaged land and water to linger, the more these sites threaten coalfield communities, downstream residents, and the planet.[126] The need to repair mine-scarred damage is urgent. It will require drastic increases in the scale of funding as well as ambitious changes to policy.

Poverty has persisted for decades in many coal areas, where economic distress can be sharp—including for the many coal workers already laid off en masse and the many more expected to be jobless in coming years.[127] The misery that accompanies economic distress continues to be borne disproportionately by women, by people of color, and by young people: unemployment and poverty rates are higher among these groups in AML counties. Empowering these communities to pursue a new way forward is urgent, yet something as basic as the land in coal regions remains largely in the hands of absentee owners.

Amidst these intersecting crises, we must seek not just to make former mine sites safe but consider the program as part of a larger strategy. AML policy is environmental and labor and land reform policy. We should approach the program holistically, and as part of a massive national economic mobilization to address climate change and inequality.

As a federally funded program with jobs potential in rural coal communities, the program is uniquely positioned to help remedy the many crises facing former coal regions and the planet. To approach the AML program with a myopic focus on abating the hazards of AMLs—though important—is to ignore the arguably more pressing inequality and environmental crises facing these communities and with it the opportunity presented by the location, size, and nature of AML reclamation to address them.

The following policy recommendations reflect: environmental goals of local pollution abatement and reduction of greenhouse gases, labor goals of supporting well-paying, unionized jobs in former coal communities, social goals of reducing gender and racial economic inequality and bringing more of the region's land into public and local stewardship, and more.

1. Ensure reclamation workers are paid a living wage, build power in AML workplaces, and prioritize firms owned broadly and/or by historically disadvantaged groups.

- Require that Davis-Bacon wage regulations apply to all AML jobs – from design to construction to clerical work – and raise the wage floor to provide a living wage. While it is likely that most AML workers are paid a wage that keep them above the federal poverty threshold, occupations common among AML construction likely do not pay a living wage in most cases. Similar to the Biden Administration's effort to ensure all federal contractors are paid at least $15 hourly, policymakers should ensure that – as a federal public works program – AML funding carries with it the requirement of Davis-Bacon prevailing wages and a wage floor that a worker can live on—or, at the least, a $15 hourly minimum.[128]

  These wage regulations could make a massive impact on incomes for AML workers. For example, in Kentucky the lowest paid Laborers make $11.46 per hour in wages, according to BLS.[129] Under Davis-Bacon regulations, however, the lowest paid Laborer occupation on an AML project in KY AML counties would likely make $18.31 hourly in wages.[130] While the latter is slightly below a living wage, it represents a significant difference.

- Require AML construction contracts to protect the collective bargaining rights of workers.[131]

- For projects over a certain cost threshold, require project labor (or community workforce) agreements, local hire provisions, targeted hire provisions, and apprenticeship utilization.[132] For example, project labor agreements are currently utilized on Illinois AML projects—where it is likely that a majority of AML firms are union. [133]

- Require a significant portion, such as 20%, of a state/tribe's annual AML funding is spent on contracts that are large enough for union contractors to realistically consider. At present, AML contracts can be too small for union contractors to consider them; aggregating multiple reclamation projects in a similar geographic area and bidding them as a larger single contract could increase the ability of unionized firms to realistically consider them.[134] This approach is especially applicable in an environment where annual reclamation volume is increased drastically as proposed.

- Prioritize firms that are owned broadly or owned by people from historically disadvantaged groups in awarding construction contracts, including: local CCC reclamation crews (see below), women-owned firms, people of color-owned firms, local firms, and worker cooperative or other worker-owned firms.

Box 4. Pennsylvania labor policies for public construction projects

In most Appalachian states, weak state labor policies apply to AML projects. A notable exception is Pennsylvania, where state laws and regulations shape wages, hiring, firm selection, and anti-discrimination policies.[135]

Prevailing Wage Laws & Minimum Wage

For public construction projects in Pennsylvania over $25,000, Prevailing Minimum Wages (PMW) are required to be paid. These wage rates are set by the Department of Labor and Industry based on location and job classification. Importantly, the Department may consider local collective bargaining agreements and other data in setting PMW rates, so these rates may not necessarily equal the local market wage rate. Firms must contribute to workers' benefit plans as required under PMW, and if not then they must make a monetary payment equivalent in value directly to the worker. Firms must pay workers an hourly rate, on a weekly basis, and cannot pay on a lump sum basis or for meeting certain work thresholds.

The process works like this: the PA Bureau of Abandoned Mine Reclamation (BAMR) sends a new AML contract to the PA Department Labor and Industry, which then publicly issues PMW levels for job classification and location in the contract.[136] Firms which have been debarred for previous PMW violations or other labor violations are not eligible to participate in the project. Firms must post publicly and accessibly on job site the right to the PMW wage rates, and that workers have a civil right to action if their wages are less. If a firm does not pay PMW, then it may not receive payment and/or the contract may be terminated. Firms may also be debarred by the state for jobs with public funds.

In addition, minimum wage is required ($12 as of 2020; $15 as of 2024) for all direct workers and for all ancillary workers who spend at least 20% of weekly time on the project.[137] Firms may have apprentices on the project as allowed under Pennsylvania apprenticeship law.

Hiring & Firm Ownership Preferences

Pennsylvania state laws and regulations incentivize construction firms to hire veterans and local workers.[138] State policy also prioritizes certain types of firms: Small Diverse Businesses, Veteran Businesses Enterprises, and Small Businesses. For construction projects over $400,000, contractors are required to make goal(s) (dollar amounts, percentages of total contract value) to review and hire Small Diverse Businesses (SDB) and Veteran Business Enterprise (VBE). Goals are, generally, 26.3% for SDBs and 4.6% for VBS.[139] Specific goals for each project are set by the PA Department of General Services for each project, and vary from general goals based on local availability of eligible contractors to do scope listed in the project.[140] If the contractor doesn't meet these goals it can only be on the basis of price or capability.[141] SDBs include: "Minority Business Enterprises (MBE), Women Business Enterprises (WBE), Disability-Owned Business Enterprises (DOBE), LGBT-Owned Business Enterprises (LGBTBE), Service-Disabled Veteran-Owned Small Business Enterprise (SDVBE) verified by BDISBO, or otherwise deemed disadvantaged."[142]

Smaller projects—from $10,000 to $300,000—are reserved exclusively for certified Small Businesses.[143] A Small Business is for-profit, independently-owned, non-dominant, has less than 100 employees, and has less than $38.5M in annual revenue.[144]

Anti-discrimination Policies

Additionally, PA state policy requires that firms may not discriminate on basis of race, gender, creed, color, sexual orientation, gender identity or expression in hiring workers or in any manner.[145] Firms also cannot discriminate against workers for participating in labor activities protected under state and federal law, and they must make clear that sexual harassment will not be tolerated, including by clarifying penalties for workers who engage in it.[146]

2. Create a public reclamation jobs program under a Civilian Climate Corps (CCC) to ensure jobs are accessible among those most in need and in rural coal communities.

- Alongside a commitment to more reclamation funding, **Congress could require that some significant portion, such as a quarter or a third, of total reclamation is contracted to a new mine reclamation agency under a revitalized CCC**. The federal agency should establish reclamation crews in every state and tribe with AML problems, hiring from the local workforce and according to the hiring preferences below.
- Provide hiring preferences and/or set-asides for former coal workers, local workers, people of color, women, formerly incarcerated workers, and those recovering from substance abuse (i.e. local hire and targeted hire provisions).[147] OSMRE and a new CCC should prioritize training an hiring in ways that ensure AML occupations are truly accessible to people of color, women, and worker from other historically oppress and under-represented groups.
- Ban the box in hiring for public AML jobs, and require AML construction contracts to protect the sexual harassment and non-discrimination rights of their workers.[148]

In order to meet the massive backlog of unreclaimed damage, the pace and scale of annual AML reclamation will need to rise dramatically. An uptick in demand will create a massive need for increased reclamation labor. At the same time, many people in coal regions are in dire economic distress, and many are experiencing severe racial- or gender-based economic gaps. A public jobs program can help ensure that the increase in labor demand for reclamation provides income opportunities for the jobless and historically oppressed in coal communities. Given the current reclamation construction market, it is possible—perhaps likely—that many new reclamation jobs will not be accessible to people who are most in need, or even to those in rural communities in direct proximity to AML sites.

A federal reclamation construction organization could fundamentally change the impact of the AML program, transforming it from a myopic focus on making AMLs safe to a program that creates thousands of well-paying jobs that are actually accessible to those who need them most in some of the poorest communities in the country—at an investment scale that raises the bar for wages and benefits in those rural construction markets. The public organization could serve as a model in terms of hiring, labor standards, training, and reclamation techniques that incorporate high environmental standards—pushing upward on regional labor markets.

A public reclamation jobs program could also be linked with policies like a guaranteed re-employment program for displaced coal workers or a broader jobs guarantee for the public.[149]

Public jobs programs in coal mine reclamation are not without precedent. In the 1980s and 1990s, the Ohio Division of Civilian Conservation—a workforce training program that provided temporary jobs for young adults—had crews that completed dozens of mine reclamation contracts annually for the Ohio AML agency. The

Pennsylvania AML agency currently employs 2 crews of 12 full-time permanent staff each that complete more than a hundred small reclamation projects annually. Box 5 provides case studies on the programs in Ohio and Pennsylvania.

Another model can be found in Green Forests Work (GFW), a non-profit based in Kentucky that reforests mine-scarred landscapes across the Appalachian region. In just 12 years, GFW has reforested nearly 5,000 acres of mines with more than 3.1 million native trees.[150] GFW was explicitly modelled on the Roosevelt-era CCC, and the organization explains that its model creates "nursery jobs, equipment operators, tree planters, forest managers, wildlife biologists, [and potentially] those that may manage these sites for renewable energy and climate change mitigation."[151] Though GFW has worked primarily on post-SMCRA mines and uses some volunteer labor, it presents a useful model of the possibility of jobs doing reforestry as mine reclamation.

The AML department within OSMRE is not currently equipped to execute construction work. Congress should create a new CCC that could house an organization focused on executing the construction phase of mine reclamation and could partner closely with OSMRE. OSMRE or state/tribal agencies could contract a share of total reclamation work to new construction reclamation crews with the CCC, as was done in Ohio in the 1980s and 1990s.

As with other CCC jobs, some reclamation jobs can serve as a temporary employment opportunity that is accessible for workers in need, even if they lack experience with construction. For other workers with more relevant experience, reclamation jobs can serve as long-term careers. The public agency could have two employment tracks geared to accommodate both situations.

The tasks and skills required for mine reclamation can vary widely by the type of project, from manual labor for grading and seeding to compliance with surveying. Similar to the Ohio Division of Civilian Conservation in the 1980s-90s, the first employment track could provide one- or two-year terms, require no previous background in construction, and include training and skills development. These workers could be paired with project tasks that require less technical know-how or engineering compliance, which might include gathering information to update the AML inventory, tree-planting, or operation of small and some large machinery.

Similar to the in-house reclamation crews in Pennsylvania, the second track could provide permanent reclamation positions for more experienced workers. These workers could be put on project tasks that require operating large machinery or engineering knowledge. Permanent positions could also include operating and maintaining AMD treatment systems.

AML officials note that the large capital outlay of heavy reclamation machinery and the seasonal nature of some AML work provide challenges to a public jobs reclamation approach. In order to be successful, the approach would require significant increases—and long-term certainty—in funding, so that the agency could make investments in large capital outlays, like heavy machinery. Nesting the mine reclamation crews within the CCC, a larger program focused on infrastructure, could help with this and, critically, with the challenge of seasonal work. CCC mine reclamation crews could reclaim not only

AML-damaged but also legacy post-SMCRA sites (with supplemental funding), and then could be shifted to similar infrastructure or conservation projects within the CCC—such as outstanding maintenance projects at state and federal parks and other public lands, or seasonal wildland firefighting—when mine reclamation work is out of season.

Box 5. Case studies: public reclamation crews in Pennsylvania and Ohio

Though the standard throughout the AML program has been that construction is completed by private firms, there is precedent for construction being completed by public agencies.

Pennsylvania's In-House AML Crews

In Pennsylvania, the Bureau of Abandoned Mine Reclamation (BAMR)—one of the largest and most well-respected state AML agencies—has two in-house reclamation crews, one for each coal district in the state.[152] The crews have an interesting history: they trace back to a state-level reclamation program started in the 1950s, decades before the federal AML program was created in 1977. The Bituminous District in-house crew and the Anthracite District in-house crew are staffed by twelve workers each. They are full-time, permanent staff positions at BAMR.[153] As state employees, they are represented by Council 13 of the American Federation of State, County and Municipal Employees (AFSCME).

The in-house crews in Pennsylvania complete a high volume of small projects each year. In just the past 8 years (2012-2019), the in-house crews have reclaimed 1,198 projects—an average of 150 projects annually. These projects run the gambit of all types of reclamation, and include remediating: mine subsidence, mine drainage, dangerous slides, mine shafts, dangerous highwalls, clogged streams, and explosive mine gas. In-house crews completed 78% of the total number of projects completed under BAMR during that time period, though these projects were only 4% of the total reclaimed acreage. Under their current configuration, these in-house crews specialize in small projects and in quickly mobilizing to reclaim projects. BAMR officials note that if they receive an emergency request, such as a landslide threatening someone's home, it usually only takes a few days to mobilize an in-house crew to reclaim it, but if they had to go through the regular order of bidding the contract externally, it is more likely to not be addressed for a week or two.

In general, staff of Pennsylvania's in-house reclamation crews are highly skilled and have significant reclamation and/or construction experience. They typically do not complete larger projects not because of a lack of skill but because of a lack of heavy machinery. Officials explain that the largest equipment needed for some types of AML reclamation are huge capital expenditures that the state does not already own, so BAMR usually opts to bid out the projects that require specialized or massive heavy machinery.

Ohio Division of Civilian Conservation

In the 1980s and 1990s, public reclamation crews in Ohio similarly completed a notable chunk of the state's mine reclamation projects—though in Ohio, the program was focused more on temporary employment and workforce training.[154]

The Ohio Division of Civilian Conservation was patterned after the original Civilian Conservation Corps (CCC) and operated from the early 1980s to mid 2000s.[155] The Ohio Corps program hired young adults, age 18-23, for one-year terms, and focused on providing temporary employment as well as workforce and skills training. The program didn't require an associate or bachelor's degree to participate, and usually hired around three quarters of everyone they interviewed, according to Bill McGarity, former Field Operations Manager of the Ohio DCC. The program recruited from both urban and rural communities throughout Ohio and paid a little above minimum wage. Upon completing the program, many Corps members would go on to take careers at the Ohio Division of Natural Resources.

At its peak, the program had 400 Corps members and dipped to 200 at its low point. Annual state funding for the program peaked at around $6 million, according to McGarity. For 6 years, the program started with a 3-week training academy that covered first aid, CPR, small equipment (e.g. chainsaw) operation and safety, and other topics. There were three types of participants. Corps members were the largest group; some Corps members would return for second and third years and serve as Assistant Corps Leaders or Corps Leaders. Corps members could complete a wide variety of projects, including carpentry work, auto mechanic work, food service work, state park maintenance, and mine reclamation.

Ohio Division of Civilian Conservation crews completed 40-50 mine reclamation projects per year, according to McGarity. Crews would focus on smaller projects, typically around 1-5 acres each. Common projects included grading work, seeding, tree planting former surface mines, erosion control, filling in mine shafts, and constructing passive AMD treatment systems. While not the largest projects or projects that required significant engineering compliance, many of the projects did require operation of heavy machinery, including bulldozers and backhoes. The Ohio AML agency would design the reclamation plan and would then solicit a formatted proposal from the Division of Civilian Conservation. Once the proposal was approved by the AML agency, the crews would complete the work and the Division of Civilian Conservation would be paid by the AML agency.

McGarity explains that the DCC would try to recoup the salary of the supervisor and Corps members as well as the costs of the use of heavy equipment, but the DCC didn't try to make a profit on these projects. McGarity argues that the DCC saved Ohio DNR money on reclamation projects, given that DNR did not have to bid out the projects or deal with outside liability. Terry Van Offeren, who worked at the Ohio AML agency during this time period and later directed the agency, explains that the quality of work of the projects reclaimed by the DCC was high, though he notes that in some cases that the timeline for DCC projects was a longer.

3. Strengthen mine reclamation to incorporate ecological health, prioritize reforestation and abating GGH emissions, and bring more land into public and local stewardship.

Under current law, to "reclaim" an AML is only to remove its immediate danger to humans.

- Policymakers should update the goal of AML reclamation to incorporate environmental health. This could be accomplished by encouraging reforestation on applicable sites, by focusing on AMLs that emit greenhouse gases, and other policies.

Historically, coal operators used poor reclamation techniques—if they reclaimed a mine at all.[156] On strip mines in Appalachia, "conventional" reclamation consisted of tight soil compaction and the planting of grassland and non-native plants that hinder the succession of native forests.[157] One forester notes, "it would literally take centuries for native forests" to return on many sites reclaimed with conventional techniques.[158]

For some sites that have set idle for decades, ecosystems have returned in some form, and most of the deforested mine acreage in Appalachia was likely mined after 1977. Yet, many AML-damaged sites have not been successfully reforested with native species.[159] While the damage from coal extraction can never be fully repaired, reforestation presents many advantages.

Reforestation has four key benefits: 1) forests sequester carbon, 2) forests clean water that can be polluted by coal deposits and other minerals on mine sites, 3) forests reduce water runoff, and 4) forests increase biodiversity and the wildlife habitat that native species require.[160] There are many examples of successful reforestation of native tree and plant species—such as tulip poplar, northern red oak, green ash, and imperiled species like the shortleaf pine and red spruce—on previously mined lands, though growth can depend on soil conditions and competition from invasive species.[161]

Reforestation sequesters carbon

Soil, trees, and other biomass naturally absorb and store carbon on reforested areas of reclaimed mines, though carbon sequestration can depend on mine conditions and species composition of new forests.[162] According to one estimate by the Forest Resources Association, young forests in Appalachia and surrounding states sequester about 1.6 metric tons of CO_2 per acre per year on average.[163] If a quarter of the unreclaimed acres of AML damage were reforested, then these forests could potentially sequester 232,000 metric tons of CO_2 per year—about as much as is emitted from powering 40,000 homes for a year.[164]

Reforestation can reduce flooding

Reforested mine sites have been shown to reduce runoff and increase water in the soil for plant availability.[165] Soil that is loosely dumped (not compacted) on reclaimed mine sites has been shown to lower total and peak rates of water discharge, meaning reforestation could help reduce flooding in areas like Central Appalachia where flood damage can be devastating and is more likely with climate change.[166] Reforestation also often lowers pollution and sediment carried from mine sites by water discharge, and has been shown to improve headwater stream quality.[167]

Reforestation can increase biodiversity

By restoring forest canopy and native trees, reforestation on mine sites can provide wildlife habitat needed for native species and increase biodiversity.[168] For example, the Cerulean Warbler, which makes its way from the Andes to the Appalachians every year and is one of North America's most threatened migratory songbirds, requires tall and large stands of trees that reforestation can help provide.[169] Reforestation can also help species like the golden-winged warbler, pollinator bees, and the endangered Indiana bat.[170]

AML reclamation should be updated so that reclamation plans seek not to just make them safe for humans but also improve ecosystem health and biodiversity. Since 2004 the Appalachian Regional Reforestation Initiative (ARRI), a coalition led by a team within OSMRE, has promoted the Forestry Reclamation Approach (FRA) as a superior method of reclamation for many sites.[171] In 2007, then-OSMRE Director Brent Wahlquist testified before Congress of the advantages of reforestation on land damaged by AMLs.[172]

ARRI and others have succeeded in making the FRA more common throughout Appalachia, including among state AML agencies. Yet, reforestation remains optional under SMCRA. Policymakers should consider prioritizing reforestation on AML sites where it is applicable. ARRI's goals – plant more hardwoods and increase their growth rate, and establish forest habitat through natural succession – provide a good starting point for environmental objectives of AML reclamation. While not applicable for many AML problem types, reforesting areas that were forested prior to mining should be a policy priority. More forests can help make Appalachia less sensitive to climate change, yet reforestation on mine sites is likely to be more difficult as the climate changes.[173] This suggests benefits to reforesting as quickly as possible.

Target GGH emissions from AMLs

Though greenhouse gas emissions from AMLs are not monitored or regulated, many underground mines leak CH_4 and mine fires emit CO_2, and they should similarly be prioritized for reclamation in order to lower contributions to climate change.

Stewardship of AML-impacted property

With current data, it is difficult to know who owns the land where AMLs are located. Many AMLs threaten private homes and local landowners, but it is likely that many are located on land whose surface or mineral rights are owned by corporate or absentee owners. The impacts of a long history of land theft in Appalachian and other coal regions – first dispossessed from Indigenous Peoples in the area, then from local residents whose land was often deceitfully purchased or illicitly stolen by speculators and capitalists seeking coal and other natural resources, to the significant loss of land held by Black farmers and Black residents across the country through racist policies and unscrupulous practices – continue to this day.[174]

Despite the stunning beauty of the land and waters in throughout Appalachia, the people who live in the region now are often unable to legally take advantage of this place because relatively little of the land is owned publicly. Further, much of the property (surface and/or mineral rights) remains owned by absentee or corporate owners.[175]

As the AML program transitions to a program that drastically ramps up reclamation and will address thousands of sites through Appalachia and other coal regions, the CCC reclamation agency could use mine reclamation as a legal mechanism to bring more property under public and local stewardship – especially in cases with absentee or corporate owners and where such owners are persistently tax delinquent. For applicable cases, the CCC could purchase impacted property, reclaim it, and then either put it into public stewardship or the stewardship of local land trusts or non-profits. Such efforts, if pursued, should be led by local communities.

4. Support mine reclamation training and research program(s).

The uptick in reclamation will present a large need for reclamation workforce development and training programs.

- Congress should fund OSMRE to support existing and create new reclamation workforce training programs(s) – in partnership with state and tribal agencies, universities, community colleges, and unions – to train the next generation of reclamation laborers, operators, engineers, scientists, inspectors, administrators, and more.

These programs, and their associated partnerships, should also lead the country in continuing to improve safe, environmentally sustainable, and efficient reclamation techniques through research.
Training centers should be located in impacted regions across the country and could be paired in locations with new CCC reclamation crews. Such programs at universities and community colleges could serve as key institutions in rural coal communities, helping anchor broader place-based community development efforts.[176]

As an example, in the late 1980s and early 1990s, Hocking College and the Ohio AML agency partnered on the College's 2-year reclamation degree (design and construction).[177] The state agency provided some projects to the college, so that participants in the program could gain real project experience while in the program.

5. Update the federal AML inventory and strengthen AML data collection and reporting.

- Congress should fund OSMRE to update the federal AML inventory in 3 years, using a combination of field and/or satellite assessment techniques.

The project should seek to have a (nearly) complete assessment of the remaining AML damage in states and tribes –including problem types, units, updated cost estimates, data on land owner(s), data on CH_4, CO_2, and other emissions, long-term AMD treatment needs, payroll data for completed projects, data on nearby populations (incl. race, ethnicity, and income), and other measures.[178] By updating AML funding to be based on the inventory after the 3-year window, OSMRE can incentivize states/tribes to quickly complete their inventorying efforts. In order to ensure accuracy, OSMRE will need to significantly strengthen oversight and verification, so that estimated costs in the inventory are reasonable and accurate.

6. Double AML fee levels and extend collections through 2050.

When the AML fees were created by Congress they represented an effective fee rate of 1.08% of the average price of coal.[179] The effective rate has now fallen to 0.60% because Congress decreased fee levels by 20% in 2006 and the average price of coal has risen 49% since 1979.[180] Doubling the current fee levels to $0.24 (underground), $0.56 (surface), and $0.16 (lignite) per ton would bring the fee levels to an effective fee rate of about 1.20% of the average price of coal in 2019 – a rate nearly identical to the original effective fee rate.[181]

The current fee levels will continue to be assessed through September 2021, generating a projected $0.11 billion in 2021 collections. Doubling fee levels starting in 2022 would generate a projected $1.1 to $5.9 billion in collections between 2022-2050, depending on coal production. [182] Even in the high production scenario AML fee collections will be far outstripped by the $26.3 of remaining need (medium scenario, 2050)—unless AML fees were drastically increased. If AML fees were increased to *ten times* their current levels, then collections would be a projected $5.4 to $29.4 billion by 2050 (assuming fees do not impact coal production projections in EIA2020), the higher end of which is within the range of remaining AML costs.[183] Fee levels at ten times the current levels would represent an effective fee rate of 4.80%.[184]

- If policymakers do not raise fee levels high enough to provide enough revenue to repair the remaining damage from the coal industry, **Congress should at least double the current AML fee levels through 2050, which could provide $1.1 to $5.9 billion in revenue from the responsible industry before it disappears.**

The maximum length Congress has extended the AML program in the past has been 15 years, which it has done twice.[185] The program has now been in place for more than 40 years, yet the job ahead is at least three times larger than what has been accomplished to this point. Given that the AML problem is not going away any time soon, Congress should extend AML fee collections for 29 years, through 2050, providing certainty to operators, AML officials, reclamation workers and owners, and communities. This long-term commitment to AML cleanup could prove critical in how these stakeholders plan for future reclamation.

7. Appropriate $13 billion in AML reclamation over the next 10 years. In 3-5 years, once the inventory is updated and more precise remaining AML costs are available, then appropriate more funding to complete (nearly) all remaining AML cleanup by 2050.

Without any new revenue, it will cost an estimated $26.3 billion to clean up all of the remaining AML damage (medium scenario; includes $5.4 billion in unreclaimed AML costs projected to be discovered between 2021-2050). Assuming $0.7 billion in more AML fees are collected, then $25.6 billion in costs remain (medium scenario).

- Congress should appropriate $13.1 billion for AML cleanup in the next 10 years, which would address roughly half of remaining AML damage according to current estimates.

Given the urgency of the climate crises and the economic distress facing coal regions, AML reclamation should be frontloaded. Such an approach would repair AML damage whose impacts worsen over time and would immediately ramp up job creation. The remaining half should then be appropriated and reclaimed between 2030 and 2050, perhaps by phasing down reclamation each decade, with 33% of remaining AML reclaimed in the 2030s and the last 17% in the 2040s. This funding timeline would support/create 6,909 direct jobs per year during from 2021-2030; the number of jobs supported would slowly decline over time as funding phased out. See figures 11 and 12 for jobs estimates.

This should be paired with an effort to update the inventory. Once a more accurate inventory is available, Congress should appropriate funding to reclaim the remaining damage. It is entirely possible that remaining costs will exceed our best estimates at present. In the event that costs are more than expected, front-loading AML reclamation will put the program in a better position in 2030 than otherwise. The AML formula could be simplified and updated to be based on the updated AML inventory.[186]

It is important that state and tribal AML agencies have long-term funding certainty in order to effectively staff their agencies. Congress should avoid short-term or annual funding and instead secure clear long-term appropriations so that agencies can effectively plan and hire up. Failing to do this could significantly and negatively hinder the ability of state/tribal agencies to complete effective and timely reclamation.

Congress should leave a sizeable portion, such as $1 billion, of the AML Fund untouched for reclamation post-2050, and whose interest helps finance key UMWA health and pension funds.[187] AML problems will continue to deteriorate over time even after "all" AML damage has been reclaimed in 2050, and AMD treatment systems will require ongoing maintenance costs.[188] Preserving a large portion of the AML Fund will provide dedicated funding for lingering AML reclamation after the program has largely wound down in 2050.

NOTES AND SOURCES

[1] This report builds on an earlier report written by this author and Kendall Bilbrey, “Abandoned Mine Land Program: A Policy Analysis for Central Appalachia and the Nation.” Appalachian Citizen’ Law Center, The Alliance for Appalachia. 2015. URL: https://aclc.org/wp-content/uploads/2020/08/aml-policy-paper.pdf

See Chapter 2 of the 2015 report for a history of the AML program.

[2] Completed AML reclamation plus in-process reclamation (designated as “Funded” in eAMLIS) equals $7.88 billion (medium scenario, as of 2020), which is 23% of the $34.17 billion in total estimated reclamation costs (medium scenario, projected for 2050). See sections II and III of Technical Note for details.

[3] **The AML program has reclaimed $7.9 billion in AML damage – *only 27%* of the $28.8 billion of AMLs** discovered as of 2020. That represents an even smaller *23%* of the $34.17 billion worth of all AMLs projected to be discovered by 2050 (medium scenario). See figures 1, 2, and 5, and the Technical Note.

[4] AML fee levels, originally set in 1977, have never been updated for inflation. To the contrary, in 2006, Congress reduced AML fee levels by 20%, despite calls from multiple parties, including OSMRE, that doing so would be insufficient to address remaining AML problems. For 2005 Congressional hearing see: https://www.congress.gov/event/109th-congress/senate-event/LC11673/text

For history of AML fee reauthorization and fee levels, see Chapters 2 and 5 of Dixon and Bilbrey, “Abandoned Mine Land Program: A Policy Analysis for Central Appalachia and the Nation.” Appalachian Citizen’ Law Center, The Alliance for Appalachia. 2015. URL: https://aclc.org/wp-content/uploads/2020/08/aml-policy-paper.pdf

[5] Unreclaimed cost estimates include construction, administration, and design costs. See sections I-V of Technical Note for details.

[6] See Technical Note and Ohio River Valley Institute blog post (March 2021) for details: https://ohiorivervalleyinstitute.org/the-true-cost-of-cleaning-up-historic-damage-from-the-coal-industry/

[7] This represents unreclaimed AML costs (construction, design, and administration) as of 2020 plus unreclaimed AML costs (construction, design, and administration) projected to be discovered 2021-2050 minus AML fee collections (current levels) from 2021-2050. All figures are medium scenario estimates. See sections I-VI of Technical Note for details.

[8] AML hazards have caused serious injury and death in the past. For more information on the danger of abandoned mines, see the section above on why AMLs are a problem, and see:
https://www.blm.gov/sites/blm.gov/files/uploads/AML_PUB_DangersAtAbandonedMines.pdf and
https://www.msha.gov/sosa
Methane emissions from some AMLs contribute to climate change, which the WHO and Haines et al. project will cause hundreds of thousands of annual premature deaths from 2030- 2050. See https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health and Haines, Andy, and Kristie Ebi. “The Imperative for Climate Action to Protect Health.” *New England Journal of Medicine* 380, no. 3 (January 17, 2019): 263–73. https://doi.org/10.1056/NEJMra1807873.

[9] For background on the decline in the coal industry, see: Houser, Trevor, Jason Bordoff, and Peter Marsters. “Can Coal Make A Comeback?” Rhodium Group. Center on Global Energy Policy, Columbia University., April 2017.
https://energypolicy.columbia.edu/sites/default/files/Center_on_Global_Energy_Policy_Can_Coal_Ma ke_Comeback_April_2017.pdf. ;
https://www.brookings.edu/blog/planetpolicy/2019/01/16/why-theres-no-bringing-coal-back/ ; and https://www.eia.gov/todayinenergy/detail.php?id=44115

[10] Wages and salary income per job in Appalachian mining and non-mining counties alike have been persistently lower than the US average since at least 2000 (pp. 33-34 of Bowen et al.); poverty rates of Appalachian mining and non-mining counties alike have been higher than the US average since at least 2000 (pp. 35-36 of Bowen et al.). Nearly 100 counties in Appalachia were economically distressed in both 1960 and 1990 (pp. 39, Wood and Bischak 2000). In 2020, 78 Appalachian counties are economically distressed, according to the FY2021 “County Economic Status in Appalachia” report from the Appalachian Regional Commission. The Appalachian regions of KY, WV, and OH – which contain significant unreclaimed AML damage – had poverty rates higher than the national average in 1979, 1989, 1999, and 2003 (pp. 3, Ziliak 2007).

Sources: Wood, L. Bischak, G. “Progress and Challenges in Reducing Economic Distress in Appalachia: An Analysis of National and Regional Trends Since 1960.” Prepared for the Appalachian Regional Commission. 2000. URL: https://www.arc.gov/report/progress-and-challenges-in-reducing-economic-distress-in-appalachia-an-analysis-of-national-and-regional-trends-since-1960/
For 2020 county distress data from the Appalachian Regional Commission see: https://www.arc.gov/map/county-economic-status-in-appalachia-fy-2021/

Ziliac, J. “Human Capital and the Challenges of Persistent Poverty in Appalachia.” Federal Reserve Bank of Cleveland. 2007. URL: https://www.clevelandfed.org/en/newsroom-and-events/publications/economic-commentary/economic-commentary-archives/2007-economic-commentaries/ec-20070201-human-capital-and-the-challenge-of-persistent-poverty-in-appalachia.aspx

Bowen, Eric, Christiadi, John Deskins, and Brian Lego. “An Overview of the Coal Economy in Appalachia.” West Virginia University. Commissioned by the Appalachian Regional Commission., January 2018. https://www.arc.gov/assets/research_reports/CIE1-OverviewofCoalEconomyinAppalachia.pdf.

[11] Coal jobs have been on a steady decline since the 1920s, despite relative upticks in the late 1970s and late 2000s (pp. 10, Houser et al.; see also pp. 25 of Stanley et al.). Total US coal production was 432,677,000 tons in 1959, 1,171,808,669 tons in 2008, and 706,309,263 tons in 2019 (Table ES1., EIA 2020). Total US coal employment was 862,536 in 1923, 203,597 in 1959, 133,828 in 2008, and 81,361 in 2019 (MSHA 2020). Thus, coal production in 2008 was 2.7 times *larger* than in 1959, while coal employment in 2008 was 0.65 times *smaller* than in 1959. Sources:
Houser, Trevor, Jason Bordoff, and Peter Marsters. “Can Coal Make A Comeback?” Rhodium Group. Center on Global Energy Policy, Columbia University., April 2017. https://energypolicy.columbia.edu/sites/default/files/Center_on_Global_Energy_Policy_Can_Coal_Ma ke_Comeback_April_2017.pdf.
Stanley, Michael C., John E. Strongman, Rachel Bernice Perks, Helen Ba Thanh Nguyen, Wendy Cunningham, Achim Daniel Schmillen, and Michael Stephen Mccormick. “Managing Coal Mine Closure : Achieving a Just Transition for All.” The World Bank, August 1, 2018.
http://documents.worldbank.org/curated/en/484541544643269894/Managing-Coal-Mine-Closure-Achieving-a-Just-Transition-for-All.
“Table ES1. Coal Production, 1949-2019.” Annual Coal Report 2019. US Energy Information Administration. October 2020. URL: https://www.eia.gov/coal/annual/pdf/tableES1.pdf
“Coal Statistics, 1900-2020.” Mine Safety and Health Administration. US Department of Labor. URL: https://arlweb.msha.gov/stats/centurystats/coalstats.asp

[12] According to the US Bureau of Labor Statistics, in 2011 Q4, coal mining employment was about 89,500 (excludes contractors); as of Q4 2020, coal mining employment was about 40,300 (excludes contractors), a 55% reduction in the past decade. Between 2011 and 2016 alone, coal jobs (*including contractors*) declined from **132,156 to 58,407, a 44% reduction (pp. 13., Houser et al.).**

Sources: U.S. Bureau of Labor Statistics, All Employees, Coal Mining [CES1021210001], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/CES1021210001, March 30, 2021.

Houser, Trevor, Jason Bordoff, and Peter Marsters. "Can Coal Make A Comeback?" Rhodium Group. Center on Global Energy Policy, Columbia University., April 2017. https://energypolicy.columbia.edu/sites/default/files/Center_on_Global_Energy_Policy_Can_Coal_Ma ke_Comeback_April_2017.pdf.

[13] For a classic analysis of land ownership patterns in Appalachia, see: Appalachian Land Ownership Task Force, "Who Owns Appalachia? Landownership and Its Impact" (1983). *Appalachian Studies*. 8. https://uknowledge.uky.edu/upk_appalachian_studies/8

For a more recent analysis of land ownership patterns in West Virginia, see: Boettner, Ted. "Who owns West Virginia?" West Virginia Center on Budget and Policy. American Friends Service Committee. December 2013. https://wvpolicy.org/who-owns-west-virginia-in-the-21st-century-2/

For a current project assessing land ownership in Appalachia see the Appalachian Land Study: https://www.appalachianlandstudy.org/about

[14] In *Black Coal Miners in America*, Lewis explores historic discrimination in coal mining across regions, from lower wages to exclusion from the industry. Among 15 states (PA, WV, KY, KS, OH, AL, VA, OK, ND, MT, MO, IA, MD, IL, TN) that include 98% of unreclaimed AML costs (medium scenario, as of 2020), poverty rates in 2019 were: 10.4% for the white population, 23.5% for the Black population, 22.2% for the Native population, 19.8% for the Hispanic/Latino population, and 11% for the Asian population. These figures include communities within these states that do not include AML damage, but these figures provide a rough picture of the racial poverty gaps in states with AML. Sources:
American Community Survey (5-year estimates), 2019, US Census Bureau. Downloaded from Social Explorer, March 30, 2021. https://www.socialexplorer.com/tables/ACS2019_5yr/R12789489
Lewis, Ronald L. *Black Coal Miners in America: Race, Class, and Community Conflict, 1780-1980*. Lexington, Ky. : University Press of Kentucky, c1987., 1987. https://find.library.duke.edu/catalog/DUKE008472397.

[15] Today coal mining is a largely white industry nationally: 93.1% of those employed in the coal mining industry in 2020 were white, and only 3.1% were Black people (Table 18. BLS 2020). In 1920, 23% of miners in the Southern Appalachian States were Black, but by 1980 this figure had dropped to 2.6% (pp. 191-2, Lewis 1987).
Sources: "Table 18. Employed persons by detailed industry, sex, race, and Hispanic or Latino ethnicity." 2020. Household data. Current Population Survey. US Bureau of Labor Statistics. https://www.bls.gov/cps/cpsaat18.htm

[16] For historic data on weekly hours of "home production" in the US by gender, see: https://ourworldindata.org/grapher/weekly-hours-dedicated-to-home-production-in-the-usa-by-gender
It is based on underlying data from: Ramey, Valerie R. (2009); Francis, Neville. A Century of Work and Leisure. American Economic Journal: Macroeconomics.

For historic data on the labor force participation rates of men and women in the US, see:
U.S. Bureau of Labor Statistics, Labor Force Participation Rate - Women [LNS11300002], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/LNS11300002, March 30, 2021.
And see: U.S. Bureau of Labor Statistics, Labor Force Participation Rate - Men [LNS11300001], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/LNS11300001, March 30, 2021.

Women's participation in the formal labor force has grown significantly over the past half century, though it still lags the rate of men in states with AML. Among 15 states (PA, WV, KY, KS, OH, AL, VA, OK, ND, MT, MO, IA, MD, IL, TN) that include 98% of unreclaimed AML costs (medium scenario, as of 2020), the labor force participation rate of women in 2019 was 58%, compared to 66% among men (among those age >15, the population of women was 36,617,829, and women in the labor force were 21,162,128; among those age >15, the population of men was 34,657,066, and men in the labor force were 22,984,264). Source: American Community Survey (5-year estimates), 2019, US Census Bureau. Downloaded from Social Explorer, March 31, 2021. https://www.socialexplorer.com/tables/ACS2019_5yr/R12789489

[17] Among 15 states (PA, WV, KY, KS, OH, AL, VA, OK, ND, MT, MO, IA, MD, IL, TN) that include 98% of unreclaimed AML costs (medium scenario, as of 2020), median income of men who worked full-time in 2019 was $53,157, and median income of women who worked full-time in 2019 was $42,036, a more than $10,000 gap. The poverty rate among men was 12.0% and among women was 14.5% in these states in 2019. These figures include many communities within these states that do not include AML damage, but these figures provide a rough picture of the gender pay gaps in states with AML. Source: American Community Survey (5-year estimates), 2019, US Census Bureau. Downloaded from Social Explorer, March 30, 2021. https://www.socialexplorer.com/tables/ACS2019_5yr/R12789489

For commentary on the shifting formal labor force in coal regions, see: Robertson, Campbell. "In Coal Country, the Mines Shut Down, the Women Went to Work and the World Quietly Changed." *The New York Times*, September 14, 2019, sec. U.S. https://www.nytimes.com/2019/09/14/us/appalachia-coal-women-work-.html.

[18] For a history and overview of coal mining and reclamation techniques see Zipper, Carl E., and Jeff Skousen. "Coal Mining and Reclamation in Appalachia." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[19] For a history of early coal mining in the US, a history of coal's contribution to the various sectors in the economy (home heating, transportation, electrical power production, steel, etc.), a historical analysis at surface and underground coal production in Appalachian counties, and a summary of the human health, fatality, and environmental legacy costs of coal mining, see pp. 10-22 of Zipper, Carl E., Jeff Skousen, and Mary Beth Adams. "The Appalachian Coalfield in Historical Context." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

Some portions of this report are lifted verbatim from the Executive Summary and Chapters 1 and 2 of Dixon and Bilbrey, "Abandoned Mine Land Program: A Policy Analysis for Central Appalachia and the Nation." Appalachian Citizen' Law Center, The Alliance for Appalachia. 2015. URL: https://aclc.org/wp-content/uploads/2020/08/aml-policy-paper.pdf

[20] For a pre-1977 history of coal mining reclamation, see pp. 66-67 of Zipper and Skousen (2021). They provide a basic definition of reclamation and its link to mining: "Reclamation includes landscape reconstruction, mine-site revegetation, and environmental impact mitigation. In a narrow sense, reclamation is not essential to mining since it occurs following mineral extraction; hence, it is possible to extract and sell coal while performing no reclamation. Without reclamation, however, coal mining can cause severe negative effects on environmental resources both on and beyond the mine site." (pp. 65-66, 2021).

Zipper, Carl E., and Jeff Skousen. "Coal Mining and Reclamation in Appalachia." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[21] 3,000 (9.38%) of the 32,000 km of highwalls were characterized as "massive slides." Findings of this 1969 US Department of Interior study are referenced on pp. 66 of Skousen and Zipper (2021): "By the mid-1960s, approximately 3600 km^2 had been surface-mined for coal in the seven Appalachian states extending from Tennessee north to Pennsylvania and Ohio; but > 60% of those mined areas were described as having experienced reclamation that was not "adequate" to mitigate negative effects (USDI 1969... By the mid-1960s, approximately 32,000 km of contour-mine highwall had been created, with more than 3,000 km of outslope characterized by "massive slides" (USDI 1969)." A Congressional report (1976), citing the US Soil Conservation Service, found that there were at least 11,000 acres of "land disturbed by coal surface mining" in need of reclamation nationally by 1974.

Zipper, Carl E., and Jeff Skousen. "Coal Mining and Reclamation in Appalachia." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

US Department of Interior (USDI) (1969) Surface mining and our environment

"House Report to Accompany H.R. 13950, Surface Mining Control and Reclamation Act of 1976." Report of the Committee on Interior and Insular Affairs, US House of Representatives. U.S. Government Printing Office, August 31, 1976.

[22] Skousen and Zipper (pp. 66, 2021) explain, "By the late-1970's, the land affected by surface mining in those same seven [Appalachian] states was estimated at 9300 km^2, most of which had been mined for coal (Johnson and Paone 1981)."

Zipper, Carl E., and Jeff Skousen. "Coal Mining and Reclamation in Appalachia." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[23] See pp. 67 of Zipper and Skousen (2021), which cites a study from Biesecker and George (1966).
Zipper, Carl E., and Jeff Skousen. "Coal Mining and Reclamation in Appalachia." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[24] K. W. James Rochow was the Assistant Attorney General of Pennsylvania. See K. W. J. Rochow, *The Far Side of Paradox: State Regulation of the Environmental Effects of Coal Mining*, 81 W. Va. L. Rev. (1979).
https://researchrepository.wvu.edu/wvlr/vol81/iss4/3

[25] Under current law, Group A are considered "High Priority" due to their immediate danger to human safety, and Group B are considered "low priority." The "Polluted Water: Human Consumption" problem type, though in Group B, is considered a "high priority" problem type by OSMRE. See OSMRE's website for current priority designations of problem types: https://www.osmre.gov/programs/AMLIS/priority1_2.shtm

[26] Estimates are based on data from eAMLIS (10.19.20); median cost per unit estimates come from 2019 IMCC/NAAMLP report, which calculated median construction cost estimates for Group A PTs using eAMLIS data from 2013-2018 and the professional opinion of AML officials; estimates of the percent of total unreclaimed cost assume the author's medium scenario of unreclaimed costs. See sections I-V of Technical Note for details.

[27] "2019 Ohio Annual Evaluation Report."

[28] See page 24 of "Frequently Asked Questions (FAQ) Re: The SMCRA Title IV AML Program." Prepared by the Interstate Mining Compact Commission (IMCC) and National Association of Abandoned Mine Land Programs (NAAMLP), January 2019.

[29] According to a 2016 analysis conducted by OSMRE/VISTA C. M. Mayne using 2010 Census data, 5,513,668 people (9.06% of total population) live within 1 mile of an AML in the 8 Appalachian states of PA, OH, WV, KY, TN, VA, AL, and MD. In West Virginia, nearly 1 in 3 (30.41%) people live within 1 mile of an AML.
https://static1.squarespace.com/static/564cc14be4b0f1c73e2cb294/t/57520e3907eaa0e9cd835a74/1464995405606/AML+Report.pdf

[30] See the following article for an overview of the potential health impacts of residents in coal mining communities in West Virginia—though the article does not focus on AMLs specifically.

Hendryx, Michael, and Melissa M. Ahern. "Relations Between Health Indicators and Residential Proximity to Coal Mining in West Virginia." *American Journal of Public Health* 98, no. 4 (April 2008): 669–71. https://doi.org/10.2105/AJPH.2007.113472.

[31] There are no studies directly investing health impacts from coal mine fires on nearby residents but Melody and Johnston (2015) provide a good investigation of adjacent literature, showing that emissions from coal fires are likely to be harmful with certain degrees of exposure.
Melody, S.M., and F.H. Johnston. "Coal Mine Fires and Human Health: What Do We Know?" *International Journal of Coal Geology* 152 (December 1, 2015): 1–14. https://doi.org/10.1016/j.coal.2015.11.001.

[32] Bowen, Eric, Christiadi, John Deskins, and Brian Lego. "An Overview of the Coal Economy in Appalachia." West Virginia University. Commissioned by the Appalachian Regional Commission., January 2018. https://www.arc.gov/assets/research_reports/CIE1-OverviewofCoalEconomyinAppalachia.pdf.

[33] Hansen, Evan, Alan Collins, Julie Svetlik, Sarah McClurg, Alyse Shrecongost, Rob Stenger, Mariya Schilz, and Fritz Boettner. "AN ECONOMIC BENEFIT ANALYSIS FOR ABANDONED MINE DRAINAGE REMEDIATION IN THE WEST BRANCH SUSQUEHANNA RIVER WATERSHED, PENNSYLVANIA." (2008): 1-72. *Downstream Strategies*.

[34] *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era* (2021), edited by Skousen and Zipper, provides an excellent compilation of the geologic, biological, chemical, human health, economic, history, and many other aspects of coal mining and reclamation in Appalachia before and after the 1977 passage of SMCRA. For a general history of coal reclamation prior to 1977, see pp. 66-67 of Zipper and Skousen (2021); for a history of pre-1977 coal mining's soil and related impacts, see pp. 86-88 of Skousen et al. (2021); for an account of the chemistry of acid mine drainage (AMD), a history of AMD and its biological impacts, and a basic account of the engineering behind AMD remediation techniques, see pp. 194-213 of Kruse Daniels et al. (2021); for a history of the plant-related impacts of pre-1977 mining, see pp. 114-117 of Sena et al. (2021); for an account of the impacts of (pre-1977 and post-1977) coal mining on terrestrial wildlife, see pp. 135-158 of Lituma et al. (2021); for a review of uses of post-mined land see pp. 167-192 of Zipper et al. (2021).

Zipper, Carl E., and Jeff Skousen. "Coal Mining and Reclamation in Appalachia." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

Skousen, Jeff, W. Lee Daniels, and Carl E. Zipper. "Soils on Appalachian Coal-Mined Lands." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

Sena, Kenton, Jennifer A. Franklin, Rebecca M. Swab, and Sarah L. Hall. "Plant Communities on Appalachian Mined Lands." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

Sena, Kenton, Christopher M. Lituma, John. J. Cox, Stephen F. Spear, John W. Edwards, Jesee L. De La Cruz, Lisa I. Muller, and W Ford Mark. "Terrestrial Wildlife in the Post-Mined Appalachian Landscape: Status and Opportunities." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

Zipper, Carl E., Carmen T. Agouridis, Christoper T. Barton, and Jeff Skousen. "Conversion Options for Mining-Affected Lands and Waters in Appalachia." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

Kruse Daniels, Natalie, Julie A. LaBar, and Louis M. McDonald. "Acid Mine Drainage in Appalachia: Sources, Legacy, and Treatment." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[35] See pp. 114-118 of Sena et al. (2021) for impacts on plant communities; see pp. 137 and 139-158 of Lituma et al. (2021) for mining and reclamation impacts on wildlife, including herptofauna (salamanders, reptiles), avifauna (forest obligate birds, grassland-dependent birds, raptors), and mammals (bats, small and meso-mammals, white-tailed deer, black bear, elk); see Wood et al. (2013) for impacts on terrestrial wildlife and biodiversity.

Sena, Kenton, Christopher M. Lituma, John. J. Cox, Stephen F. Spear, John W. Edwards, Jesee L. De La Cruz, Lisa I. Muller, and W Ford Mark. "Terrestrial Wildlife in the Post-Mined Appalachian Landscape: Status and Opportunities." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

Wood, Petra, Jeff Larkin, Jeremy Mizel, Carl Zipper, and Patrick Angel. "Reforestation To Enhance Appalachian Mined Lands As Habitat For Terrestrial Wildlife." Appalachian Regional Reforestation Initiative (ARRI), November 2013.

[36] See pp. 170 of Zipper, Carl E., Carmen T. Agouridis, Christoper T. Barton, and Jeff Skousen. "Conversion Options for Mining-Affected Lands and Waters in Appalachia." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[37] See pp. 88 of Skousen, Jeff, W. Lee Daniels, and Carl E. Zipper. "Soils on Appalachian Coal-Mined Lands." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

Sena et al. state, "Plant diversity was not a priority and planted areas were considerably lower in species diversity than in pre-mining forests (Holl and Cairns 1994)" (pp. 116, 2021). Many plants on post-mined sites before 1977 were not native (pp. 116, Sena et al. 2021). Sena et al. also note, pre-SMCRA sites "may lack large trees, overstory species diversity, larger-sized downed woody debris, and standing snags; and may have understories lacking native species or dominated by invasive shrubs" (pp. 117, 2021).

Sena, Kenton, Jennifer A. Franklin, Rebecca M. Swab, and Sarah L. Hall. "Plant Communities on Appalachian Mined Lands." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[38] For quotation and impacts on wildlife diversity, see Wood et al. (2013). For some environmental impacts of pre-1977, see pp. 116 of Sena et al. (2021).
Wood, Petra, Jeff Larkin, Jeremy Mizel, Carl Zipper, and Patrick Angel. "Reforestation To Enhance Appalachian Mined Lands As Habitat For Terrestrial Wildlife." Appalachian Regional Reforestation Initiative (ARRI), November 2013.
Sena, Kenton, Jennifer A. Franklin, Rebecca M. Swab, and Sarah L. Hall. "Plant Communities on Appalachian Mined Lands." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[39] See pp. 67 of Zipper, Carl E., and Jeff Skousen. "Coal Mining and Reclamation in Appalachia." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[40] Unreclaimed AMLs in Clogged Streams and Clogged Stream Lands (eAMLIS, 10.19.20). See Figure 3.
[41] Zipper and Skouson note, "Results of poor revegetation included excessive erosion and water-borne movement of the exposed mineral material into streams, in some cases clogging those streams and causing local flooding (USDI 1969). Other forms of water pollution occurred when sulfur- bearing spoils were excavated and exposed to air and water, causing acid drainage and mobilizing acid-soluble trace metals (Kruse Daniels et al. 2021)" (pp. 67, Zipper and Skousen 2021).

Zipper, Carl E., and Jeff Skousen. "Coal Mining and Reclamation in Appalachia." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[42] See Bruggers (2021), who quotes William C. Haneberg, Kentucky state geologist and research professor at the University of Kentucky.
Bruggers, James. "Appalachia's Strip-Mined Mountains Face a Growing Climate Risk: Flooding." *Inside Climate News*, November 21, 2019. https://insideclimatenews.org/news/21112019/appalachia-mountains-flood-risk-climate-change-coal-mining-west-virginia-extreme-rainfall-runoff-analysis.

[43] See Bruggers (2021), who references the hydrologists who studied the flash flood in the Pigeon River watershed and was litigated in Mingo County Circuit Court in West Virginia. See also Leven and Goldstein (2019), who explain, "Harless Creek was one of at least three cases in Kentucky in which engineering studies found that inappropriately operated or cleaned-up mines worsened flood damage, said Jack Spadaro, a former federal mine regulator who served as an expert witness for plaintiffs in lawsuits about those incidents. The floods collectively killed at least one person and destroyed the homes or belongings of more than 250 residents, according to news reports." The 2010 engineering report for the Harless Creek watershed in Pike County, KY, prepared by the firm Faulkner & Flynn, can be found here; it found that active mine sites nearby contributed to 44% more water rushing into the area during the flood.

Bruggers, James. "Appalachia's Strip-Mined Mountains Face a Growing Climate Risk: Flooding." *Inside Climate News*, November 21, 2019. https://insideclimatenews.org/news/21112019/appalachia-mountains-flood-risk-climate-change-coal-mining-west-virginia-extreme-rainfall-runoff-analysis.

Leven, Rachel, and Zach Goldstein. "Disastrous Disconnect: Coal, Climate And Catastrophe In Kentucky." *Ohio Valley ReSource*, October 28, 2019. https://ohiovalleyresource.org/2019/10/28/disastrous-disconnect-coal-climate-and-catastrophe-in-kentucky/.

[44] Skousen et al. (pp. 102, 2021) explain, "Appalachian mine sites often produce greater peak surface water stormflows and greater baseflows than do corresponding natural landscapes primarily due to greater water availability from decreased evapotranspiration and greater runoff caused by forest removal (Evans et al. 2015). Mine soil hydrology is fundamental to those effects which vary widely among mine sites."

Skousen, Jeff, W. Lee Daniels, and Carl E. Zipper. "Soils on Appalachian Coal-Mined Lands." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3

[45] For some recent news reports on damages of flooding in Appalachia, see:
Gaffney, Austyn. "Floods Inundating Appalachian Communities Are 'Public Health Nightmares.'" *Southerly*, February 17, 2020. https://southerlymag.org/2020/02/17/floodwaters-inundating-appalachian-communities-are-public-health-nightmares/.
Myers, Katie, and Corinne Boyer. "Slow Recovery: Repeated Floods And Storms Strain East Kentucky's Aging Infrastructure." Ohio Valley ReSource, March 18, 2021. https://ohiovalleyresource.org/2021/03/17/slow-recovery-repeated-floods-and-storms-strain-east-kentuckys-aging-infrastructure/.
Hersher, Rebecca, Huo Jingnan, and Sophia Schmidt. "A Looming Disaster: New Data Reveal Where Flood Damage Is An Existential Threat." *NPR*, February 22, 2021. https://www.npr.org/2021/02/22/966428165/a-looming-disaster-new-data-reveal-where-flood-damage-is-an-existential-threat.

[46] According to Leven and Goldstein (2019), "Flooding is already the state's 'most frequent and costly natural hazard,' killing 41 people over a recent 11-year period and causing an average of $40 million in annual losses, according to the Kentucky Division of Emergency Management.'"

Leven, Rachel, and Zach Goldstein. "Disastrous Disconnect: Coal, Climate And Catastrophe In Kentucky." *Ohio Valley ReSource*, October 28, 2019. https://ohiovalleyresource.org/2019/10/28/disastrous-disconnect-coal-climate-and-catastrophe-in-kentucky/.

[47] For recent reporting on increased flooding and landslides in Appalachian Kentucky and its relation to mining, see Myers (April 2021).

Myers, Katie. "Slip Sliding Away: Landslides Follow Flooding As Major Risk To Appalachian Communities." Ohio Valley ReSource, April 9, 2021. https://ohiovalleyresource.org/2021/04/09/slip-sliding-away-landslides-follow-flooding-as-major-risk-to-appalachian-communities/.

[48] See Bruggers (2019) and Butler et al. (2015), in which precipitation increases in multiple watersheds in Central Appalachia assessed by the researchers.
Bruggers, James. "Appalachia's Strip-Mined Mountains Face a Growing Climate Risk: Flooding." *Inside Climate News*, November 21, 2019. https://insideclimatenews.org/news/21112019/appalachia-mountains-flood-risk-climate-change-coal-mining-west-virginia-extreme-rainfall-runoff-analysis.
Butler, Patricia, Louis Iverson, Frank Thompson, Leslie Brandt, Stephen Handler, Maria Janowiak, Danielle Shannon, et al. *Central Appalachians Forest Ecosystem Vulnerability Assessment and Synthesis*, 2015.

[49] Analysis is from researchers Megan Ossmann and Alexander Yoshizumi of Duke University and *Inside Climate News*, using data from a 2017 US Army Corps of Engineers study.
Bruggers, James. "Appalachia's Strip-Mined Mountains Face a Growing Climate Risk: Flooding." *Inside Climate News*, November 21, 2019. https://insideclimatenews.org/news/21112019/appalachia-mountains-flood-risk-climate-change-coal-mining-west-virginia-extreme-rainfall-runoff-analysis.

[50] According to the *Ohio Valley ReSource*, a 2018 National Climate Assessment report from the US Global Change Research Program "shows that intense rainstorms have increased significantly in the Ohio Valley over the past half-century. In West Virginia and parts of the northeastern U.S., the proportion of precipitation that comes down in the heaviest storms went up by more than 50%. In Kentucky and Ohio, those heavy storms are up by about a third over the same period." Similiarly, Leven and Goldstein (2020) report, "Kentucky storms dumping at least 2 inches of rain over a 24-hour period — storms that pose a flood risk — have increased 20 percent since the early 20th century, said Kenneth Kunkel, lead scientist for technical support for the federal government's National Climate Assessment."

Leven, Rachel, and Zach Goldstein. "Disastrous Disconnect: Coal, Climate And Catastrophe In Kentucky." *Ohio Valley ReSource*, October 28, 2019. https://ohiovalleyresource.org/2019/10/28/disastrous-disconnect-coal-climate-and-catastrophe-in-kentucky/.

Suhail, Bhat, and Jeff Young. "Climate Change Increases Flooding Risk For Some 230,000 Ohio Valley Homes." *Ohio Valley ReSource*, February 26, 2021. https://www.wkms.org/post/climate-change-increases-flooding-risk-some-230000-ohio-valley-homes.

USGCRP, 2018: *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 1515 pp. doi: 10.7930/NCA4.2018.

[51] According to the *Ohio Valley ReSource's analysis of* a report from First Street Foundation, "flooding risk that accounts for the effects of climate change finds many more homes in Appalachian communities in Kentucky, Ohio and West Virginia are at risk of flooding than the federal government's emergency managers have indicated. In 12 Appalachian counties in the region, at least half of all residences are at risk, and in West Virginia one in five homes carry a high risk of flooding, according to an analysis of the data released by the nonprofit First Street Foundation." Similarly, Levan and Goldstein report, "a 2018 [Kentucky] state flood risk assessment, citing a 2017 federal study about climate effects in the region, warns that flooding events are likely to become more frequent and severe."

Suhail, Bhat, and Jeff Young. "Climate Change Increases Flooding Risk For Some 230,000 Ohio Valley Homes." *Ohio Valley ReSource*, February 26, 2021. https://www.wkms.org/post/climate-change-increases-flooding-risk-some-230000-ohio-valley-homes.

[52] Nearby population figures are from a 2016 analysis by OSMRE/VISTA C. M. Wayne using 2010 Census data. https://static1.squarespace.com/static/564cc14be4b0f1c73e2cb294/t/57520e3907eaa0e9cd835a74/1464995405606/AML+Report.pdf

Acres are a standardized measurement (GPRA) from OSMRE's official AML inventory, eAMLIS (10.19.20). Unreclaimed costs are calculated by the author (medium scenario, as of 2020), and are rooted in data from eAMLIS (10.19.20) and from a 2019 report from IMCC/NAAMLP. See above and Technical Note for details. Common problem types are ranked according to largest unreclaimed GPRA for each type in each state. Mean hourly gross pay data is for all industries – *not just AML reclamation*—for a) Construction Laborers (SOC Code472061) and b) Operating Engineers and Other Construction Equipment Operators (SOC Code472073). BLS data is from May 2019: "Occupational Employment and Wages, May 2019. 47-2061 Construction Laborers." Bureau of Labor Statistics (BLS). URL: < https://www.bls.gov/oes/current/oes472061.htm#nat>. State statistics were access through the BLS Occupational Employment Statistics Query System: <https://data.bls.gov/oes/#/occGeo/One%20occupation%20for%20multiple%20geographical%20areas>

[53] See pp. 246 of Merovich Jr. et al. (2021), who cite Jelks et al. (2008), Crandall and Buhay (2008), Warren et al. (2000), Kozak and Wiens (2010), and Mynsberge et al. (2009).

Merovich Jr., George T., Nathaniel P. Hitt, Eric R. Merriam, and Jess W. Jones. "Response of Aquatic Life to Coal Mining in Appalachia." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[54] See pp. 193 of Kruse Daniels, Natalie, Julie A. LaBar, and Louis M. McDonald. "Acid Mine Drainage in Appalachia: Sources, Legacy, and Treatment." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[55] See pp. 193 of Kruse Daniels, Natalie, Julie A. LaBar, and Louis M. McDonald. "Acid Mine Drainage in Appalachia: Sources, Legacy, and Treatment." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[56] See pp. 194 of Kruse Daniels, Natalie, Julie A. LaBar, and Louis M. McDonald. "Acid Mine Drainage in Appalachia: Sources, Legacy, and Treatment." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[57] See pp. 194 of Kruse Daniels, Natalie, Julie A. LaBar, and Louis M. McDonald. "Acid Mine Drainage in Appalachia: Sources, Legacy, and Treatment." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[58] See pp. 195 of Kruse Daniels et al (2021). For a more detailed account of the chemistry behind AMD, Daniels Kruse (pp. 194, 2021) explain, "Coals and associated rocks are often laden with pyrite and other metal sulfides, which upon exposure to air and water during mining or other land disturbance react to form protons (H^+), sulfate (SO_4^{2-}), dissolved iron (Fe), and other products. These low- pH waters can dissolve or otherwise react with other rocks and minerals to increase dissolved concentrations of other metals, especially aluminum (Al) and sometimes manganese (Mn). These acids and metals are released into mine drainage waters to contaminate local streams and waterways."

Kruse Daniels, Natalie, Julie A. LaBar, and Louis M. McDonald. "Acid Mine Drainage in Appalachia: Sources, Legacy, and Treatment." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[59] See pp. 193, 212 of Kruse Daniels, Natalie, Julie A. LaBar, and Louis M. McDonald. "Acid Mine Drainage in Appalachia: Sources, Legacy, and Treatment." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[60] See pp. 194, 195, 198 of Kruse Daniels, Natalie, Julie A. LaBar, and Louis M. McDonald. "Acid Mine Drainage in Appalachia: Sources, Legacy, and Treatment." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[61] See pp. 195 of Kruse Daniels, Natalie, Julie A. LaBar, and Louis M. McDonald. "Acid Mine Drainage in Appalachia: Sources, Legacy, and Treatment." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[62] See pp. 196 of Kruse Daniels et al. (2021), who cite Cravotta and Brady (2015).
Kruse Daniels, Natalie, Julie A. LaBar, and Louis M. McDonald. "Acid Mine Drainage in Appalachia: Sources, Legacy, and Treatment." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[63] For macroinvertebrates, see pp. 196 of Kruse Daniels et al. (2020), who cite Simmons et al. (2005) and Bott et al. (2017). Regarding fish species, Merovich et al. underline that AMD "is associated with decreased stream fish diversity and biomass," citing Cannon and Kimmel (1992)" (pp. 259, 2021).

Kruse Daniels, Natalie, Julie A. LaBar, and Louis M. McDonald. "Acid Mine Drainage in Appalachia: Sources, Legacy, and Treatment." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

Merovich Jr., George T., Nathaniel P. Hitt, Eric R. Merriam, and Jess W. Jones. "Response of Aquatic Life to Coal Mining in Appalachia." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

Cannon, William E., and William G. Kimmel. "A Comparison Of Fish And Macroinvertebrate Communities Between An Unpolluted Stream And The Recovery Zone Of A Stream Receiving Acid Mine Drainage." *Journal of the Pennsylvania Academy of Science* 66, no. 2 (1992): 58–62.

[64] See pp. 196 of Daniels Kruse et al. (2020), who cite Bott et al. (2012).

Bott, Thomas L., John K. Jackson, Matthew E. McTammany, J. Denis Newbold, Steven T. Rier, Bernard W. Sweeney, and Juliann M. Battle. "Abandoned Coal Mine Drainage and Its Remediation: Impacts on Stream Ecosystem Structure and Function." *Ecological Applications* 22, no. 8 (2012): 2144–63. https://doi.org/10.1890/11-1735.1.

Kruse Daniels, Natalie, Julie A. LaBar, and Louis M. McDonald. "Acid Mine Drainage in Appalachia: Sources, Legacy, and Treatment." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[65] Quote is from pp. 259 of Merovich Jr. et al. (2021); study is from Schorr et al. (2013).

Merovich Jr., George T., Nathaniel P. Hitt, Eric R. Merriam, and Jess W. Jones. "Response of Aquatic Life to Coal Mining in Appalachia." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

Schorr, Mark S., Melissa C. Dyson, Charles H. Nelson, Gene S. Van Horn, David E. Collins, and Sean M. Richards. "Effects of Stream Acidification on Lotic Salamander Assemblages in a Coal-Mined Watershed in the Cumberland Plateau." *Journal of Freshwater Ecology* 28, no. 3 (September 1, 2013): 339–53. https://doi.org/10.1080/02705060.2013.778219.

[66] See pp. 211 of Kruse Daniels et al. (2020), who cite Kruse et al. (2012a) and others.

Kruse Daniels, Natalie, Julie A. LaBar, and Louis M. McDonald. "Acid Mine Drainage in Appalachia: Sources, Legacy, and Treatment." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[67] See Freund and Petty (2007); Merovich Jr. et al. (pp. 274-275, 2021) explain, "One important finding to date includes evidence that mining may have watershed- scale impacts, even to aquatic assemblages typically believed to be largely sessile (i.e., macroinvertebrates). Mining not only directly impacts local stream segments and aquatic life, but also indirectly impacts biota in unaffected streams not receiving mine runoff; these communities can show reduced richness, reduced IBI scores, and simpler food webs, because they can be cut off from the larger species pool by chemical barriers to dispersal (e.g., Freund and Petty 2007). Consequently, isolated stream reaches within a mosaic of mining impacts can lose biodiversity or struggle to recover from disturbance."

Merovich Jr., George T., Nathaniel P. Hitt, Eric R. Merriam, and Jess W. Jones. "Response of Aquatic Life to Coal Mining in Appalachia." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

Freund, Jason G., and J. Todd Petty. "Response of Fish and Macroinvertebrate Bioassessment Indices to Water Chemistry in a Mined Appalachian Watershed." *Environmental Management* 39, no. 5 (May 1, 2007): 707–20. https://doi.org/10.1007/s00267-005-0116-3.

[68] See pp. 200 of Kruse Daniels et al. (2020), who cite Meek (1996) and others.

Kruse Daniels, Natalie, Julie A. LaBar, and Louis M. McDonald. "Acid Mine Drainage in Appalachia: Sources, Legacy, and Treatment." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[69] See pp. 200 of Kruse Daniels et al. (2020), who cite Simmons et al. (2005), Drerup and Vis (2017), and Bowman et al. (2017).

Kruse Daniels, Natalie, Julie A. LaBar, and Louis M. McDonald. "Acid Mine Drainage in Appalachia: Sources, Legacy, and Treatment." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[70] See pp. 194, 198 of Kruse Daniels et al. (2021), who cite ARC (1969), and Herlihy et al. (1990). See also pp. 15 of House Report (1976), which also estimates around 11,000 miles of streams impacted by AMD.

"House Report to Accompany H.R. 13950, Surface Mining Control and Reclamation Act of 1976." Report of the Committee on Interior and Insular Affairs, US House of Representatives. U.S. Government Printing Office, August 31, 1976.

Acid Mine Drainage in Appalachia, a Report by the Appalachian Regional Commission. Appendix A-[F]. Acid Mine Drainage in Appalachia, a Report by the Appalachian Regional Commission. Appendix A-[F]. Appalachian Regional Commission (ARC), 1969.

Herlihy, Alan T., Philip R. Kaufmann, Mark E. Mitch, and Douglas D. Brown. "Regional Estimates of Acid Mine Drainage Impact on Streams in the Mid-Atlantic and Southeastern United States." *Water, Air, and Soil Pollution* 50, no. 1 (March 1, 1990): 91–107. https://doi.org/10.1007/BF00284786.

[71] This includes the unreclaimed standard units (Count) for problem types Polluted Water: Agricultural & Industrial and Polluted Water: Human Consumption, as well as the flow for unreclaimed problem type Water Problems (eAMLIS, 10.19.20).

[72] See pp. 201-212 of Kruse Daniels et al. (2021) for an account of various AMD treatment methods. Treatment systems are summarized here: "Multiple methods for treating AMD are available. Selection of the most effective method for a given AMD problem will depend on site-specific characteristics, including the potential for AMD-generating mineral depletion over time. Active treatment entails the addition of alkaline chemicals to neutralize the AMD acidity, and may require other ongoing inputs such as electric power. Hence, long-term funding is necessary to maintain the stream recovery, and lack of resources adequate to maintain treatment can lead to treatment-system failure and the return of stream impairment. Passive treatment systems, when selected and designed in a manner appropriate to AMD discharge chemistry and volume, can allow for effective and long-term treatment. Due to their passive nature, passive treatment systems can be resilient to change. Most passive treatment systems, however, also require long-term maintenance; such systems can be difficult to monitor in remote areas and, in the absence of AMD-source depletion, may require eventual replacement in order to maintain effective AMD remediation and ecosystem improvement." (pp. 212-213, 2021).

Kruse Daniels, Natalie, Julie A. LaBar, and Louis M. McDonald. "Acid Mine Drainage in Appalachia: Sources, Legacy, and Treatment." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[73] See pp. 211 212 of Kruse Daniels et al. (2021); Merovich Jr. et al. (pp. 268, 2021) explain, "Occupancy, abundance, density, and community richness have been shown to improve with AMD treatment, but these measures poorly reflect recovery because they do not consider the ecology of specific species (DeNicola et al. 2012)."

Merovich Jr., George T., Nathaniel P. Hitt, Eric R. Merriam, and Jess W. Jones. "Response of Aquatic Life to Coal Mining in Appalachia." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

Kruse Daniels, Natalie, Julie A. LaBar, and Louis M. McDonald. "Acid Mine Drainage in Appalachia: Sources, Legacy, and Treatment." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[74] "Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2018." As of 2018, abandoned underground coal mines released 8.9 MMT CO2 Eq. of methane, of which 2.7 MMT was recovered and used. 6.2 net CH_4 emissions from abandoned coal mines is 0.977% of total CH_4 emissions (634.5 MMT) (See Tables 3-33 and ES-2 of "Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2018").

[75] See Khalod et al. (2020) "Methane emissions from coal mining are growing." American Geophysical Union. Fall Meeting. https://agu.confex.com/agu/fm20/webprogram/Paper667289.html

And "Methane Emissions from Coal Mines Are Higher Than Previously Thought." Pacific Northwest National Laboratory. News Release. January 2021. https://www.pnnl.gov/news-media/methane-emissions-coal-mines-are-higher-previously-thought

[76] "Methane Emissions from Abandoned Coal Mines in the United States: Emission Inventory Methodology and 1990-2002 Emissions Estimates"; "Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2018." The underlying analysis for these estimates is based on a 2004 EPA report that included 145 mines closed before 1972 and 258 mines closed between 1972 and 1990 (see 3-67 of source). The author assumes that at least 55 of these 258 mines were closed between 1972-1977, yielding an estimate of at least 200 methane-releasing abandoned coal mines abandoned prior to 1977.

[77] See pp. 1 of Kolker, Allan, Mark Engle, Glenn Stratcher, James Hower, Anupma Prakesh, Lawrence Radke, Arnout ter Schure, and Ed Heffern. "Emissions from Coal Fires and Their Impact on the Environment." Fact Sheet. U.S. Geological Survey, 2009.

[78] See pp. 1 of Kolker, Allan, Mark Engle, Glenn Stratcher, James Hower, Anupma Prakesh, Lawrence Radke, Arnout ter Schure, and Ed Heffern. "Emissions from Coal Fires and Their Impact on the Environment." Fact Sheet. U.S. Geological Survey, 2009.

[79] See pp. 1 of Kolker et al. (2007). For more info on the Centralia mine fire see O'Carroll (2010) and Clayton (2010).

Kolker, Allan, Mark Engle, Glenn Stratcher, James Hower, Anupma Prakesh, Lawrence Radke, Arnout ter Schure, and Ed Heffern. "Emissions from Coal Fires and Their Impact on the Environment." Fact Sheet. U.S. Geological Survey, 2009.
O'Carroll, Eoin. "Centralia, Pa.: How an Underground Coal Fire Erased a Town." *Christian Science Monitor*, February 5, 2010. https://www.csmonitor.com/Environment/Bright-Green/2010/0205/Centralia-Pa.-How-an-underground-coal-fire-erased-a-town.
Clayton, Mark. "Centralia, Pa., Coal Fire Is One of Hundreds That Burn in the U.S." *Christian Science Monitor*, February 5, 2010. https://www.csmonitor.com/Environment/2010/0205/Centralia-Pa.-coal-fire-is-one-of-hundreds-that-burn-in-the-U.S.

[80] Unreclaimed acres of Underground Mine Fire AMLs and Surface Burning AMLs total 6,928 acres (eAMLIS, 10.19.20). Some researchers have provided estimates of the number of fires; Clayton (2010) states, "Approximately 200 underground coal fires burn in about 20 states, according to Glenn Stracher, a researcher at East Georgia College in Swainsboro, Ga."
Clayton, Mark. "Centralia, Pa., Coal Fire Is One of Hundreds That Burn in the U.S." *Christian Science Monitor*, February 5, 2010. https://www.csmonitor.com/Environment/2010/0205/Centralia-Pa.-coal-fire-is-one-of-hundreds-that-burn-in-the-U.S.

[81] See pp. 2 of Kolker. et al (2009). Hower et al (pp. 1, 2013) estimate that one mine fire in eastern Kentucky, for example, annually emits 65.69 tons of CO_2, 5.73 tons of CH_4, 4.51 tons of CO, and 1.667 kg Hg. For more information on methods to estimate CO_2 emissions from mines see Orr et al. (2016).

Orr, Franklin M., Claudia Kuenzer, and S. Taku Ide. "Estimating CO2 Emissions from Subsurface Coal Fires." In *Exploring Natural Hazards: A Case Study Approach*. Chapman and Hall, 2016. https://www.taylorfrancis.com/chapters/edit/10.1201/9781315166858-9/estimating-co2-emissions-subsurface-coal-fires-taku-ide-claudia-kuenzer-franklin-orr.

Kolker, Allan, Mark Engle, Glenn Stratcher, James Hower, Anupma Prakesh, Lawrence Radke, Arnout ter Schure, and Ed Heffern. "Emissions from Coal Fires and Their Impact on the Environment." Fact Sheet. U.S. Geological Survey, 2009.

Hower, James C., Jennifer M. K. O'Keefe, Kevin R. Henke, Nicola J. Wagner, Gregory Copley, Donald R. Blake, Trent Garrison, Marcos L. S. Oliveira, Rubens M. Kautzmann, and Luis F. O. Silva. "Gaseous Emissions and Sublimates from the Truman Shepherd Coal Fire, Floyd County, Kentucky: A Re-Investigation Following Attempted Mitigation of the Fire." *International Journal of Coal Geology* 116–117 (September 1, 2013): 63–74. https://doi.org/10.1016/j.coal.2013.06.007.

[82] A mine fire has been burning below the town of Centralia, Pennsylvania since 1962; most residents of the town have had to be relocated (pp. 1, Kolker et al. 2007). For more info on the Centralia mine fire see Eoin (2010) and Clayton (2010). In Jefferson County, Alabama, a fire lit in 2007 on a 32 acre coal refuse pile of the former Mulga Mine, which operated until 1960 (Collins 2007). In addition to CO_2 emissions, the site was also reported to leak CH_4—so much so that El Paso Corp. acquired a permit to install gas wells on part of the property. In a local news report, workers addressing the fire – which was 2,200 degrees in areas – called it "working in hell" (Collins 2007). Local residents claimed that trees had been removed in the area surrounding the gob pile, which had previously filtered the air and reduced the smell from the fire for nearby residents.

See pp. 2, 3 of Kolker, Allan, Mark Engle, Glenn Stratcher, James Hower, Anupma Prakesh, Lawrence Radke, Arnout ter Schure, and Ed Heffern. "Emissions from Coal Fires and Their Impact on the Environment." Fact Sheet. U.S. Geological Survey, 2009.
Collins, Michelle. "Gob Burn Smells Bad, Irks Jeffco Residents." *The Birmingham News*. September 23, 2007. Accessed April 2, 2021.
https://www.tuscaloosanews.com/article/20070923/News/606121914.
O'Carroll, Eoin. "Centralia, Pa.: How an Underground Coal Fire Erased a Town." *Christian Science Monitor*, February 5, 2010.
https://www.csmonitor.com/Environment/Bright-Green/2010/0205/Centralia-Pa.-How-an-underground-coal-fire-erased-a-town.
Clayton, Mark. "Centralia, Pa., Coal Fire Is One of Hundreds That Burn in the U.S." *Christian Science Monitor*, February 5, 2010.
https://www.csmonitor.com/Environment/2010/0205/Centralia-Pa.-coal-fire-is-one-of-hundreds-that-burn-in-the-U.S.

[83] As of 2020, the unreclaimed construction cost of Underground Mine Fire AMLs is $733,514,180 (medium scenario; eAMLIS 10.19.20). With estimated administration and design costs added, total estimated costs are $982,909,001. As explored in Box 1, OSMRE historically barred $1 billion of underground mine fire projects in West Virginia from the inventory because they were deemed unlikely to become reclamation projects or represented costs that were too significant. According to Mr. Parsons, a state AML official in West Virginia, these represent about 40 Underground Mine Fire (UMF) PADs that were barred from eAMLIS "because of the significant costs, and unlikelihood of becoming reclamation projects." Traditionally, underground mine fires have not been added to the inventory until they become emergencies and projects are mobilized to address them. (Nov. 2020 email exchange with the author).

[84] As of 2020, the unreclaimed construction cost of Surface Burning AMLs is $22,899,853 (medium scenario; eAMLIS 10.19.20). With estimated administration and design costs added, total estimated costs are $30,685,803.

[85] Most state and tribal AML programs are 100% federally funded through annual AML grants from OSMRE. For a more thorough description of the AML program and its history, see: Dixon and Bilbrey, "Abandoned Mine Land Program: A Policy Analysis for Central Appalachia and the Nation." Appalachian Citizen' Law Center, The Alliance for Appalachia. 2015. URL: https://aclc.org/wp-content/uploads/2020/08/aml-policy-paper.pdf

[86] These estimates were developed by IMCC/NAAMLP (2019) and are median completed construction cost per unit estimates using data from eAMLIS (2013-2018) for each Group A problem type. See Technical Note for details, and: "Projecting Costs for Future AML Reclamation." Interstate Mining Compact Commission (IMCC). National Association of Abandoned Mine Land Programs (NAAMLP)., September 2019.

[87] Interview (November 2020) with Brian Bradley, current Acting Director, and Eric Cavazza, then-Director, of the PA Bureau of Abandoned Mine Reclamation.

[88] Interview (November 2020) with Brian Bradley, current Acting Director of the PA Bureau of Abandoned Mine Reclamation.

[89] "Projecting Costs for Future AML Reclamation." Interstate Mining Compact Commission (IMCC). National Association of Abandoned Mine Land Programs (NAAMLP)., September 2019.

[90] According to OSMRE's FBMS data, over the course of the AML program, construction costs (which I assume include AMD costs) have accounted for 74.7% of all AML expenditures. See section V of Technical Note, and: Abandoned Mine Land (AML) Program landing page of the OSMRE website, accessed December 2020. "OSMRE's DOI Financial Business Management System (FBMS) is the system of record for the AML Program that contains comprehensive information on AML grant allocations and expenditures." < https://www.osmre.gov/programs/aml.shtm>.

[91] Interview (November 2020) with Brian Bradley, current Acting Director, and Eric Cavazza, then-Director, of the PA Bureau of Abandoned Mine Reclamation.

[92] "Projecting Costs for Future AML Reclamation." Interstate Mining Compact Commission (IMCC). National Association of Abandoned Mine Land Programs (NAAMLP)., September 2019.

[93] Under current law, Priority 3 ("low priority") AMLs are sometimes reclaimed in conjunction with a Priority 1 or 2 ("High priority") reclamation project. When this happens, AML officials will often attribute most of the reclamation cost to the high priority AML in the federal inventory. The result is that the cost estimates of many reclaimed low priority AMLs in the inventory are not accurate.

[94] See Harris, Robbie. "Appalachia to Become Hotter Wetter AND Drier in Climate Model with Severe Ecoomic Impacts." *Virginia Public Radio, WVTF*, August 11, 2019. https://www.wvtf.org/post/appalachia-become-hotter-wetter-and-drier-climate-model-severe-economic-impacts.

And: Bruggers, James. "Appalachia's Strip-Mined Mountains Face a Growing Climate Risk: Flooding." *Inside Climate News* (blog), November 21, 2019. https://insideclimatenews.org/news/21112019/appalachia-mountains-flood-risk-climate-change-coal-mining-west-virginia-extreme-rainfall-runoff-analysis/.

[95] The existence of AML mine pools were also raised as a difficulty in ever developing a "complete" inventory. Interviews and email exchanges (November and December 2020) with the directors of the AML agencies in Pennsylvania, West Virginia, Virginia, and Kentucky.

[96] This history of the federal inventory is informed by interviews in late 2020 with Brian Bradley (Acting Director of the PA Bureau of Abandoned Mine Reclamation (BAMR)), Eric Cavazza (Director of the OSMRE Field Office in Pittsburgh and formerly the Director of PA BAMR), Terry Van Offeren (former Director of the Ohio AML Program), and an email exchange with Travis Parsons (formerly the President of the National Association of Abandoned Mine Land Programs (NAAMLP) and presently the Planning Administrator of the WV Office of Abandoned Mine Lands and Reclamation). For more information on the inventory, see a history of PA's AML inventory from PA BAMR (https://www.dep.pa.gov/Business/Land/Mining/AbandonedMineReclamation/AMLProgramInformation/Pages/History-of-PA's-AML-Inventory.aspx) and see Dixon and Bilbrey, "Abandoned Mine Land Program: A Policy Analysis for Central Appalachia and the Nation." Appalachian Citizen' Law Center, The Alliance for Appalachia. 2015. URL: https://aclc.org/wp-content/uploads/2020/08/aml-policy-paper.pdf

[97] When the law first passed, "High priority" meant an AML where there has been a documented human death or injury (Priority 1) or where a human death or injury could likely result (Priority 2). Over time, this definition has been relaxed to include proximity to AMLs that pose threats to human health or safety.

[98] Information on "the scrub" is from interviews and email correspondence with AML state officials, including Brian Bradley (Acting Director of the PA Bureau of Abandoned Mine Reclamation (BAMR)), Eric Cavazza (Director of the OSMRE Field Office in Pittsburgh and formerly the Director of PA BAMR), and Travis Parsons

(formerly the President of the National Association of Abandoned Mine Land Programs (NAAMLP) and presently the Planning Administrator of the WV Office of Abandoned Mine Lands and Reclamation).

[99] Traditionally, underground mine fires have not been added to the inventory until they become emergencies and projects are mobilized to address them. According to Mr. Parsons, these represent about 40 Underground Mine Fire (UMF) PADs that were barred from eAMLIS "because of the significant costs, and unlikelihood of becoming reclamation projects."

[100] Email correspondence with Travis Parsons (November 2020).

[101] Email correspondence with Travis Parsons (November 2020).

[102] Email correspondence with Travis Parsons (November 2020).

[103] Completed AML reclamation plus in-process reclamation (designated as "Funded" in eAMLIS) equals $7.88 billion (medium scenario, as of 2020), which is 23% of the $34.17 billion in total estimated reclamation costs (medium scenario, projected for 2050). The total cost includes an estimated 17.7% spent on design, 74.7% on construction, and 7.6% on administration. See sections II and III of Technical Note for details.

[104] AML fee collection estimates assume: Current AML fee levels will be assessed through 2050, and coal production will equal the projection in the EIA2020 $35 CO2 fee scenario (the 2020 EIA projection with the lowest coal production). All coal production -- except for metallurgical coal production -- will end in 2035.

[105] Low scenario AML fee collections assume: AML fee levels will be doubled and assessed through 2050, and coal production will equal the projection in the EIA2020 Reference Case. See section VI of Technical Note for assumptions and methods.

[106] See Technical Note for all assumptions and calculations behind these estimates.

[107] See pp. 62 of Pollin et al. (2021). Pollin et al. also provide a *direct* jobs multiplier of 5.2 for AML reclamation spending, which is consistent with the 5.25 jobs multiplier implied by my estimates (6,909 direct jobs / 1,314.52 billion in annual AML reclamation spending). The 13.1 total (direct, indirect, induced) jobs multiplier for AML reclamation estimated by Pollin et al. is slightly lower than the 15.6 total jobs multiplier provided in annual US Department of Interior economic reports for FY2011-2013 (pp. 116-117, Dixon and Bilbrey 2015) and slightly higher than the 10.2 total jobs multiplier in a 2014 report that estimated AML spending in Ohio (Voinovich School, 2014). Notably, the Ohio report estimated a total jobs multiplier of 9.5 for the impacts within the 30 county coal region in Ohio (65.2 total jobs / $6.9 million in AML spending in 2013) and a 10.2 total jobs multiplier for the impacts across the whole state (70.1 total jobs / $6.9 million in AML spending in 2013), which suggests that the vast majority of the AML jobs and spending impacts remain in coal regions, at least in the state of Ohio. Interestingly, the 2014 Ohio report estimated that 29% of federal AML spending is spent on payroll, payroll taxes, and proprietor income $1.997 million in labor income/ $6.9 in AML spending in 2013).

Pollin, Robert, Shouvik Chakraborty, and Jeannette Wicks-Lim. "Employment Impacts of Proposed U.S. Economic Stimulus Programs: Job Creation, Job Quality, and Demographic Distribution Measures." Political Economic Research Institute (PERI), University of Massachusetts-Amherst, March 2021. https://www.peri.umass.edu/publication/item/1397-employment-impacts-of-proposed-u-s-economic-stimulus-programs.

Dixon & Bilbrey, "Abandoned Mine Land Program: A Policy Analysis for Central Appalachia and the Nation." 2015. Appalachian Citizens' Law Center; The Alliance for Appalachia.

"Economic Impact Analysis of the Ohio Abandoned Mine Land Program." Voinovich School of Leadership and Public Affairs, Ohio University, April 2014. https://www.ohio.edu/voinovich-school/sites/ohio.edu.voinovich-school/files/sites/voinovich-school/files/AML%20Report%20to%20Print.pdf.

[108] See section 7-10 of Technical for detailed explanations of wage analysis and assumptions.

[109] This approximation is based on BLS data for Laborers and Operators generally: the weighted average of their median wages in each of 25 AML states. Data on the *range* of wages among AML workers in OH and PA—where we have a bit more information on AML wages specifically due to state wage regulations—provides no evidence that AML workers earn more/less than Laborers or Operators in general in a given state. Though, the author acknowledges that these comparisons are done in states where prevailing wage laws apply. See section 7-10 of the Technical Note for more on the assumptions and calculations related to AML jobs and AML construction wages.

[110] The medium scenario wage could potentially be lower if: AML wages/fringes are considerably lower than that of Laborers and Operators in general; the number of AML workers is greater in states with below-median wages; prevailing wage laws are weakened or unionization declines in states with relatively high AML wages. The low scenario assumes any/all of these. See Technical Note, section 9 for more details.

[111] Annual State Evaluation Reports, OSMRE, 2019. Accessed here: <https://www.odocs.osmre.gov/>. Note: annual report for the Hope Tribe is from 2018, and for Tennessee is from 2017 (they were the most recent, as of Nov. 2020).

[112] Though funded through annual discretionary funds, OSMRE's budget to administer and staff the AML program is sourced from the federal share of the unappropriated balance of the AML Fund (i.e. unspent AML fee collections). See Larson (2020) for more on federal AML spending.

Larson, Lance N. "The Abandoned Mine Reclamation Fund: Reauthorization Issues in the 116th Congress." Congressional Research Service (CRS), March 12, 2020.

[113] I assume that every $1 million in AML discretionary funding supports 4.25 federal AML jobs at OSMRE. According to official "Budget Justification and Performance Information" reports from OSMRE, there were an average of 4.24 FTEs per $1 million in discretionary AML funding across 2009, 2010, 2019, and 2020. See technical note section X for details.

[114] FY2011 and FY2021 "Budget Justifications and Performance Information" reports, Office of Surface Mining Reclamation and Enforcement (OSMRE), US Department of Interior. FY2009 and FY2019 figures are Actual; FY2010 and 2020 figures are Enacted. FY2011 URL: https://www.osmre.gov/resources/budget/docs/FY2011_Justification.pdf; FY2021 URL: https://www.osmre.gov/resources/budget/docs/FY2021_OSMRE_Budget_Justifications.pdf.

[115] See "Total Mandatory Distributions (after reductions)" in the FY2009, FY2010, FY2019, and FY2020 OSMRE AML Grant reports: https://www.osmre.gov/resources/grants.shtm.

[116] See section 11 of the Technical Note.

[117] Laborer and Operator occupation list, as well as required minimum wages for Ohio, were found at: Bid Documents, Division of Mineral Resources Management, Department of Natural Resources, State of Ohio. 2020. See Division O – Bidding and Contract Requirements, Section 00200 – Wage and Hour Requirements.

Common salaried occupations are informed by an interview (November 2020) with Brian Bradley, current Acting Director, and Eric Cavazza, then-Director, of the PA Bureau of Abandoned Mine Reclamation.

[118] The assumed 32.5% is comparable to the 30.9% average across the construction industry nationally, according to BLS. See section IX of Technical Note for details.

[119] See section IX of Technical Note for methods and calculations. Wage data is from BLS: “Occupational Employment and Wages, May 2019. 47-2061 Construction Laborers.” Bureau of Labor Statistics (BLS). URL: < https://www.bls.gov/oes/current/oes472061.htm#nat>. State statistics were access through the BLS Occupational Employment Statistics Query System: https://data.bls.gov/oes/#/occGeo/One%20occupation%20for%20multiple%20geographical%20areas.

[120] Assuming a family of four with both adults working, the median Laborer wage in only 4 AML states pays a living wage. Assuming a family of four with only one adult working, the median Laborer wage pays a living wage in no AML state. The MIT living wage might be better defined as a “minimum subsistence wage”—it calculates local cost of living based on the costs of local food, childcare, health, housing, transportation, other necessities, and civic engagement related expenses, and is updated annually. I use state-level living wage levels developed by the MIT Living Wage Calculator: Glasmeier, Amy K. Living Wage Calculator. 2020. Massachusetts Institute of Technology. livingwage.mit.edu.

[121] Assuming both adults are working in a family of four, the 10th percentile Operator wage is paid a living wage in only 3 AML states, and in no AML states if only one adult is working.

[122] Assuming a family of four with both adults working, median wage levels and 10th percentile wage levels for both Laborers and Operators are above the poverty threshold in all 25 AML states. Assuming a family of four with only one adult working, the median wages for Laborers and Operators are above the poverty threshold in all 25 AML states. Assuming a family of four with only one adult working, the 10th percentile wage for Operators is above poverty threshold in 23 AML states but the 10th percentile wages for Laborers is above the poverty threshold in only 7 AML states.

[123] According to May 2019 BLS data, the 10th percentile hourly wage for Construction Laborers in Ohio was $12.98.

[124] **INSERT SOURCES**

[125] Interview (April 2020) with Rita Lee, Manager, Abandoned Mine Land Reclamation Division, Department of Natural Resources, State of Illinois. Manager Lee noted that the state prevailing wage law – and to a lesser extent the recent policy regarding project-labor agreements – contribute to the union density and relatively higher wages among AML workers in Illinois.

[126] AML hazards have caused serious injury and death in the past. For more information on the danger of abandoned mines, see the section above on why AMLs are a problem, and see:
https://www.blm.gov/sites/blm.gov/files/uploads/AML_PUB_DangersAtAbandonedMines.pdf and
https://www.msha.gov/sosa
Methane emissions from some AMLs contribute to climate change, which the WHO and Haines et al. project will cause hundreds of thousands of annual premature deaths from 2030- 2050. See https://www.who.int/news-room/fact-sheets/detail/climate-change-and-health and Haines, Andy, and Kristie Ebi. “The Imperative for Climate Action to Protect Health.” *New England Journal of Medicine* 380, no. 3 (January 17, 2019): 263–73. https://doi.org/10.1056/NEJMra1807873.

[127] For background on the decline in the coal industry, see: Houser, Trevor, Jason Bordoff, and Peter Marsters. “Can Coal Make A Comeback?” Rhodium Group. Center on Global Energy Policy, Columbia University., April 2017.
https://energypolicy.columbia.edu/sites/default/files/Center_on_Global_Energy_Policy_Can_Coal_Ma ke_Comeback_April_2017.pdf. ;
https://www.brookings.edu/blog/planetpolicy/2019/01/16/why-theres-no-bringing-coal-back/ ; and https://www.eia.gov/todayinenergy/detail.php?id=44115

[128] Bublé, Courtney. “Biden Aims for Federal Contractors to Pay a $15 Minimum Wage.” *Government Executive*, January 22, 2021. https://www.govexec.com/management/2021/01/biden-aims-federal-contractors-pay-15-minimum-wage/171578/.

[129] According to the Bureau of Labor Statistics (May 2019), the 10th percentile wage for Construction Laborers in Kentucky was $11.46 per hour. See: “Occupational Employment and Wages, May 2019. 47-2061 Construction Laborers.” Bureau of Labor Statistics (BLS). URL: https://www.bls.gov/oes/current/oes472061.htm#nat. State statistics were access through the BLS Occupational Employment Statistics Query System: https://data.bls.gov/oes/#/occGeo/One%20occupation%20for%20multiple%20geographical%20areas

[130] The $18.31 per hour wage estimate is the median of the hourly wage rate required for the “Flagger” occupation on Davis-Bacon wage determinations issued by the Department of Labor (January 2021) for KY AML counties; the author included wage determinations that covered counties which include 95% of unreclaimed AML costs in Kentucky. Davis-Bacon wage determinations for heavy civil engineering projects were utilized.

[131] See pp. 12-14 of BlueGreen Alliance (2020.
“State-Based Policies to Build a Cleaner, Safer, More Equitable Economy: A Policy Toolkit.” BlueGreen Alliance, 2020. https://www.bluegreenalliance.org/wp-content/uploads/2020/07/StatePolicyToolkit_Report2020_vFINAL.pdf.

[132] For an overview of these provisions see BlueGreen Alliance (2020).
Regarding apprenticeships, the 2020 Reimagine Appalachia Blueprint proposes “a percentage of union apprentices to come from low-income neighborhoods near project sites and set aside 2% of any project’s resources for registered pre-apprenticeship programs managed via labor-community partnerships to build the pipeline of diverse workers into union work.”

Blueprint, Reimagine Appalachia. 2020. https://reimagineappalachia.org/wp-content/uploads/2020/09/ReImagineAppalachia_Blueprint_092020.pdf

[133] Interview (April 2020) with Rita Lee, Manager, Abandoned Mine Land Reclamation Division, Department of Natural Resources, State of Illinois. Manager Lee noted that the state prevailing wage law – and to a lesser extent the recent policy regarding project-labor agreements – contribute to the union density and relatively higher wages among AML workers in Illinois.

[134] This is based on an interview with a union official who operates in the Appalachian region.

[135] Sources for PA’s labor and hiring policies as they apply to AML projects include: p44,45 of PA DEP "General Conditions for Construction" 2016; pp. 1 of Regulations for PA PWA; pp. SR-4, SR-5 of Conditions of Contract No. OSM 07(4339)104.1.

[136] The database of these PMW levels for specific BAMR contracts can be accessed here: https://www.dli.pa.gov/Individuals/Labor-Management-Relations/llc/prevailing-wage/Pages/Prevailing-Wage-App.aspx

[137] See pp. SR-5 of Conditions of Contract No. OSM 07(4339)104.1.

[138] The Pennsylvania Department of Environmental Protection requires preferential rating for honorably-discharged US military veterans and local people, in order to lower local unemployment.

[139] See pp. 1 of “Taking Action Against Disparities.” Department of General Services, Commonwealth of Pennsylvania, June 16, 2020. https://www.dgs.pa.gov/Small%20Diverse%20Business%20Program/Documents/Taking%20Action%20Against%20Disparities.pdf.

[140] See pp. 2 of “Small Diverse Business Goal Setting Program.” Commonwealth of Pennsylvania, 2020.

[141] See pp. 2-6 of “Small Diverse Business Goal Setting Program.” Commonwealth of Pennsylvania, 2020.

[142] See pp. SDB 4.0 of “Small Diverse Business Goal Setting Program.” Commonwealth of Pennsylvania, 2020.

[143] See pp. 1 of “DGS Small Business Initiative Information.” Commonwealth of Pennsylvania, 2020.

[144] See https://www.dgs.pa.gov/Small%20Business%20Contracting%20Program/Pages/default.aspx

[145] See pp. 47 of PA DEP "General Conditions for Construction" 2016; and see pSR-1 of Conditions of Contract No. OSM 07(4339)104.1 for example.

[146] See pp. SR-2 of Conditions of Contract No. OSM 07(4339)104.1 for example.

[147] For more on how a new CCC could include hiring preference see DeMarco et al. (2020), and see BlueGreen Alliance (2020) for more on local hire and targeted hire provisions.
DeMarco et al., "HEAL OUR LAND
AND OUR PEOPLE: Create a Modern Civilian Conservation Corps and Promote Regenerative Agriculture and Agroforestry." Reimagine Appalachia. 2020. https://reimagineappalachia.org/reimagine-appalachia-regenerative-ag-ccc-whitepaper-10-28-2020/
"State-Based Policies to Build a Cleaner, Safer, More Equitable Economy: A Policy Toolkit." BlueGreen Alliance, 2020. https://www.bluegreenalliance.org/wp-content/uploads/2020/07/StatePolicyToolkit_Report2020_vFINAL.pdf.

[148] See Hanks (2017 for an overview of banning the box policies.
Hanks, Angela. "Ban the Box and Beyond." Center for American Progress, July 2017. https://www.americanprogress.org/issues/economy/reports/2017/07/27/436756/ban-box-beyond/.

[149] For more on a jobs guarantee for displaced coal workers, see section 5 of Pollin et al. (Feb. 2021).

Pollin, Robert, Jeannette Wicks-Lim, Shouvik Chakraborty, and Gregor Semieniuk. "Impacts of Reimagine Appalachia & Clean Energy Transition Programs for West Virginia: Job Creation, Economic Recovery, and Long-Term Sustainability." Political Economic Research Institute (PERI), University of Massachusetts-Amherst, February 2021. https://www.peri.umass.edu/images/WV-CleanEnergy-2-22-21.pdf.

[150] "2020 Annual Report." Green Forests Work, 2020. https://ad06d36b-644f-4e42-ba86-95596c62d192.filesusr.com/ugd/f07753_bc616b45c1264875a9fdec629dfcaa57.pdf.

[151] See https://arri.osmre.gov/Legacy/PlantingTreesOnLegacyMines.shtm

[152] Information on the Pennsylvania in-house reclamation crews was informed by interviews in late 2020 with Brian Bradley (Acting Director of the PA Bureau of Abandoned Mine Reclamation (BAMR)) and Eric Cavazza (Director of the OSMRE Field Office in Pittsburgh and formerly the Director of PA BAMR).
[153] Interview and email correspondence (November 2020) with Brian Bradley, current Acting Director, and Eric Cavazza, then-Director, of the PA Bureau of Abandoned Mine Reclamation.

[154] Information on the Ohio AML program and Ohio Division of Civilian Conservation were informed by interviews (December 2020) with Terry Van Offeren, former Director of Ohio Abandoned Mine Land program, and Bill McGarity, Field Operations Manager (1992-1999), Ohio Division of Civilian Conservation.
[155] Interview with Bill McGarity, Field Operations Manager (1992-1999), Ohio Division of Civilian Conservation.

[156] For more on reclamation prior to SMCRA, see above sections in this report and see pp. 66-67 of Zipper, Carl E., and Jeff Skousen. "Coal Mining and Reclamation in Appalachia." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.
[157] Zipper, Carl E., and Jeff Skousen. "Coal Mining and Reclamation in Appalachia." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[158] The quote is from Popkin (2020) and is attributed to James Burger at Virginia Tech, who began to demonstrate in the 1990s that conventional reclamation was hindering native forest succession.
Popkin, Gabriel. "The Green Miles." *Washington Post*, February 13, 2020. https://www.washingtonpost.com/graphics/2020/lifestyle/magazine/appalachia-kentucky-reforestation/.

[159] Speaking of mining before 1977, Skousen and Zipper (2021) state, "spoils from early surface mining were often left in an uncompacted condition more favorable to native vegetation growth than the compacted mine soils constructed immediately following SMCRA (Angel et al. 2005). However, soil conditions on the older mine sites were not always favorable, especially when mining left acidic strata exposed at the surface. Hence, state-level reclamation laws generally mandated revegetation and miners generally seeded non-native plants that could colonize a wide variety of mine soil materials (Brenner et al. 1984; Wade et al. 1985)" (pp. 66-67, Skousen and Zipper 2021). For more on the lack of reclamation prior to SMCRA and soil on pre-SMCRA mine sites, including results of the "shoot and shove" method of contour mining common during this period, see pp. 86-87 of Skousen et al. (2021). Sena et al. (pp. 111, 2021) speak to some successful reforestation on pre-1977 reclaimed lands, **"**Pre-SMCRA, mined land was sometimes left barren for natural regeneration, and sometimes revegetated with varying levels of success. Much pre-SMCRA mined land is now revegetated with trees. In places, such plant communities have achieved above-ground biomass similar to forests in unmined areas, but they often attain low species diversity and are covered by non-native invasive species."

Zipper, Carl E., and Jeff Skousen. "Coal Mining and Reclamation in Appalachia." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

Skousen, Jeff, W. Lee Daniels, and Carl E. Zipper. "Soils on Appalachian Coal-Mined Lands." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

Sena, Kenton, Jennifer A. Franklin, Rebecca M. Swab, and Sarah L. Hall. "Plant Communities on Appalachian Mined Lands." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[160] See pp. 1 of Burger, J A, C E Zipper, P N Angel, N Hall, J G Skousen, C D Barton, and S Eggerud. "Establishing Native Trees On Legacy Surface Mines." Appalachian Regional Reforestation Initiative (ARRI), November 2013. https://arri.osmre.gov/Publications/Publications.shtm#FRAs

For more on the benefits of reforestation, see https://www.greenforestswork.org/reforestation-benefits

For more on how forests are needed for many species native to Appalachia, see. Pp. 1 of Wood, Petra, Jeff Larkin, Jeremy Mizel, Carl Zipper, and Patrick Angel. "Reforestation To Enhance Appalachian Mined Lands As Habitat For Terrestrial Wildlife." Appalachian Regional Reforestation Initiative (ARRI), November 2013.

[161] See pp. 78 of Zipper and Skousen (2021): "Multiple experimental studies have shown growth and productivity of native forest trees on mine soils, with the level of productivity based on mine soil material, compaction, and competition from other invading species (Dallaire and Skousen, 2019; Zipper et al. 2013)." See also pp.120 of Sena et al (2021): "In a Kentucky study, planted trees of multiple species (white oak, *Quercus alba*, northern red oak, tulip poplar, and green ash, *Fraxinus pennsylvanica*) exhibited excellent growth and survival on uncompacted brown sandstone and had established canopy closure in patches by the ninth growing season after planting (Sena et al. 2015)."

Zipper, Carl E., and Jeff Skousen. "Coal Mining and Reclamation in Appalachia." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

Sena, Kenton, Jennifer A. Franklin, Rebecca M. Swab, and Sarah L. Hall. "Plant Communities on Appalachian Mined Lands." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[162] Evans, Daniel M., Carl E. Zipper, James A. Burger, Brian D. Strahm, and Amy M. Villamagna. "Reforestation Practice for Enhancement of Ecosystem Services on a Compacted Surface Mine: Path toward Ecosystem Recovery." *Ecological Engineering* 51 (February 1, 2013): 16–23. https://doi.org/10.1016/j.ecoleng.2012.12.065.

See pp. 345 of Zipper, Carl E., and Jeff Skousen, eds. *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

For a study on soil on mined lands as carbon sinks, see Littlefield, Tara, Chris Barton, Mary Arthur, and Mark Coyne. "Factors Controlling Carbon Distribution on Reforested Minelands and Regenerating Clearcuts in Appalachia, USA." *Science of The Total Environment*, Soil as a Source & Sink for Greenhouse Gases, 465 (November 1, 2013): 240–47. https://doi.org/10.1016/j.scitotenv.2012.12.029.

[163] According to the Forest Resources Association, average carbon sequestration of forests aged 6-10 years in the Appalachian region (TN, KY, WV, MO, IL, IN, OH, PA, MD, DE, NJ, western VA, western NC) is approximately 0.49 US tons of per acre per year (1.80 tons of CO_2 per acre per year). Forest Resources Association "represents the interests of nearly 300 organizations and businesses in the forest products industry. Our members range from loggers, mills, equipment manufacturers, local forestry associations to large corporations." FRA cites the USDA Forest Service for carbon storage data.

See also Sharma and Wang for a 2011 analysis of carbon sequestration on forests in West Virginia, including on abandoned mines. See Toochi (2018) for a primer on calculating carbon sequestration by forests.

Sharma, Benktesh D, and Jingxin Wang. "Status And Potential Of Terrestrial Carbon Sequestration In West Virginia." In *Roceedings of the 17th Central Hardwood Forest Conference*, 10, 2011.
Toochi, Egbuche Christian. "Carbon Sequestration: How Much Can Forestry Sequester CO2?" *Forestry Research and Engineering: International Journal* 2, no. 3 (May 31, 2018). https://doi.org/10.15406/freij.2018.02.00040.
"Forest Carbon Report: Appalachian Region." Forest Resources Association, 2020. https://www.forestresources.org/pdf/Appalachian.pdf.

[164] One quarter of the 853,426 of unreclaimed acres (GPRA) equals 213,356.5 acres. According to Amichev et al. (2008), which compared carbon storage in 22 forest stands on mined and non-mined land in Appalachia and the Midwest, non-mined hardwood stands sequestered about 62% more carbon than the average of all forest stands on mined land. Assuming forests on post-mine land sequesters carbon at two-thirds the rate of forests on non-mined land, then forests on post-mined land would sequester carbon at around 1.2 US tons of CO_2 per acre per year, using the above estimate for Appalachia from the Forest Resources Association. This means forests on a quarter of unreclaimed AML land would sequester about 256,027.8 US tons of CO_2 per year, or about 232,264 metric tons of CO_2 per year. According to the EPA greenhouse gas emissions equivalency calculator, this is equivalent to the amount of CO2 emitted from 39,324 homes' electricity use for one year.

Amichev, Beyhan Y., James A. Burger, and Jason A. Rodrigue. "Carbon Sequestration by Forests and Soils on Mined Land in the Midwestern and Appalachian Coalfields of the U.S." *Forest Ecology and Management* 256, no. 11 (November 20, 2008): 1949–59. https://doi.org/10.1016/j.foreco.2008.07.020.

[165] Williamson, Tanja N., and Christopher D. Barton. "Hydrologic Modeling to Examine the Influence of the Forestry Reclamation Approach and Climate Change on Mineland Hydrology." *Science of The Total Environment* 743 (November 15, 2020): 140605. https://doi.org/10.1016/j.scitotenv.2020.140605.

[166] See Taylor et al. (2009) and Angel et al. (2008). For a similar study of forests' ability to decrease water runoff in Madagascar, see Merveld et al. (2021).

Taylor, Timothy J., Carmen T. Agouridis, Richard C. Warner, Christopher D. Barton, and Patrick N. Angel. "Hydrologic Characteristics of Appalachian Loose-dumped Spoil in the Cumberland Plateau of Eastern Kentucky." *Hydrological Processes* 23, no. 23 (November 15, 2009): 3372–81. https://doi.org/10.1002/hyp.7443.
Angel, Patrick, Christopher Barton, Richard Warner, Carmen Agouridis, Tim Taylor, and Sarah Hall. "Forest Establishment and Water Quality Characteristics as Influenced by Spoil Type on a Loose-Graded Surface Mine in Eastern Kentucky." *25th Annual Meetings of the American Society of Mining and Reclamation and 10th Meeting of IALR 2008* 1 (October 3, 2008). https://doi.org/10.21000/JASMR08010028.
Meerveld, H. J. (Ilja) van, Julia P. G. Jones, Chandra P. Ghimire, Bob W. Zwartendijk, Jaona Lahitiana, Maafaka Ravelona, and Mark Mulligan. "Forest Regeneration Can Positively Contribute to Local Hydrological Ecosystem Services: Implications for Forest Landscape Restoration." *Journal of Applied Ecology* n/a, no. n/a. Accessed April 1, 2021. https://doi.org/10.1111/1365-2664.13836.

[167] See. Pp. 173 of Zipper, Carl E., Carmen T. Agouridis, Christoper T. Barton, and Jeff Skousen. "Conversion Options for Mining-Affected Lands and Waters in Appalachia." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[168] See pp. 7 of Burger, J A, C E Zipper, P N Angel, N Hall, J G Skousen, C D Barton, and S Eggerud. "Establishing Native Trees On Legacy Surface Mines." Appalachian Regional Reforestation Initiative (ARRI), November 2013. https://arri.osmre.gov/Publications/Publications.shtm#FRAs.

[169] https://abcbirds.org/bird/cerulean-warbler/

[170] See https://www.greenforestswork.org/reforestation-benefits

[171] See pp. 120 of Sena, Kenton, Jennifer A. Franklin, Rebecca M. Swab, and Sarah L. Hall. "Plant Communities on Appalachian Mined Lands." In *Appalachia's Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.

[172] In a 2007 Congressional hearing, former OSMRE Director Brent Wahlquist acknowledged the poor environmental performance of past reclamation techniques and pointed to the benefits of reforestation on AML-damaged land: "Appalachia was forested before it was mined. However, the vast majority of that land has not been returned to forest. Instead, much of it has been reclaimed to hayland/pasture with smoothly graded (and thus compacted) surfaces and heavy groundcover unsuitable for growing trees. Yet, forests moderate temperatures, control runoff, improve water quality, sequester carbon, and provide enormous biological diversity. Researchers at several universities have demonstrated that mined land, if properly reclaimed, can sustain tree survival and growth rates even greater than average sites on unmined land." See: https://www.doi.gov/ocl/hearings/110/SurfaceMiningPolicy_111307

[173] Reforested mine sites still tend to have thinner soil beds than unmined forests. As the climate changes, this could make it more difficult forests to grow in the future because there may be less plant-available water in the growing season. Young et al. suggests that deforested areas in Appalachia are more sensitive to climate change than forested areas.

Young, David, Nicolas Zėgre, Pamela Edwards, and Rodrigo Fernandez. "Assessing Streamflow Sensitivity of Forested Headwater Catchments to Disturbance and Climate Change in the Central Appalachian Mountains Region, USA." *Science of The Total Environment* 694 (December 1, 2019): 133382. https://doi.org/10.1016/j.scitotenv.2019.07.188.

[174] For more on the history of the forced displacement of Indigenous People in the Appalachian region, see chapter 2 of Dunaway (1996). For more on the history of the transfer of property in Appalachia to largely absentee and non-local owners in the nineteenth and early twentieth centuries, see: Eller (1982), especially chapter 2; Caudill (2001); Stoll (2017); Gaventa (1980), especially chapters 2 and 3; and Dunaway (1996), especially chapters 3-6. Eller argues, "Behind this transition in political culture lay the integration of the region into the national economy and the subordination of local interests to those of outside corporations. Nowhere was this process more evident than in the concentration of absentee owners. Beginning in the 1870s, northern speculators and outside businessmen carved out huge domains in the rich timberlands and mineral regions of Appalachia. By 1910, outlanders controlled not only the best stands of hardwood timber and the thickest seams of coal but a large percentage of the surface land in the region as well" (p. xxxi, Eller 1982). Eller also states, "Most mountain families sold their land voluntarily, but the negotiations were hardly between equals…A few residents, however, were reluctant to sell their land at any price, and aggressive land buyers occasionally turned to illicit methods….methods of deceit in land acquisition soon angered local residents…" (pp. 56-7, Eller 1982).

For more on the history of Black land loss across the US, and especially in the South, see: Gilbert et al. (2002), Mitchell (2010), Newkirk II (2019), Rosenberg and Wilson Stucki (2019), Castro and Willingham (2019), and USDA (1998). Gilbert et al. state, "Land ownership by Black farmers peaked in 1910 at 16-19 million acres, according to the Census of Agriculture. However, the 1997 census reports that Black farmers owned only 1.5 million acres. This drastic decline contrasts sharply with an increase in acres owned by White farmers…[though a contrasting figure from the] 1999 AELOS is that…Blacks own 7.8 million acres. (pp. 55, Gilbert et al.).

Sources:
Eller, Ron. *Miners, Millhands, and Mountaineers: Industrialization of the Appalachian South, 1880-1930.* Knoxville: University of Tennessee Press, 1982.
Gaventa, John. *Power and Powerlessness: Quiescence and Rebellion in an Appalachian Valley*. Urbana: University of Illinois Press, 1980.
Stoll, Steven. *Ramp Hollow: The Ordeal of Appalachia*. Hill and Wang, 2017.
Caudill, Harry M. *Night Comes to the Cumberlands*. Jesse Stuart Foundation, 2001.
Dunaway, Wilma A. *The First American Frontier: Transition to Capitalism in Southern Appalachia, 1700-1860*. University of North Carolina Press, 1996.
Mitchell, Thomas W. "From Reconstruction to Deconstruction: Undermining Black Ownership, Political Independence, and Community Through Partition Sales of Tenancy in Common Property." SSRN Scholarly Paper. Rochester, NY: Social Science Research Network, January 29, 2010. https://papers.ssrn.com/abstract=1544380.
Daniels, Pete. *Dispossession: Discrimination against African American Farmers in the Age of Civil Rights*. University of North Carolina Press, 2013.
Newkirk II, Vann R. "The Great Land Robbery." *The Atlantic*. Accessed April 1, 2021. https://www.theatlantic.com/magazine/archive/2019/09/this-land-was-our-land/594742/.
Rosenberg, Nathan, and Bryce Wilson Stucki. "How USDA Distorted Data to Conceal Decades of Discrimination against Black Farmers | New Food Economy." *The Counter*, June 26, 2019. https://thecounter.org/usda-black-farmers-discrimination-tom-vilsack-reparations-civil-rights/.
"A Time to Act: A Report on the USDA National Commission on Small Farms." National Commission on Small Farms. US Department of Agriculture, 1998. https://archive.org/details/timetoact1545usda.
Castro, Abril, and Zoe Willingham. "Progressive Governance Can Turn the Tide for Black Farmers." Center for American Progress, 2019. https://www.americanprogress.org/issues/economy/reports/2019/04/03/467892/progressive-governance-can-turn-tide-black-farmers/.
Gilbert, Jess, Spencer D. Wood, and Gwen Sharp. "Who Owns the Land? Agricultural Land Ownership by Race/Ethnicity." *Rural America. Economic Research Service. US Department of Agriculture.*, Winter 2002. https://www.ers.usda.gov/webdocs/publications/46984/19362_ra174_1_.pdf?v=41056

[175] For a classic analysis of land ownership patterns in Appalachia, see: Appalachian Land Ownership Task Force, "Who Owns Appalachia? Landownership and Its Impact" (1983). *Appalachian Studies*. 8. https://uknowledge.uky.edu/upk_appalachian_studies/8

For a more recent analysis of land ownership patterns in West Virginia, see: Boettner, Ted. "Who owns West Virginia?" West Virginia Center on Budget and Policy. American Friends Service Committee. December 2013. https://wvpolicy.org/who-owns-west-virginia-in-the-21st-century-2/

For a current project assessing land ownership in Appalachia see the Appalachian Land Study: https://www.appalachianlandstudy.org/about

[176] For more on how schools can serve as anchor institutions in place-based community wealth building, see: https://community-wealth.org/strategies/panel/anchors/index.html

[177] Interview (December 2020) with Terry Van Offeren, former Director of Ohio Abandoned Mine Land program.

[178] Researchers at the US Geological Survey argue that collecting more data on specific characteristics of AML sites could enable estimates of emissions using standardized methods. Kolker et al. (pp. 2, Kolker at al. 2009) argue, “comparison of emissions from coal fires with similar attributes (for example, coal rank and type, caloric content, composition, size, and intensity) and weighting them according to the size and intensity of the fire may allow us to estimate areas or volumes of burning coal in order to calculate emissions on larger scales.”

Kolker, Allan, Mark Engle, Glenn Stratcher, James Hower, Anupma Prakesh, Lawrence Radke, Arnout ter Schure, and Ed Heffern. “Emissions from Coal Fires and Their Impact on the Environment.” Fact Sheet. U.S. Geological Survey, 2009.

[179] In the US in 1979, the average price of coal was $23.50 and the AML fee level (weighted by production of underground, surface, and lignite coal) was $0.25 per ton. See Boettner (2021), Ohio River Valley Institute for data.
[180] In the US in 2019, the average price of coal was $35.03 and the AML fee level (weighted by production of underground, surface, and lignite coal) was $0.21 per ton. The average price of coal rose from $23.50 in 1979 to $35.03 in 2019. See Boettner (2021), Ohio River Valley Institute for data.
[181] In the US in 2019, the average price of coal was $35.03. If the current AML fee levels were doubled and then weighted by production of underground, surface, and lignite coal in 2019, then the AML fee level would be $0.42 per ton overall. $0.42 is 1.20% of $35.03. See Boettner (2021), Ohio River Valley Institute for data.
[182] If current AML fees were doubled and assessed from 2022-2050, then projected AML collections would be: $1.1 assuming coal production as projected by the EIA2020 $35 CO_2 fee case and assuming all coal production ends in 2035 except metallurgical coal; $5.9 billion assuming coal production as projected by the EIA2020 reference case.
[183] If current AML fee levels were ten times higher, they would stand at $2.80 (surface), $1.20 (underground), and $0.80 (lignite) per ton. Assuming coal production projections in the EIA2020 $35 CO2 fee case and assuming that all coal production except for metallurgical coal ends in 2035, this would generate a projected **$5,475,245,120** in collections between 2022-2050. Assuming coal production projections in the EIA2020 reference case, this would generate a projected **$29,375,847,739** in collections between 2022-2050. Critically, these projections do *not* take into account how increases in fee levels might impact coal production levels.
[184] If the current $0.21 effective AML fee level were ten times higher, it would stand at $2.10, which is 5.98% of the $35.03 average price of coal in 2019. The fee levels for underground coal ($1.2 per ton) and surface coal ($2.8 per ton) would have effective rates of 2.04% and 12.46%, respectively. See Technical Note for more on AML fee collection projections and assumptions.
[185] See Larson (2020) and Dixon and Bilbrey (2015).
Larson, Lance N. “The Abandoned Mine Reclamation Fund: Reauthorization Issues in the 116th Congress.” Congressional Research Service (CRS), March 12, 2020.

[186] For more on AML funding and the distribution formula see Dixon and Bilbrey (2015) and Larson (2020).

Larson, Lance N. “The Abandoned Mine Reclamation Fund: Reauthorization Issues in the 116th Congress.” Congressional Research Service (CRS), March 12, 2020.

Dixon, Eric, and Kendall Bilbrey. “Abandoned Mine Land Program: A Policy Analysis for Central Appalachia and the Nation.” Appalachian Citizens’ Law Center; The Alliance for Appalachia, July 8, 2015. https://appalachiancitizenslaw.files.wordpress.com/2015/07/abandoned-mine-reclamation-policy-anal ysis.pdf.

[187] The interest on the Fund can continue to support critical UMWA health and pension plans; for more on UMWA funds supported by AML Fund interest see Larson (2020).

Larson, Lance N. “The Abandoned Mine Reclamation Fund: Reauthorization Issues in the 116th Congress.” Congressional Research Service (CRS), March 12, 2020.

[188] For more on the long-term costs of AMD treatment programs, see pp. 202, 211 of Kruse Daniels et al. (2021).
Kruse Daniels, Natalie, Julie A. LaBar, and Louis M. McDonald. “Acid Mine Drainage in Appalachia: Sources, Legacy, and Treatment.” In *Appalachia’s Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.
Kruse Daniels, Natalie, Julie A. LaBar, and Louis M. McDonald. “Acid Mine Drainage in Appalachia: Sources, Legacy, and Treatment.” In *Appalachia’s Coal-Mined Landscapes: Resources and Communities in a New Energy Era*, edited by Carl E. Zipper and Jeff Skousen. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-57780-3.