TURNING LIABILITIES INTO OPPORTUNITIES

Coal Ash and the Cement and Concrete Industries

by Wendy Patton

ReImagine Appalachia

Today, governments worldwide are funding the creation of new technologies and products to lower carbon emissions and slow the looming climate change crisis. Opportunities in clean and green manufacturing are emerging in Appalachia because of historical strengths, location, and unconventional resources – like coal ash, used in "green" concrete. Community oversight will be needed to ensure new economic activity is safe, healthy, and sustainable.

Executive Summary

The Ohio River Valley of Appalachia, better known as coal country, provided the energy that fueled the nation's growth and prosperity, with the many coal-burning power plants located throughout the region powering the industrial revolution. As we now move into the new clean economy, and old coal power plants are decommissioned, the region's workforce has lost good union jobs – and communities, their tax base – while waste residues from burning coal over the past century or so have left behind blighted communities, damaged lands, and polluted waterways. This paper looks at one way to address the environmental damage and create jobs through growing market utilization of some of these waste products in sectors that could create jobs and contribute to prosperity in the region – if done right.

Coal ash as a liability

An estimated 4.3 billion metric tons of coal combustion residuals – generically referred to as coal ash – has been stored in landfills or mixed with water and stored in ponds (surface impoundments) across the nation.[1] Coal ash is not classified as a hazardous waste, but it contains toxins, like mercury, cadmium, and arsenic – and others.[2] Coal ash ponds have burst through retaining walls and flooded communities and water sources, with terrible health effects, particularly to the workers who clean up the mess.[3] Research has shown the majority of coal ash disposal sites seep into the groundwater. Regulations have never been strong enough or enforced well enough to prevent its toxic elements from seeping into the surface and groundwater.[4] It is estimated that 91% of such sites seep hazardous materials into the groundwater of surrounding communities.[5]

Appalachia has more than its share of coal ash disposal sites. There are over 800 million cubic yards of coal ash in 161 storage sites in the Ohio River Valley Basin alone – one in five of the coal ash disposal sites (also referred to as coal ash dumps) in the nation.[6]

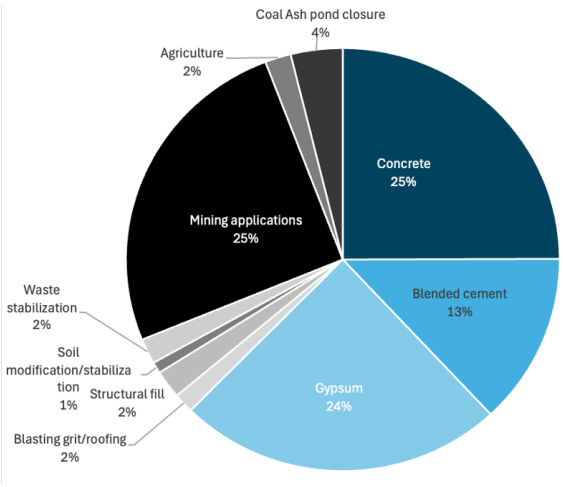
The owners of active coal-burning power plants continue to dispose of newly burned coal ash in these sites, so they grow in number and size each year. But the owners also sold almost two-thirds of what they produced in 2022 for various uses, primarily in the manufacture of building materials – concrete, cement, brick, and synthetic gypsum, and for mine reclamation.[7]

Clean-up of the coal ash waste that has built up over the decades is a critical and expensive task that poses a barrier to the repurposing of shuttered coal plant sites for new, job-creating uses. But with the right regulations, safety protocols, and policy incentives, market demand for recycled coal ash can help fund clean-up efforts.

Coal ash as an opportunity:

Coal ash is one of the largest industrial waste streams in America,[8] producing over 75 million tons in 2022. About two-thirds of that – 46 million tons – was purchased by manufacturers, farmers, mine operators, and other end-users.[9] The share of freshly-burned coal ash that is sold instead of disposed of has risen over time.[10]

2022 USES OF THE BENEFICIAL USES OF COAL ASH



Source: Based on data from the 2022 American Coal Ash Association survey of uses

Recycling coal ash into building materials reduces the carbon footprint of the manufacturing process by replacing some raw materials and in some cases, reducing emissions caused by chemical reactions in the manufacturing process.[11] For that reason, concrete and cement made with recycled coal ash are referred to as "green" or, in the case of bricks, "eco-bricks." This is a growing market. The North American green concrete and cement market was valued at US$ 3,423.61 million in 2022 and is expected to reach $6,130 million by 2030, growing at a CAGR of 7.6% from 2022 to 2030.[12]

Federal policy affects the market

New federal carrots are strengthening the market for coal ash. The federal government has targeted the use of more supplementary cementitious materials like coal ash as the most efficient approach to decarbonization of the concrete and cement industry in the short term and is providing incentives for the industry to help.[13] The Bipartisan Infrastructure Law, which provides funding for infrastructure construction and repair, will boost demand. The state and local governments undertaking the projects have climate action plans of their own and are significant bidders in the construction materials market, procuring 33% to 46% of cement.[14] With the right procurement policies, such as requirements to meet LEED building standards, these communities could further increase the demand for green building materials to help meet their own climate goals.

The supply of domestically produced fresh coal ash used to reduce the carbon footprint of cement and concrete has declined as coal-burning power plants have been decommissioned and replaced with generators that use different energy sources. As a result, some manufacturers have turned to imports of

coal ash.[15] Public policy could turn this around. Federal policy could tighten regulations of disposal – in other words, strengthen sticks. Tightened regulations around coal ash disposal and clean-up of existing sites could change the cost/benefit calculation that allows utilities to dump new coal ash instead and ignore the seeping disposal sites, forcing them to harvest and sell both "fresh" ash and the legacy coal ash dumps they own.

Opportunities in Appalachia

A virtually inexhaustible supply of coal ash creates a huge environmental problem, but it also offers an unusual resource for the building materials industry. Appalachia has a concentration of firms that produce building materials. Central Appalachia first provided the timber, then the cement, concrete, brick, iron, and steel, and other critical materials used in building the factories and cities of the industrial economy. The region retains a concentration of employment in cement, concrete, clay, and refractory material factories, which use coal ash to reduce the carbon footprint of the manufactured products.

Global corporations in the building materials supply chain are recognizing the opportunities in central Appalachia's shuttered coal plants. Not only do these sites have strong connection to the electrical grid; proximity to strong regional construction markets; good water, rail and highway access to get product to market; and a skilled workforce, but they have access to what may become an important source of coal ash needed to create green building materials.

Charah Solutions subsidiary purchases the shuttered Cheswick Power Plant site

Charah, which describes itself as a leading provider of environmental services and byproduct recycling to the power generation industry, says the Cheswick acquisitions have been made through three companies related to its subsidiary, Charah Environmental Redevelopment Group LLC (CERG).

The retired Cheswick Generating Station in Springdale, Pennsylvania, is near Pittsburgh and located along the Allegheny River. The 56-acre primary generating station site, along with an adjacent 27-acre parcel, consists of an operating rail line, coal yard, bottom ash emergency and recycle ponds, waste ponds, coal pile runoff pond, coal delivery equipment, and an ash handling parcel, says Charah.

"CERG will be responsible for the shutdown and decommissioning of the coal power plant, the remediation of the two ash ponds, and performing all environmental remediation and redevelopment work at the site," states the firm.

Source: Brian Taylor, "Charah Solutions adds PA power plant to its demo list," Construction and Demolition Recycling, April 7, 2022 at https://www.cdrecycler.com/news/charah-cheswick-power-plant-demolition-redevelopment-pennsylvania/

Cement, concrete, and coal ash are heavy materials that are costly to transport very far, so they serve regional markets. Central Appalachia's coal ash supply could make it an important hub for green concrete, cement, and other building materials to serve some of the biggest construction markets in the nation. Coal ash could, over time, become a source for other uses as well: researchers are evaluating coal ash as a source of aluminum, lithium, and rare earth materials essential for clean energy, communication, defense, and other technologies. It could become viewed as a resource and bring new markets, industries, and jobs to Appalachia.

An increase in the market value of what is now a liability – coal ash – could create opportunity for expansion of jobs in the building materials factories throughout the region. Increased recovery from current production and even from disposal sites can slow growth of the waste and could, with improvements in harvesting and refining technology, help reduce the huge backlog of waste polluting Appalachia. The future potential, however, does not solve the ongoing need to clean up the current waste threatening communities. Permanent solutions remain elusive until technology and investment incentives are enacted to help remediate the vast coal ash repositories from past operations, as well as penalties for not doing so. The market must be encouraged, but environmental regulations mandating remediation and elimination of toxic and seeping coal ash waste sites must also remain a policy priority. New technology, financing mechanisms, and approaches must be developed to address the enormous problems of coal ash and its environmental hazards, and safety protocols put in place for the workers. The report concludes with a series of recommendations for keeping people and the environment safe as the liabilities – coal ash – increase in market value and become an opportunity, in so doing, creating jobs and helping – while not solving – the ongoing need to clean up the environmental hazards threatening communities.

Table of Contents

Overview

Appalachia provided the energy that fueled the nation's growth for over a century. King Coal created generations of skilled workers with deep expertise in mining, electricity production, and engineering at the region's many manufacturers that served the needs of the heavy industries of the heartland. Today, in a changed economy where manufacturing plants have closed and coal power plants are being decommissioned, the residue from burning coal is painfully evident. The waters and land are burdened with environmental toxins left behind in coal ash ponds and landfills. Coal ash pollution slows the redevelopment of shuttered coal power plants, which could be critical industrial sites supporting thousands of jobs.

The market may not be able to solve the problem, but it can help. Almost two-thirds of the waste left behind by active coal-fired power plants is sold to end users, including manufacturers of cement, concrete, and brick.[16] Using coal ash as a raw material in production can reduce the carbon footprint of these materials. Today, nations compete for leadership in new and/or greener markets created by the need to mitigate climate change. Lawmakers are providing funding and incentives to develop technologies and products to reduce carbon emissions and slow climate change.

With the passage of the federal climate infrastructure package, including the Bipartisan Infrastructure Law (BIL) and the Inflation Reduction Act (IRA), Congress has appropriated funding to restore infrastructure and build supply chains to manufacture the energy-efficient and clean economy products of the future. The new construction generated by the climate infrastructure package will require a lot of concrete and cement. State and local government officials have their own climate change goals to achieve; they can use their buying power for less carbon-intensive cement and concrete in their procurement and seed the green concrete sector. Central Appalachia can meet this demand, becoming a national hub for green concrete, with concrete and cement sectors that employ thousands of workers in hundreds of plants while expanding the Midwest and Atlantic Coast construction markets. Recovery of coal ash from the coal ash ponds and landfills throughout the region could provide an inexhaustible supply to produce green products and meet increasing demand for them – if it can be harvested at a cost acceptable to the market and a quality appropriate for use in building materials.

Realizing that kind of economic process entails risk. Will adopting relatively new technologies to recover old coal ash in ponds and landfills be economically viable and widely used? Utilities that own the coal ash ponds and coal-burning power plants will have to use resources to expand the harvest and sale of freshly burned coal ash and recover the old waste in the region's many coal ash ponds, which contain toxic substances. Currently, federal programs incentivize manufacturers to decarbonize products and production processes, but will the incentives last long enough? Will private investors step in to commercialize new and improved technologies to harvest the coal ash and to safely use it in products?

There are risks for Appalachian communities. Care must be taken to prevent the new technologies from yielding the same harms as the old industries that extracted the natural resources of Appalachia and left with the profits, leaving poverty and pollution in their wake. The report concludes with a series of recommendations for keeping people and the environment safe as the region's liabilities – coal ash – develop value and, in so doing, create jobs and help to clean up the environmental hazards threatening communities.

Coal Ash as a Liability

Environmental Impact of a Century Of Disposal

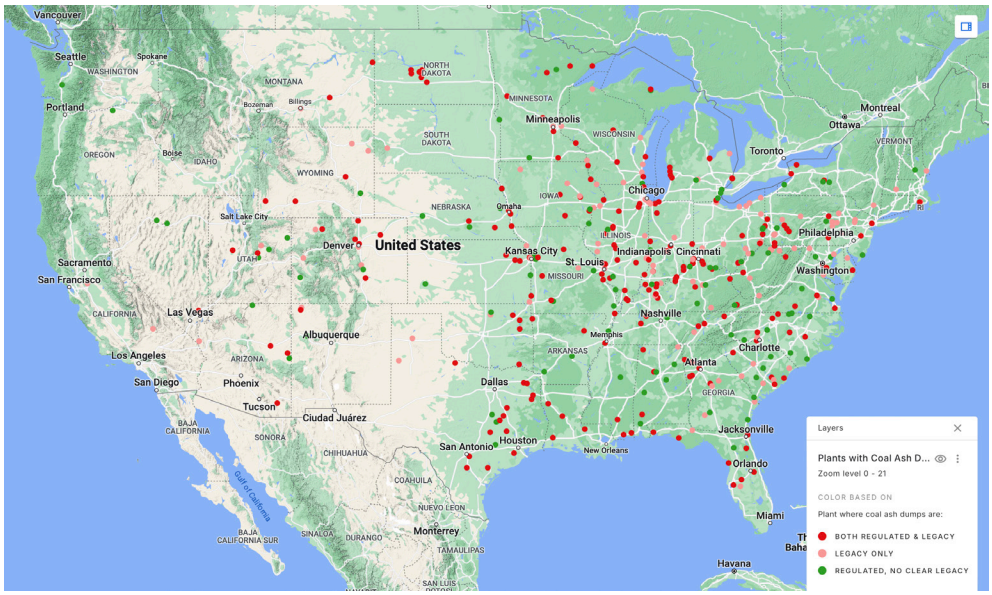
Coal ash is the residue left over after burning coal to create electricity. The residue consists of several different types of ash that comprise one of the nation's largest industrial waste streams.[17] It is estimated that between 1966 and 2019, utilities disposed of an estimated 4.3 billion metric tons of coal ash.[18] The residue is still with us and is growing.

The federal Environmental Protection Agency (US EPA) does not classify coal ash as hazardous waste, but it can contain mercury, cadmium, arsenic, and other toxins.[19] The American Coal Ash Association found that in 2022 about two-thirds of freshly produced coal ash was sold for various uses. What is not sold is disposed of in storage sites, a requirement since the passage of the Clean Air Act of 1970, which mandated that utilities begin storing coal ash in landfills and coal ash ponds ("surface impoundments").[20]

These rules have not prevented environmental contamination. Environmentalists and activists pushed for stronger regulation after a dike holding a coal ash pond at the Tennessee Valley Authority's Kingston Plant failed in 2008, releasing millions of cubic yards of coal ash. Waters laced with toxins flowed into tributaries of the Tennessee River, upon which more than five million people depend for drinking water.[21] The spill caused millions of dollars of damage and rendered many properties uninhabitable.[22] The coal waste was so toxic that hundreds of clean-up workers were sickened, and dozens died later of various forms of cancer.[23] This was not the only spill that endangered people and communities.[24]

Figure 1

COAL ASH WASTE DUMPS IN THE UNITED STATES



Source: "Where are Coal Ash Dump Sites," Earth Justice at https://earthjustice.org/feature/coal-ash-map-sites-legacy-inactive-regulated#:~:text=Industry's%20own%20data%20indicate%20that,75%20million%20tons%20every%20year.

Seven years later, in 2015, Congress imposed additional regulations on those storage sites in the "Disposal of Coal Combustion Residuals from Electric Utilities Act" (sometimes referred to informally as the "2015 Coal Ash Rule").[25] The 2015 Coal Ash Rule finalized national regulations on coal ash disposal under the Resource Conservation and Recovery Act. It required that existing unlined coal ash ponds causing groundwater contamination above certain levels had to stop receiving newly generated ash.[26] The rule created a loophole excluding from regulation hundreds of "legacy" storage sites at retired plants, likely the result of Big Energy lobbying, where coal-fired generation had ceased before 2015.[27] These storage sites were mostly unlined ponds and landfills, and the most in need of stronger regulations, with little to prevent spills or the leaking of hazardous chemicals.[28]

The Washington Post recently estimated that 1000 coal ash ponds exist in the United States, of which a quarter were "grandfathered" in and excluded from regulation under the 2015 Coal Ash Rule.[29] The environmental watchdog group Earthjustice estimates that there are 1400 sites in total, both regulated and unregulated, and that an estimated 500 million tons is not regulated.[30] Appalachia has a disproportionate share of these sites because of the long history of coal mining and coal use in power plants throughout the industrial region.[31] The map in Figure 1 shows the concentration of coal ash waste in Central Appalachia.

Toxins from coal ash and other pollutants affect the site of virtually every coal-burning power plant. The Earth Justice and the Environmental Integrity Project documented coal ash pollution affecting groundwater at 91% of 265 such power plants across the country.[32] This can pose a barrier to redeveloping shuttered coal power plants, leaving valuable land and infrastructure vacant and a blight on their respective communities.[33] Pollution typically requires remediation before other investors are willing to take title, and remediation can be prohibitively costly.[34] For example, clean-up at the Alabama Power sites was estimated at $3.3 billion in 2019; the utility attributed the 3% increase in customer rates to coal ash clean-up. Clean-up will take 7-12 years to close the ponds, with an additional 30 years of groundwater monitoring required after closure.[35]

The Federal Energy Regulatory Commission (FERC) regulates municipal fossil fuel power plants and requires remediation as part of decommissioning, but state public utility commissions (PUCs) regulate investor-owned fossil fuel power plants, so decommissioning requirements differ state-to-state.[36] Who pays for the remediation may be a major point of negotiation in the sale or transfer of the site. While new approaches for mitigating the cost of remediation are under development, complexity and scale of remediation can make redevelopment difficult.

> "Traditionally, redevelopment of a coal plant averaged 27 years, according to a 2014 study by the Delta Institute, an environmental nonprofit group. Utilities would simply mothball them because of the high remediation costs. But a process called environmental liability transfer, which allows utilities to discharge their responsibilities via structured asset sales, has encouraged owners to part with retired plants. An increasing array of subsidies, including state tax credits; opportunity zones; and a number of benefits from the 2022 Inflation Reduction Act have created opportunities for creative reuse."

Source: Patrick Sission, 'As Coal Plants Shutter, a Chance to Redevelop 'the Gates of Hell,' New York Times, October 17, 2023 at https://www.nytimes.com/2023/10/17/business/coal-plant-redevelopment.html

The US EPA recently tightened the regulations of the 2015 coal ash rule and closed loopholes (discussed later in this report). The new rules face challenges in courts, which could delay some state implementation and enforcement. The effect of these changes on the clean-up and the redevelopment of decommissioned coal plant sites is unknown, but it could change the cost-benefit analysis of utilities around the choice of disposing of coal ash or harvesting it for resale. To the extent it is the stick that moves that calculation more towards harvesting it, it will slow the growth of disposal sites and contribute to the remediation of the enormous environmental problem of coal ash dumps.

Coal Ash as an Opportunity

"Beneficial Uses" In A Mature and Growing Market for Coal Ash

Growing markets that use coal ash can slow the growth of disposal sites. Some utilities are remediating surface impoundments and landfills and selling the recycled product for beneficial uses, like cement and concrete.

While "coal ash" refers generically to the residue left behind after burning coal, power plants produce several different types of coal ash from different processes. The American Coal Ash Association (ACAA) found that in 2022, almost two-thirds – 48.6 million tons – was recycled and sold for various uses. Power plant operators dispose of the rest in landfills and surface impoundments (coal ash ponds).[37] The American Coal Ash Association tracks the production and use of these various types of coal ash.

"Coal ash" is the umbrella term for coal combustion products, or byproducts, formed during the burning of coal to produce electricity. They are commonly divided into four categories, each with a resale market.

- **Coal Fly ash** is a fine, powdery substance that floats up the smokestack. It is made of mainly silica and is one of the most economically productive forms of coal waste. It can be used as a partial or complete replacement for Portland cement in concrete and as a structural fill in road construction and foundations. It can also be used to make bricks, ceramic tiles, plaster, grout fill, wallboard, and concrete pipes.
- **Bottom Ash** is made up of larger, coarser ash particles that are too heavy to be carried up the smokestack and form in the bottom of the furnace; it is used as an aggregate to replace sand and gravel in construction uses. It is also used in masonry products, including concrete blocks, and in the production of green roofs.[116]
- **Boiler Slag** consists of smooth, glassy pellets from molten bottom ash cooled with water. It is used for roofing granules, asphalt coatings, and blasting grit.
- **Flue gas desulfurization materials** are the byproducts created by scrubbing sulfur dioxide emissions out of the fumes generated by burning coal. It is used in synthetic gypsum products, including panel products (wallboard or drywall), ceilings and flooring underlayments, cement and concrete, and other construction uses.[117]

In 2022, almost two-thirds of newly burned coal ash produced by power plants was harvested and sold into different markets. The market for coal ash is mature: the product has been used domestically in the production of concrete, for example, since 1932.[38] The 2015 Coal Ash Rule defined "beneficial uses" of coal ash for recycling and sale to end users and, under general guidelines, delegated oversight of the sale of coal ash for "beneficial use" to the states.

State policies for the beneficial use of coal ash vary, although they are subject to these federal guidelines: The coal ash product sold must provide a functional benefit;

- It must substitute for the use of a virgin material;
- It must meet product specifications and design standards; and

- When the unencapsulated use of coal ash involves placing 12,400 tons or more on land in non-
- roadway applications, the user must demonstrate that the environmental effect is not harmful.

Three of the guidelines apply to uses that encapsulate the hazardous elements of coal ash through industrial processes. However, with certain restrictions, the sale of coal ash for unencapsulated uses is also allowed. Unencapsulated uses do not treat the coal ash to reduce potential health hazards.

The largest domestic use of coal ash is in cement, concrete, and drywall production. It reduces the carbon footprint of these building materials, which are a major source of carbon emissions in their manufacture and use. The American Coal Ash Association (ACAA) does not break out the use of coal ash in bricks separately, but manufacturers of brick, which is among the most significant global construction products, use coal fly ash.[39]

According to the ACAA, for every ton of fly ash used to replace traditional cement in manufacturing brick construction products, a ton of carbon dioxide is saved from entering the Earth's atmosphere; over the past decade, coal ash recycling eliminated nearly a billion tons of greenhouse gas. Builders use high-performance fly ash concrete mixes in bridges, skyscrapers, roads, dams, and many other construction projects. They routinely use 40% fly ash mixes, a component that can reach 70% or more in massive walls, girders, dams, and foundations.[40]

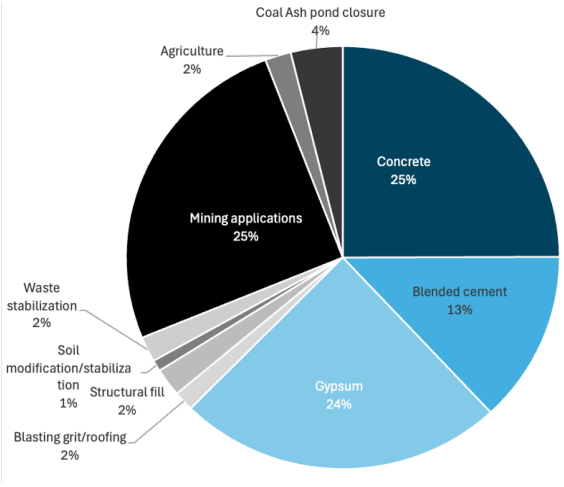
In 2022, coal-fired power plants produced 75.2 million tons of coal ash, down from 114 million tons in 2014. Top uses and tonnage included:

- **Concrete:** Although concrete manufacturers use all types of coal ash in production, coal fly ash is the largest component.
- **Cement:** Cement is used to manufacture concrete and accounts for the lion's share of its massive carbon footprint.
- **Synthetic gypsum used for panels and wallboard:** Synthetic gypsum is a byproduct of flue gas desulphurization units (also known as "scrubbers"). It is used in the production of cement, and also in the manufacture of drywall and panelboard.
- **Cenospheres** are hollow, lightweight particles of silica, alumina, and iron oxide used in industrial applications.
- **Synthetic gypsum used in agricultural applications:** Synthetic gypsum, used to improve soil conditions and prevent fertilizer runoff.
- **Utility coal ash pond closures:** This use is driven by utility compliance with coal ash regulations enacted in 2015, which effectively require an end to wet disposal.
- **Grit and roofing granules:** Boiler slag is used in this application, and a small portion of these materials is used for structural fill.
- **Structural fills (road and related uses):** Coal ash in structural fills declined by nearly half in 2022 to one million tons.

About two-thirds of coal ash sold for production is 'encapsulated' by industrial processes into building materials.[41] When used without encapsulation, coal ash can blow into the air people breathe and the water they drink. Unencapsulated uses, like structural fills and related uses, are considered dangerous: a November 2023 US EPA report found that exposure to even small amounts of coal ash can lead to harmful health effects due to gamma radiation from radium, including risks of cancer 35 times higher than previously suggested by the federal regulator.[42] There is concern that unencapsulated uses are a backdoor means of coal ash disposal that avoids regulation and health hazards. In a 2011 report, the inspector general of the US EPA acknowledged that "sand and gravel pits, as well as fill operations, represent disposal rather than beneficial use."[43]

Figure 2

2022 USES OF THE BENEFICIAL USES OF COAL ASH



Source: Based on data from the 2022 American Coal Ash Association survey of uses

An examination of overall coal ash production sold for all uses over time reveals a changing market. The American Coal Ash Association's annual survey categorizes uses by market and by type of coal ash (Figure 2).

- The largest overall share of all coal ash produced and sold into the market in 2022 was coal fly ash, with 16.8 million tons sold into 12 sectors, of which concrete is the largest, down from 26.6 million tons sold in 2002. In 2022, this encapsulated use comprised 35.8% of all coal ash sold for beneficial use; in 2002, it made up 58%.

- Flue gas desulphurization (FGD), used in the production of synthetic gypsum, is the second-largest form of coal ash used beneficially, rising from 7.7 million tons in 2002 to about 14.5 million in 2022. Today, this product makes up about a third of all the coal ash sold compared to 18% in 2002.[44] These products, making up just under two-thirds of the beneficial uses of coal ash, encapsulate the coal ash in the manufacturing process.

- Fluidized Bed Combustion (FBC) coal ash is the third-largest type of coal ash product, with 11.8 million tons or 25% of total coal ash sales in 2022, up from 2% — just under a million tons — in 2002, when it was first reported on this annual survey. This is an unencapsulated use. Mine operators use FBC ash, which has an alkaline composition, to neutralize acid mine drainage of operations.[45] [46]

Utilities and other stakeholders are exploring new end uses for coal ash. Some researchers are exploring the potential of reusing coal ash for carbon nanomaterials, which could be used for many applications.[47] They are pursuing cenospheres for potential use in lightweight car manufacturing, battery casings, and other applications.[48] Coal ash contains metals and critical minerals.[49] The United States has no natural domestic source of aluminum; researchers are exploring the potential of extracting it from coal ash.[50] Stress-tested metals made with up to 50% fly ash instead of aluminum have been tested at the University of Wisconsin.[51] Coal ash particles have a chemical structure that can easily be manipulated to absorb oil.[52] Coal ash may contain commercially viable quantities of lithium and rare earth elements, which are in short supply but have high demand for use in smartphones, renewable and clean tech products, jet fighters, batteries, and other electronic sectors.[53]

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Dynamics of the Coal Ash Market

"Beneficial Uses" In A Mature and Growing Market for Coal Ash

"Green(er)" Concrete and Demand for Coal Ash

An estimated eight to nine percent of global carbon emissions come from the production of concrete and the cement used in production.[54] While cement makes up only a small portion of the concrete mix by volume, it accounts for up to 90% of the total carbon embodied in the material. Substitution of alternative materials like coal ash can reduce the carbon intensity of production, shrinking the overall carbon footprint of building materials. Climate change concerns drive increased demand for green building products. Many state and local governments, which purchase nearly one-third of all concrete used for construction in the United States, have carbon reduction goals that will increasingly affect their procurement practices.[55]

Cement is a central ingredient in the production of concrete, which is among the most widely used building construction materials in the world. [56] Portland cement – a specific type of commonly used cement – was first developed by Joseph Aspdin, a 19th-century British stonemason, who heated a mix of ground limestone and clay, pulverized the concoction into a fine powder, and created the world's first hydraulic cement: one that hardens when water is added. Today, it is the basic ingredient of concrete. Concrete is formed when Portland cement creates a paste with water that binds with sand and rock to harden. (Aspdin called it Portland cement due to its similarity to a stone quarried on the Isle of Portland, off the British coast.)[57] Coal ash has been used in the manufacture of concrete in the United States since 1932; it was first used in large quantities in the construction of the Hungry Horse Dam, built by the Bureau of Reclamation between 1948 to 1953.[58] It is an inexpensive replacement for the Portland cement used in concrete. It has been found to improve strength, durability, and ease of pumping concrete, as well as reduce the carbon footprint in manufacturing.[59]

The production of Portland cement is energy-intensive in terms of process and materials.[60] According to the National Precast Concrete Association, cement manufacturing alone accounts for nearly 5% of global CO2 emissions. Cement is made by heating limestone to very high temperatures, which induces a chemical reaction that transforms the limestone into a product called clinker, which is then ground together with gypsum to form cement.[61] Coal itself is used in approximately 90% of cement plants globally to deliver the energy needed for the heat inside the kiln.[62] Emissions from fuel burning alone are responsible for 40% of the carbon emissions in cement; the other 60% of emissions are released in the chemical reaction as heat releases calcium carbonate in the limestone.[63] Replacing a portion of the cement with alternative binding ingredients – like coal ash – reduces carbon content in concrete because it eliminates raw material consumption and uses lower energy.

As of 2022, the U.S. had 91 operating cement plants that are responsible for 68 million metric tons (Mt) of direct CO2 emissions — the emissions equivalent of around 16 million gas-powered cars — annually.[64] The emissions intensity of cement production in the U.S. is around 20% higher than that of other major cement-producing parts of the world because it uses more clinker and less "supplementary cementitious materials" (SCM) like coal ash. This may be due in part to building standards that are set by state agencies: 37 states set prescriptive content-based standards for concrete that define the maximum amount of cement substitution allowed.[65] The United States Department of Energy has outlined both short- and long-term approaches to decarbonization of this sector. It identified the use of more SCMs in concrete production and less cement as the most important approach to decarbonizing the sector during the current decade.[66]

Concrete or cement containing fly ash is called "green" because the carbon footprint is smaller than ordinary concrete. Coal ash is commonly used to replace up to 25% of cement content in concrete (by weight), although some applications go much higher.[67] This is a mature technology that is applied at a commercial scale.[68] Surveys find the cost of making concrete "greener" with materials like fly ash does not increase the price of the material substantially.[69]

Market growth

As the economy recovers from the pandemic recession and state and local governments build infrastructure, the critical markets that use coal ash for decarbonization are strong.

Growing markets for coal ash and for the building products that are "greened" with it

- The North American fly ash market is expected to grow from $3.8 billion in 2021 to $5.231 billion by 2028, with a compound average growth rate (CAGR) of 4.6% during the forecast period.[118]
- The North American green concrete and cement market was valued at US $3,423.61 million in 2022 and is expected to reach $6,130 billion by 2030, growing at a CAGR of 7.6% from 2022 to 2030.[119]
- The North American gypsum board market is valued at $14.3 billion in 2024 and is anticipated to grow to $21.9 billion by the end of 2031, with a CAGR of 6.3%.[120]
- The American Coal Ash Association does not break out the use of coal ash in brick, but investment analysts estimate that the brick market is among the world's largest. The domestic market was valued at $6.5 billion in 2024. It had declined slightly over the past five years, but the future outlook is positive.[121]

In response to international concern about global warming, many governments developed incentives to reduce carbon emissions associated with building materials.[70] The United States incentives included targeted funding to decarbonize cement and concrete. Examples include the following programs:

- The Department of Energy's Industrial Demonstration Program anticipates investing $1.6 billion in six decarbonization projects in the cement industry.[71]
- The Inflation Reduction Act provides specific tax credits for buildings with a reduced carbon footprint during construction and over the structure's life, which will help drive demand for greener concrete.
- More than $5 billion will be spent on federal procurement of American-made clean technologies to create a stable market for clean products. This program includes funding to incentivize use of low-carbon building materials in public infrastructure projects and certain government-owned buildings.
- Another $2.15 billion is set aside to install low-carbon materials in General Services Administration-owned buildings.[72] These federal procurement policies can serve as a model for state and local government procurement as well.

Supply of Coal Ash for the Market

Over 75 million tons of coal ash was produced in 2022. Almost two-thirds were sold. The supply has fallen significantly since 2014 (when 114 million tons were produced), largely because so many coal-burning power plants have been closed. Now is a good time to get serious about tackling the old waste littering the region.

Newly burned or "fresh" coal ash is far easier to process and sell than the old waste stored in coal ash ponds and landfills, so bigger carrots and sticks may be required. Some utilities are expanding their recovery of fresh coal ash and exploring ways to derive adequate quality from old storage sites. Recent utility activity in recycling coal ash includes:

- Duke Energy has built several facilities using SEFA technology to recycle its own waste.[73]
- Alabama Power is working with Eco Material Technologies to build a recycling facility at the Berry Plant in Mobile, Alabama.[74]
- Tennessee Valley Authority's Kingston Fossil Plant recycles about 65%of the fly ash produced, supplying 200 ready-mix concrete companies across seven states with fly ash from the Bull Run, Cumberland, and Kingston plants.[75]
- Georgia Power, working with Eco Materials Technologies to recover coal ash for use in concrete manufacture, partnered in 2021 with the Electric Power Research Institute and the Southern Company in establishing the Ash Beneficial Use Center to pilot new methods of coal ash reuse.[76]
- Charah Solutions formed a five-year marketing and sales contract for the beneficial recycling of fly ash from the Gavin Power Plant in Cheshire, Ohio, the Miami Fort Power Plant, and the Zimmer Power Plant in southern Ohio.[77] It has purchased the Cheswick plant in Pennsylvania as well.
- First Energy reports that it has used recycling in its power plant reclamation work. In 2016, it was reported that 80% of coal ash waste from the Bruce Mansfield Plant would be removed from the site and sold for use in mine reclamation, which is an unencapsulated use.[78] More recently, a First Energy press release noted that the sale of recycled coal ash recovered from subsidiary Allegheny Energy Supply Company's landfill was for cement manufacture, an encapsulated use.[79]

Recycling helps, but as supply of newly generated domestic coal ash dwindles, manufacturers that need coal ash are turning to imports, despite long-distance transportation increasing its carbon footprint. Little is known of the volume of such imports because federal trade statistics don't include coal ash, and no one currently tracks how much arrives at ports nationwide.[80]

The Port of Virginia handled just one shipping container of coal ash in 2015 from India. Last year, there were about 22 from China and Poland. According to a port spokesman who didn't know the final destinations, it all went on to Ohio and Wisconsin. Meanwhile, more ash has been trucked in from other states for concrete production in Virginia.

Source: Sarah Rankin, "Coal ash: 'Why in the world would we be importing it?' Associated Press, carried in the Salina Journal, March 23, 2017, at https://www.salina.com/story/news/nation-world/2017/03/23/coal-ash-why-in-world/21206425007/

Barriers to Market Growth

Markets for coal ash are growing, but thorny problems in the domestic market remain. Fresh coal ash has low economic value: it can cost several dollars a ton if trucked directly from a utility to a factory or job site.[81] The low value discouraged utilities from investing in operations to harvest and sell all of the coal ash they produce.[82] Some of the factors driving the cost of recovery of coal ash include both technical and regulatory barriers.

Technical barriers include the need to sort and refine the different types of coal ash. The quality of the ash and even the type of coal burned influence what is acceptable for use in cement and concrete manufacture. Pollution control equipment used in a generator can affect the quality of the ash.[83] Sorting is a step that adds expense even for newly-burned coal ash and affects the cost-benefit lens through which utilities consider the viability of recovery. Extracting usable materials from coal ash ponds, which contain a jumble of types of ash, other coal wastes, and even garbage, poses even more significant technical challenges in harvesting.[84] Federal investments in the manufacture of separation technologies, like those of Separation Technologies LLC, can help reduce these costs.[85]

Handling coal ash is complex because of the structure of regulation, with federal regulators overseeing the storage of disposed coal ash and state regulators overseeing beneficial use (sale into the market). Laws for beneficial use are not standardized. Wisconsin has one of the country's highest levels of coal ash reuse, thanks to standardized laws that encourage reuse. Without clear standards, companies can fear lawsuits and be reluctant to reuse industrial waste.[86]

> "There are many headwinds to shifting the industry, including long-standing historical practices, institutional inertia, a lack of information about the use of blended cements and the risk-averse nature of the construction industry. This combination leads to low acceptance levels of lower-carbon blended cements by purchasers."
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> Source: Ankita Gangotra, Kevin Kennedy and Willy Carlsen, "The US Needs to Lower Cement Emissions — 'Blended Cement' Can Help," World Resources Institute, May 9, 2024 at https://www.wri.org/insights/lower-carbon-blended-cement (Accessed August 26, 2024)

More utilities and other companies are beginning to harvest, treat, and sell legacy coal ash, as described earlier in this report. The sheer scale of coal ash supply in surface impoundments and landfills remains staggering. Recent changes to the 2015 coal ash rule attempt to tighten requirements and oversight, and can incentivize utilities to turn their attention to recycling of legacy waste.[87] The new rules of 2024 require utilities to remediate their unlined legacy coal ash dumps excluded from the 2015 rule and close loopholes in reporting and monitoring these sites, which will increase the cost of maintaining disposal sites.[88] However, the role of the states in implementing federal environmental laws weakens enforcement, even with the newly-tightened regulations. Across the 50 states, decisions on acceptable cleanup steps will be made in individual state regulatory proceedings where the industry has often captured the ear and pen of regulators.[89] Some states are waiting out the clock on both court rulings and the results of the 2024 presidential election, thinking a change in administration may result in the rescinding of the new rules.[90]

There are also concerns about both unencapsulated uses of coal ash[91] and the safety of encapsulated coal ash used in concrete, brick, and drywall over the product life cycle. The U.S. EPA finds no such risk, but some nations, described earlier in this report, set standards for building materials made with coal ash in residential buildings.[92] Treatments exist to address the life-cycle emissions, but they increase the cost of cement made with fly ash and could be subject to the variation in state regulation, so the actual cost of the product may vary from state to state.[93]

Opportunities for Appalachia

A historical manufacturing sector could grow again

Appalachia has a concentration of firms that produce goods for the building sector. Central Appalachia first provided the timber, then the cement and concrete, brick, iron and steel, and other critical materials used in building the factories and cities of the industrial economy. The region retains a competitive advantage in producing building materials, including cement, concrete, clay, and refractory materials. Cement, concrete, and coal ash are all heavy materials that serve regional markets. Central Appalachia's coal ash supply could make it an important hub for green concrete, cement, and other building materials to serve some of the biggest construction markets in the nation. Demand for green buildings and products will increase as cities, states, and federal agencies strive to achieve the goals of their own climate strategies. Such demand could reduce growth in the many coal ash ponds and landfills in the region.

The concrete and cement industry in central Appalachia

Builders used Portland Cement in Europe in the first half of the 19th century, and by the Civil War era a similar product based on domestic resources was produced in the Lehigh Valley of Pennsylvania. Domestic use on a large scale emerged first in and around Appalachia. The first high-rise concrete building was erected in Cincinnati in 1927. The first use of concrete in a roadway was in Ohio.[94]

Cement, concrete and brick manufacture are classified under the North American Industrial Code System (NAICS) as "Nonmetallic mineral product manufacturing." The NAICS code assigned to this sector is 327. It includes clay and refractory materials, [95] concrete and concrete products, cement, glass, lime, gypsum, and miscellaneous products like mineral wool (used in insulation). This section focuses on concrete, cement, and bricks because they use coal ash to reduce their carbon footprint. Central Appalachia has a historical strength in the sector that remains important in local economies throughout the region today.

Location quotients evaluate sectoral strength in a particular place based on employment relative to that typical of the larger region or nation. Sectors with a location quotient of greater than one in a particular industry have a higher concentration of jobs than is usual, indicating economic strength and competitive advantage because of the skills of the workforce and the number or size of productive facilities. The location quotients for the sectors included in NAICS 327 within Central Appalachia show such strength. In other words, more people work in the manufacture of these products in the region than the national average (Figure 3).

The entire sector employed 45,552 workers in Ohio, Pennsylvania, West Virginia and Kentucky in 2022. The industry is concentrated in counties that are within the Appalachian counties of the states (Figure 3). For example, the 32 counties that make up Ohio's Appalachian Region have employment in the brick industry that is eight times higher than typical for the nation and more than twice as high as typical for the state. The overall central Appalachian region has almost 40%more workers in concrete and cement than is typical for the nation, with some states showing a higher concentration than others. For example, the Appalachian counties of Kentucky show a concentration of employment that is more than 50%higher than typical for the nation.

Figure 3

EMPLOYMENT LOCATION QUOTIENTS FOR NAICS 327: NONMETALLIC MINERAL PRODUCT MANUFACTURING (CONCRETE, CEMENT, BRICK, GLASS, GYPSUM AND OTHER) IN CENTRAL APPALACHIA

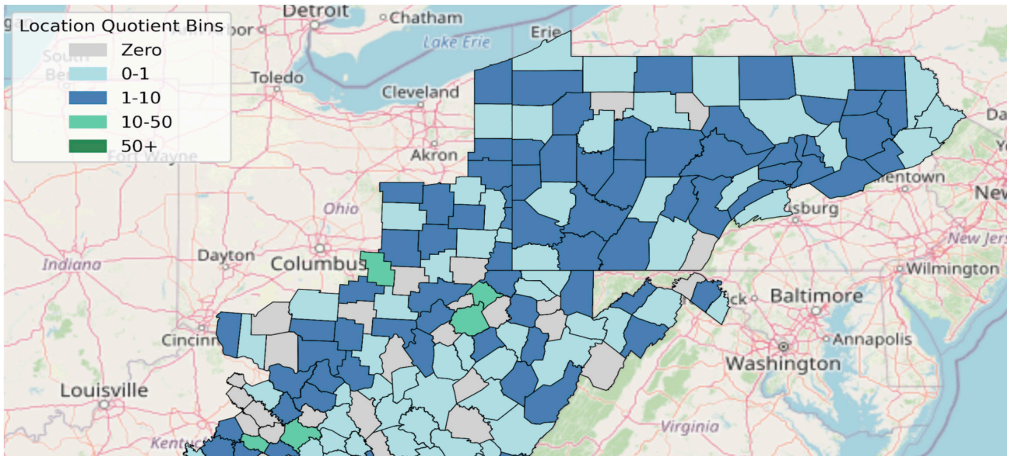
		Appalachian Counties within the 4 states					All counties of the state				
NAICS Code	NAICS Description (manufacturing)	KY	OH	PA	WV	Appalachian Region the 4 States	KY	OH	PA	WV	4- States Region
3271	Clay Product and Refractory	3.31	8.69	2.56	4.17	3.89	1.11	3.13	1.68	4.17	2.28
3272	Glass and Glass Product	0.51	2.80	2.28	0.62	1.94	2.00	2.68	1.40	0.62	1.95
3273	Cement and Concrete Product	1.53	1.44	1.43	1.09	1.39	0.99	0.91	1.22	1.09	1.06
3274	Lime and Gypsum Product*	0	1.26	1.48	1.17	1.26	1.26	1.15	1.20	1.17	1.19
3279	Other Nonmetallic Mineral Product	2.06	1.72	0.77	1.66	1.19	1.51	2.74	0.98	1.66	1.77

Source: ReImagine Appalachia, based on data derived from the federal Bureau of Labor Statistics.

Employment in this sector is broadly spread throughout the counties of central Appalachia. We found that almost all counties have some employment in NAICS 327 industries (light blue on the map in Figure 4); many counties have higher than average employment concentrations (dark blue), and a few counties have very high concentration (green). The map demonstrates visually the importance of the sector in the region, a strength that indicates a foundation upon which higher employment could be built.

Figure 4

EMPLOYMENT IN NON-METALLIC MINERAL PRODUCT MANUFACTURING (CONCRETE, CEMENT, BRICK, GLASS, GYPSUM AND OTHER) BY COUNTY IN CENTRAL APPALACHIA



Source: ReImagine Appalachia, 2024, based on data derived from the federal Bureau of Labor Statistics.

Examining the employment location quotients for product subcategories highlights industrial strength by specific product in central Appalachian states (Figure 5). Pennsylvania has strong employment in all product areas shown in Figure 5, including manufacture of cement. West Virginia and Ohio have concentrated employment in pottery, ceramics, and plumbing fixtures and clay building materials. Kentucky has about more workers than typical in ready-mix concrete – the most prominent product market.[96]

In the building materials supply chain, coal ash is used in the manufacture of the basic materials from which product will be formed. The "downstream" product is used in higher value products like block and pipe and plumbing fixtures, which are further "upstream" in the supply chain. Products rise in value moving up the supply chain as more labor and capital is needed to shape and refine the pieces and parts that eventually go into a finished product. Companies producing higher value products need more machinery and equipment and workers with specific training and skills. Products are sold for a higher cost, earning the company more money. Workers' pay rises with skill level. The earnings of higher-skilled workers strengthen the economy of their family and community as they spend their earnings at local businesses.

All the central Appalachian counties of the states examined here have strength in the downstream sectors, while some have a concentration of employment upstream in the supply chain. Figure 5 identifies specific products where the various states have strength. Demand for production of the cement, concrete, brick, and gypsum industries are forecast to rise throughout the decade. Federal funds and consumer preferences are moving demand toward "green" building materials that decarbonize the built environment.

Figure 5

EMPLOYMENT LOCATION QUOTIENTS BY STATE FOR SPECIFIC NON-METALLIC MANUFACTURED PRODUCTS IN THE FOUR-STATE REGION

		Appalachian counties					All counties within the state				
NAICS Code	NAICS Description (manufacturing)	KY	OH	PA	WV	Appalachian portion of the four states	KY	OH	PA	WV	Four states region
32711	Pottery, Ceramics, and Plumbing Fixture	0.38	3.48	2.29	5.86	2.89	0.64	2.15	1.42	5.86	1.80
32712	Clay Building Material and Refractories	5.73	12.98	2.79	2.78	4.72	1.50	3.94	1.89	2.78	2.67
32731	Cement	0.00	0.08	1.46	1.12	1.05	0.75	0.79	1.97	1.12	1.30
32732	Ready-Mix Concrete	2.48	1.58	1.12	1.24	1.33	1.23	0.85	0.81	1.24	0.91
32733	Concrete Pipe, Brick, and Block	0.88	0.75	1.27	0.55	1.03	0.98	1.03	1.28	0.55	1.10
32739	Other Concrete Products	0.53	1.85	2.06	1.09	1.74	0.62	1.00	1.74	1.09	1.26

Source: ReImagine Appalachia, based on data derived from the federal Bureau of Labor Statistics.

A virtually inexhaustible supply of coal ash creates a huge environmental problem, but it also offers central Appalachia a unique resource for the green building materials industry. An estimated 4.3 billion metric tons of coal ash is stored in surface impoundments and landfills across the nation.[97] The Ohio River Valley alone hosts more than one out of five (161) of these sites.[98] Easy access to abundant supply could increase demand for the region's green building products and boost employment in the sector. Charah Solutions, one of the largest fly ash suppliers in the world,[99] recently purchased the shuttered Cheswick plant in Pennsylvania.[100] More firms in the building materials supply chain could find shuttered coal plant sites particularly advantageous. Recyclers could be particularly appropriate for an eco-industrial park format.[101]

Charah Solutions subsidiary purchases the shuttered Cheswick Power Plant site

Charah, which describes itself as a leading provider of environmental services and byproduct recycling to the power generation industry, says the Cheswick acquisitions have been made through three companies related to its subsidiary, Charah Environmental Redevelopment Group LLC (CERG).

The retired Cheswick Generating Station in Springdale, Pennsylvania, is near Pittsburgh and located along the Allegheny River. The 56-acre primary generating station site, along with an adjacent 27-acre parcel, consists of an operating rail line, coal yard, bottom ash emergency and recycle ponds, waste ponds, coal pile runoff pond, coal delivery equipment, and an ash handling parcel, says Charah.

"CERG will be responsible for the shutdown and decommissioning of the coal power plant, the remediation of the two ash ponds, and performing all environmental remediation and redevelopment work at the site," states the firm.

Source: Brian Taylor, "Charah Solutions adds PA power plant to its demo list," Construction and Demolition Recycling, April 7, 2022 at https://www.cdrecycler.com/news/charah-cheswick-power-plant-demolition-redevelopment-pennsylvania/

Fly ash is consumed and marketed regionally because it is heavy: there is a limit to how far domestically produced coal ash can be economically moved.[102] Building material manufacturers benefit from a location near a reliable source of coal ash: For example, it is common for wallboard manufacturers to co-locate adjacent to power plants to utilize the synthetic gypsum from coal ash.[103] Locating such facilities with shuttered coal plants with surface impoundments or landfills could be a win-win for communities impacted by coal plant closures.

Building materials produced in central Appalachia have a good location for serving strong construction markets. Cement, concrete, and brick are locally or regionally produced and used because of transportation costs.[104] This is particularly important for green building materials since transportation-related emissions affect the carbon footprint. This also gives Appalachia a locational advantage with a nexus to major industrial construction markets from Cleveland, Columbus, Cincinnati, Pittsburgh, and other economically growing cities.[105] Residential construction has also accelerated, post-pandemic, in the eastern half of Pennsylvania, Ohio, and North Carolina.[106]

States and local governments, with climate action plans of their own, are significant bidders in the construction materials market, procuring 33% to 46% of cement.[107] Public purchasing policies by state and local governments in central Appalachia can strengthen the sector as they start the bidding process for Infrastructure projects funded under the Bipartisan Infrastructure Act.[108] [109] Officials can specify LEEDs or other "green" standards and award priority points in the contract evaluation for lower transportation costs to favor local green building material manufacturers. This can help create jobs and strengthen the local economy.

Recommendations for the Growing Coal Ash Industry

Protection of Communities, Residents, and Workers

With the proper regulations to protect communities and workers, the transition of coal ash as a dangerous liability to an opportunity can have a positive triple bottom line: cleaning the environment, creating jobs, and reducing carbon emissions. As the use of coal ash expands, rules governing the safety of communities and workers must be developed. Creating appropriate regulations of new rules and standards that will hold in the political environments of the federal government, the fifty states, and thousands of local governments will be a challenge to successful coal ash reuse.

Regulation

Industries of the past supported families and created communities but left behind environmental damage and poverty. The voice of residents and labor will be critical to rebuilding a new, sustainable and beneficial economy, even as the harm of the old economy continues to be addressed.

1. Strengthen environmental protections: The 2015 regulation of coal ash has been improved through the May 2024 tightening of rules around legacy storage sites and the reporting and monitoring of storage sites. The rule is being challenged in courts, and states are delaying action based on the outcomes of court cases. A strictly enforced regime for oversight and monitoring of coal ash dumps is critical to changing utilities' cost-benefit calculations so that all coal ash produced is recycled, not dumped.

2. Uniform regulation, oversight, and enforcement of disposal: Today, states are responsible for implementing federal regulations concerning coal ash disposal sites. Federal lawmakers should create interventions – both carrots and sticks – to ensure prompt and uniform implementation of federal laws, withholding important funding if states are not compliant with environmental orders. State monitoring and reports should be reviewed at the federal level. Reports to regulating entities should include a summary in lay reader's terms so the public can understand them.

3. Uniform regulation, oversight, and enforcement of the sale and use of coal ash: Today, states oversee the beneficial uses of coal ash (coal ash sold into the market). A patchwork of 50 different regulatory structures over the product's sale drives up the cost for utilities to recover, process, sell, and distribute coal ash to end users. Federal lawmakers should elevate oversight of the sale of certain coal ash products (beneficial uses) to the federal level, creating a uniform set of regulations.

4. Proactive regulation of new uses of coal ash: Ensure protective and safety regulations extend to new uses of coal ash and new industries employing coal in production. Providing funding for new uses in which the entirety of the waste is utilized, eliminating any coal ash disposal.

Incentivizing Market Demand for Coal Ash

The federal government is providing substantial financial support for decarbonizing the built environment, but challenges other than capital remain. This set of recommendations, taken from the U.S. Department of Energy and from the World Resource Institute, illustrate the kinds of policy changes needed to achieve the pace of decarbonization envisioned to meet the United State's climate goals.

This first set of recommendations is taken from the U.S. Department of Energy's "Low Carbon Cement Commercial Liftoff," one in a series of national decarbonization strategies promulgated by the federal government.[110] Six recommendations for encouraging more use of blended concrete like that utilizing coal ash include:

1. Establish a shared standards and data environment around blended concrete manufacturing (this recommendation addresses the confusion caused by state-level building material standards, among other things);

2. Targeted interventions to speed adoption of more use of SCMs in the manufacture of concrete, and to lower the cement content in concrete products;

3. Development of alternative procurement models to assure markets for new blends of concrete (this will help with financing of new equipment and processes that may be necessary);

4. Develop policy and market models to offset structural costs of change;

5. Continue financial and other supports for ongoing research and development in this area; and

6. Require robust community benefit plans to ensure development of new industrial processes that respond to public concerns, do not harm, and ensure public accountability.

The World Resources Institute also includes a set of recommendations to encourage increased use of blended concrete. These recommendations include:[111]

1. Promoting materials standards. At the cement stage of the value chain, performance and content standards that allow greater clinker substitution, such as ASTM's C1157 and C595 for blended cements, need to be promoted among state agencies and government and private contractors in lieu of the more rigid C150 Portland cement content standard. Similarly, performance standards need to be adopted for concrete to allow greater cement substitution. Standards should be frequently updated to accommodate innovation and newer cement blends. Policymakers should also encourage further production of SCMs through grants and permits, particularly for natural products like clay, to ensure robust supply chains and future availability of these substitutes.

2. Developing emissions reporting and benchmarking standards. To improve data availability, cement and concrete manufacturers should be encouraged to adopt standards such as Type III environmental product declarations (EPDs) to ensure consistent reporting of emissions intensity. The U.S. Environmental Protection Agency (EPA), which is developing the EPD assistance and carbon labeling programs for harmonized standards, must ensure manufacturers are able to demonstrate lower emissions with the use of blended cements and SCMs in the concrete mix in a consistent and accessible way.

3. Leveraging demand-side policies. Concrete producers, who are the primary purchasers of cement, need incentives and market signals to purchase low-emission, blended cements. Procurement policies like Buy Clean and advance market commitments, which aim to use the government's purchasing power to create demand for green products, can be used to build the market for blended cements.

4. Increasing awareness across the value chain. To increase awareness and acceptance throughout the value chain, pilot programs and demonstration projects should be launched by agencies such as DOE, EPA, and state departments of transportation showcasing the environmental and economic benefits as well as strength and durability of blended cements to contractors and architects.

Protecting Communities, Residents, and Environment[112]

The health, well-being, and prosperity of workers and community must be prioritized in new economic growth coming to Appalachia. Industries of the past supported families and created communities but left behind environmental damage and poverty. The voices of residents and labor will be critical to rebuilding a new, sustainable, and beneficial economy, even as the harm of the old economy continues to be addressed. Recommendations, based on those promulgated by the Blue Green Alliance, the Ohio River Valley Institute, EarthJustice, and others, include:

1. Pursue further independent research and assessment of coal ash recycling. Reusing coal ash should only be permitted when research indicates that the toxic chemicals in coal ash will not migrate from the ash in quantities that threaten human health or the environment during the entire lifecycle of the reuse application. The United States does not have lifetime standards for protecting the health effects of concrete and bricks that use coal ash in production. Studies should be done, and the regulations of other nations should be studied to determine "best practice" regulations for life cycle safety and health protection of the interior environment within buildings constructed with materials containing coal ash.

2. Assess the health and environmental impacts of the unencapsulated use of coal ash. No restrictions exist on placing unencapsulated coal ash for volumes less than 12,400 tons. There is also a need for more oversight in using larger volumes. All beneficial uses must be regulated and monitored. Extensive existing unencapsulated uses (such as unlined and unmonitored fills and mining applications, where unencapsulated coal ash is used to treat acid mine drainage) should be treated as disposal sites and must maintain all the necessary safeguards while clean-up occurs.

Protecting Workers

1. Good jobs: Companies reusing coal residuals and waste streams should be high-road companies with a proven track record of responsible practices and worker treatment. Public funding to subsidize expansion should be provided only to firms with sound safety and health plans, are open to labor unionization, and pay a living wage.

2. Worker safety: Policies to protect workers have been created based on lessons learned from the Kingston coal ash cleanup.[113] These policies and practices are critical for worker protection when handling coal ash. Any workplace handling coal ash must be monitored for safety plans and procedures by the Occupational Safety and Health Administration and meet hazardous materials handling standards, [114] including:

a. Provide thorough and ongoing safety training on the handling of coal waste;
b. Provide safety equipment and facilities, including a Safety and Health (S&H) Plan;
c. Include anti-retaliation whistleblower protections in required safety and health plans; and
d. Provide for enforcing the safety and health plans, including a worker complaint hotline.

3. Research coal ash's impact on workers. Research is needed to determine the possible health effects of coal combustion waste on workers exposed to ash and sludge at disposal facilities, construction projects, and manufacturing plants. Such research can guide the fine-tuning of OSHA regulations about people who work with coal ash.

4. Public funding should only be provided to companies with good records for worker protection in coal ash handling. All federal and state public bodies funding projects concerning the clean-up and reuse of coal waste should ensure that all private entities engaged in such clean-up have strong records of adequate worker protection.[115]

Conclusion

The interplay between coal waste and marketable materials demonstrates an opportunity to turn an environmental problem into an economic asset. Coal ash ponds and landfills have long plagued the Central Appalachian region, leaching into groundwater, causing elevated levels of cancer, bursting through dams, preventing redevelopment of old coal plant sites, and leaving what should be job-creating industrial sites vacant and blighted. Yet this toxic mixture can be made into a marketable product that contributes to decarbonization and in so doing, helps remediate an environmental problem. Converting a liability to an asset is a lengthy task. During that journey, employment and wealth may grow in the building materials sectors of central Appalachia.

The combination of federal subsidies for infrastructure construction and for building product manufacturers to decarbonize product, coupled with tightened US EPA rules governing disposal sites, may drive the recycling of newly burned and legacy coal ash. Central Appalachia is well positioned in terms of location to make green concrete, cement, drywall, and brick because of the proximity to coal ash to reduce carbon footprint and to strong construction markets. The time is right: state and local governments, which make up a third of concrete purchases, are now contracting for roads, bridges, dams, and other infrastructure using funds from the Bipartisan Infrastructure Law. Many have their own climate plans and decarbonization goals to meet. Procurement for construction will play an essential role in meeting their goals.

New uses for coal ash on the horizon may strengthen the demand for legacy coal ash. Coal ash has been found to contain valuable minerals like lithium, which is needed for batteries, and aluminum, which has many uses. It contains rare earth materials and other elements essential for everything from smartphones to windmills to fighter jets. The old industrial context (mine, manufacture, dispose) is being replaced by sustainable manufacturing systems (mine, manufacture, reuse). Reusing coal waste, which is among the nation's most significant industrial waste streams, is part of a new industrial context of circular material management. Appalachia's recovery of legacy coal ash can be part of a new identity as a hub for cleaner, sustainable, and efficient manufacturing.

Today, however, the most significant job remains clean-up. In the excitement about developing new industries, we cannot ignore the challenging task of enforcing existing regulations around cleaning up leaking coal ash storage sites. Remediation must be completed on time due to a hypothetical future potential for mineral extraction from a site. Further, as new uses of waste streams like coal ash are developed, new regulations must be implemented to protect workers and the community. Commercialization must not maximize profits at the expense of safety. The goal is to provide good jobs with living wages. It must also meet the standard to do no environmental harm. Spin-off benefits—like coal ash pond cleaning—should be prioritized as part of industrial development. Will the private market do this? Community voices will be essential as markets change and new industries emerge.

Glossary

Assets - "anything (tangible or intangible) that can be used to produce positive economic value" (https://en.wikipedia.org/wiki/Asset). In the context of this paper, assets are the products that could be leveraged to bring about positive change, like job creation, waste clean-up, and industrial restoration.

Beneficial uses - "Beneficial use is the recycling or reuse of coal ash instead of disposal. For example, coal ash is an important ingredient in manufacturing concrete and wallboard (also known as drywall). EPA supports the responsible use of coal ash in this manner." (See https://www.epa.gov/coalash/frequent-questions-about-beneficial-use-coal-ash#:~:text=Beneficialpercent20usepercent20ispercent20thepercent20recycling,coalpercent20ashpercent20inpercent20thispercent20manner.)

Brine - "Brine (or briny water) is water with a high-concentration solution of salt (typically sodium chloride or calcium chloride). In diverse contexts, brine may refer to the salt solutions ranging from about 3.5% (a typical concentration of seawater, on the lower end of that of solutions used for bringing foods) up to about 26% (a typical saturated solution, depending on temperature). Brine forms naturally due to evaporation of ground saline water but it is also generated in the mining of sodium chloride... It is also a by-product of many industrial processes, such as desalination, requiring wastewater treatment for proper disposal or further utilization (freshwater recovery)." (https://en.wikipedia.org/wiki/Brine)

Carbon emissions - "Carbon dioxide emissions or CO2 emissions are emissions stemming from the burning of fossil fuels and the manufacture of cement; they include carbon dioxide produced during consumption of solid, liquid, and gas fuels as well as gas flaring."

Carbon footprint - "A carbon footprint is the total amount of greenhouse gases (including carbon dioxide and methane) generated by our actions. The average carbon footprint for a person in the United States is 16 tons, one of the highest rates in the world. Globally, the average carbon footprint is closer to 4 tons." (https://www.nature.org/en-us/get-involved/how-to-help/carbon-footprint-calculator/#:~:text=Apercent20carbonpercent20footprintpercent20ispercent20the,ispercent20closerpercent20topercent204percent20tons.)

Clean-air Act of 1970 - "The enactment of the Clean Air Act of 1970 (1970 CAA) resulted in a major shift in the federal government's role in air pollution control. This legislation authorized the development of comprehensive federal and state regulations to limit emissions from stationary (industrial) and mobile sources." (https://www.epa.gov/clean-air-act-overview/evolution-clean-air-act#:~:text=Thepercent20enactmentpercent20ofpercent20thepercent20Clean,industrial)percent20sourcespercent20andpercent20mobilepercent20sources.)

Concrete and Cement - Concrete is a composite material composed of aggregate bonded together with a fluid cement that cures to a solid over time. A cement is a binder, a chemical substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is seldom used on its own but rather to bind sand and gravel (aggregate) together. Cement mixed with fine aggregate produces mortar for masonry, or with sand and gravel, produces concrete.

While everyday language often confuses concrete and cement, the two materials are distinct. Concrete is the final product we see in buildings, roads, and bridges. Cement is the key ingredient that holds it all together and is the primary source of greenhouse gas emissions from making concrete. The main source of emissions in cement comes from the clinker, an intermediary binding material in cement. Clinker is created using an emissions-intensive process that heats up limestone and other materials. In total, around 70% of carbon

dioxide emissions from making concrete results from the production of clinker. See, Ankita Gangotra, Kevin Kennedy and Willy Carlsen, "The US Needs to Lower Cement Emissions — 'Blended Cement' Can Help," World Resources Institute, May 9, 2024, at https://www.wri.org/insights/lower-carbon-blended-cement

Green concrete - "Green concrete is an environmentally friendly version of traditional concrete, made by incorporating recycled materials. Unlike standard concrete, which heavily relies on natural resources like limestone and clay, green concrete utilizes industrial waste such as fly ash, slag, and recycled aggregates. This approach reduces the consumption of natural resources and tackles the issue of waste management." (https://cove.tools/blog/bim-green-concrete-the-choice-for-modern-construction)

Life cycle carbon footprint - A total product carbon footprint measures the direct and indirect greenhouse gas (GHG) emissions associated with all product life cycle activities. (https://www.lifecycleinitiative.org/starting-life-cycle-thinking/life-cycle-approaches/carbon-footprint/#:~:text=Apercent20totalpercent20productpercent20carbonpercent20footprint,inpercent20thepercent20product'spercent20lifepercent20cycle.)

Coal ash -- also called coal combustion residual or coal combustion product - Coal combustion products are created as coal is burned in power plants. Also known generically as coal ash, it is one of the nation's most significant industrial waste streams, with 75 million tons produced in 2022. The EPA regulates and monitors over 700 active on-site coal ash ponds ("surface impoundments") and 310 landfills.

Coal ash pond - "An ash pond, also called a coal ash basin or surface impoundment,[1] is an engineered structure used at coal-fired power stations to dispose of two coal combustion products: bottom ash and fly ash. The pond is used as a landfill to prevent the release of ash into the atmosphere. Although using ash ponds in combination with air pollution controls (such as wet scrubbers) decreases the amount of airborne pollutants, the structures pose serious health risks to the surrounding environment.[2]
Ash ponds use gravity to settle large particulates (measured as total suspended solids) from power plant wastewater. This technology does not treat dissolved pollutants.[3] The ponds generally have not been built as lined landfills, and therefore chemicals in the ash can leach into groundwater and surface waters, accumulating in the biomass of the system." (https://en.wikipedia.org/wiki/Ash_pond)

Coal ash rule - The Clean Air Act of 1970 first started the regulation of coal ash emissions, but the storage of waste from coal-burning power plants was not regulated. After 1970, utilities began storing coal ash in landfills and coal ash ponds ("surface impoundments"). In 2015, additional regulations were imposed on those storage sites in the "Disposal of Coal Combustion Residuals from Electric Utilities Act" (sometimes referred to informally as the "2015 Coal Ash Rule") under the federal "Resource Conservation and Recovery Act." The Biden administration has implemented two Trump-era coal ash rules for the closure process for unlined coal ash ponds. EPA is conducting a unit-by-unit assessment of coal ash containment ponds, determining their closures, and whether to update the rules. In May 2024, EPA issued a pre-publication version of rules amending the CCR regulations to include legacy CCR surface impoundments." (https://eelp.law.harvard.edu/2023/08/coal-ash-rule/)

Coal-burning power plant - "A coal-fired power station is a fossil fuel power station. The coal is usually pulverized and then burned in a pulverized coal-fired boiler. The furnace heat converts boiler water to steam, which is then used to spin turbines that turn generators. Thus, chemical energy stored in coal is converted successively into thermal energy, mechanical energy, and, finally, electrical energy.

Coal-fired power stations emit over 10 billion tonnes of carbon dioxide each year,[7] about one-fifth of world greenhouse gas emissions, so they are the single largest cause of climate change." (https://en.wikipedia.org/wiki/Coal-fired_power_station)

Coal fly ash - "a very fine, powdery material composed mostly of silica made from the burning of finely ground coal in a boiler." (https://www.epa.gov/coalash/coal-ash-basics)

Community benefits - practices like targeted hiring for new jobs and local reinvestment to ensure that new development increases opportunities for the surrounding community. Community benefits can be secured through Community Benefit Agreements.

Competitive advantage - "Competitive advantage is the favorable position an organization seeks to be more profitable than its rivals. To gain and maintain a competitive advantage, an organization must demonstrate a greater comparative or differential value than its competitors and convey that information to its desired target market." (https://www.techtarget.com/searchcio/definition/competitive-advantage#:~:text=Competitivepercent20advantagepercent20ispercent20thepercent20favorable,topercent20itspercent20desiredpercent20targetpercent20market.)

Domestic supply - "The amount of a commodity, valued at producers' prices, available for domestic consumption or fixed investment. It is calculated as domestic production plus imports, fewer exports, and less change in inventories." (https://www.bea.gov/help/glossary/domestic-supply#:~:text=Thepercent20amountpercent20ofpercent20apercent20commodity,andpercent20lesspercent20changepercent20inpercent20inventories.)

Earthjustice - a nonprofit public-interest environmental law organization. (https://earthjustice.org/)

Eco-Industrial Park (EIP) - an industrial park that groups businesses together in a specific location to take advantage of collaboration and achieve efficiencies. The goal is to improve environmental and economic performance through the sharing of resources, services, and products, and by managing energy, water, and waste together. This process is known as industrial symbiosis.

Encapsulated - as used in this report, a term used to describe beneficial uses of coal ash in which the product has been mixed with concrete and hardened such that toxic elements do not escape into the air or water.

Energy communities - "Broadly speaking, an energy community is a community that has been historically sited near environmentally harmful industries like coal mining or oil extraction. It also refers to a community where a certain percentage of their tax base relies on fossil fuel industries. Critically, the IRA offers a specific legal definition of an energy community for the tax credit bonus, defining it as one of three different geographical categories." (https://www.evergreenaction.com/blog/energy-communities-can-benefit-from-ira#:~:text=What'spercent20anpercent20energypercent20communitypercent20and,coalpercent20miningpercent20orpercent20oilpercent20extraction.)

Fluidized Bed Combustion - A method of burning particulate fuel, such as coal, in which the air required for combustion far exceeds that found in conventional burners. The fuel particles are continually fed into a bed of mineral ash in the proportions of 1 part fuel to 200 parts ash while a flow of air passes up through the bed, causing it to act like a turbulent fluid. https://www.eia.gov/tools/glossary/index.php?id=Fluidized-bedpercent20combustion

Green building - "Green building (also known as green construction, sustainable building, or eco-friendly building) refers to both a structure and the application of processes that are environmentally responsible and resource-efficient throughout a building's life-cycle: from planning to design, construction, operation, maintenance, renovation, and demolition." (https://en.wikipedia.org/wiki/Green_building)

Green cement - "Green Cement uses a carbon-negative process of manufacturing or raw materials that reduce the carbon emissions of the final product. The major raw materials used to produce green cement include mostly discarded waste from the industry. The slag from the blast furnace and fly ash are the chief materials used in the manufacturing of green cement." (https://www.jklakshmicement.com/green-cement-the-future-of-sustainable-construction/#:~:text=Greenpercent20Cementpercent20ispercent20anpercent20eco,thepercent20manufacturingpercent20ofpercent20greenpercent20cement.)

Groundwater - "Groundwater is a part of the natural water cycle... Some of the precipitation that lands on the ground surface infiltrates the subsurface. The part that continues downward through the soil until it reaches saturated rock material is groundwater recharge. Water in the saturated groundwater system moves slowly and may eventually discharge into streams, lakes, and oceans." (https://www.usgs.gov/special-topics/water-science-school/science/groundwater-what-groundwater) Coal ash and acid mine drainage can pollute groundwater.

Gypsum - "Gypsum is a soft sulfate mineral composed of calcium sulfate dihydrate, with the chemical formula $CaSO_4 \cdot 2H_2O$.[4] It is widely mined and is used as a fertilizer and as the main constituent in many forms of plaster, drywall, and blackboard or sidewalk chalk."

Inflation Reduction Act - "The Inflation Reduction Act of 2022 (IRA) is a landmark[1][2] United States federal law which aims to curb inflation by possibly reducing the federal government budget deficit, lowering prescription drug prices, and investing into domestic energy production while promoting clean energy. It was passed by the 117th United States Congress and signed into law by President Joe Biden on August 16, 2022." (https://en.wikipedia.org/wiki/Inflation_Reduction_Act) This is one of the federal programs that specifically incentivizes the production of low-carbon concrete.

Landfill - some coal is stored on land in landfills instead of submerged in water in coal ash ponds.

Legacy coal ash - the ash located at coal plants that ceased operation before the 2015 Coal Ash Rule went into effect. Until recently, these coal plants were considered exempt from clean-up regulations and other requirements.

Location quotient - a measure of the concentration of employment in a sector within a region as compared to the concentration in the nation; a location quotient of greater than 1 indicates an industry concentration.

Mine tailings -- also called waste coal or gob piles - "Tailings are the left-over materials from the processing of mined ore. They consist of ground rock, unrecoverable and uneconomic metals, chemicals, organic matter, and effluent used to extract the desired products from the ore." (https://www.bhp.com/sustainability/tailings-storage-facilities/what-are-tailings-storage-facilities)

Ohio River Valley - The region surrounding the Ohio River encompasses parts of states such as Pennsylvania, West Virginia, Ohio, Kentucky, and Tennessee. This area overlaps with what is considered the Appalachian region. Coal mining has historically occurred in this area, and now this region has large quantities of coal ash.

Retaining wall - the walls surrounding coal ash ponds. If these walls break, the water can rush out and flood nearby lands and communities with hazardous waters.

Surface impoundment - another word for a coal ash pond that stores bottom ash and fly ash in water to decrease air contamination. This storage method presents pollution risks to groundwater, surface water, and the surrounding environment.

Supply chain - "A supply chain [...] is a complex logistics system that consists of facilities that convert raw materials into finished products and distribute them[2] to end consumers[3] or end customers.[4] Meanwhile, supply chain management deals with the flow of goods within the supply chain in the most efficient manner." https://en.wikipedia.org/wiki/Supply_chain

US EPA - "The Environmental Protection Agency (EPA) is an independent agency of the United States government tasked with environmental protection matters.[2] President Richard Nixon proposed the establishment of the EPA on July 9, 1970; it began operations on December 2, 1970, after Nixon signed an executive order.[3]" (https://en.wikipedia.org/wiki/United_States_Environmental_Protection_Agency)

Wallboard - also called drywall, it is a panel made of calcium sulfate dihydrate (gypsum), with or without additives, typically extruded between thick sheets of facer and backer paper, used in the construction of interior walls and ceilings.[2] The plaster is mixed with fiber (typically paper, glass wool, or a combination of these materials), plasticizer, foaming agent, and additives that can reduce mildew, flammability, and water absorption.

In the mid-20th century, drywall construction became prevalent in North America as a time- and labor-saving alternative to lath and plaster.[3]" (https://en.wikipedia.org/wiki/Drywall)

Flue gas desulfurization material makes synthetic gypsum for wallboard and other construction uses.

Wall panel - a "single piece of material, usually flat and cut into a rectangular shape, that serves as the visible and exposed covering for a wall. Wall panels are functional and decorative, providing insulation and soundproofing, with uniformity of appearance, along with some measure of durability or ease of replaceability." (https://en.wikipedia.org/wiki/Wall_panel)

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