Photo: Marcin Balcerzak

HAZARDOUS WASTE

EXECUTIVE SUMMARY

The nation's hazardous waste infrastructure is required to manage approximately 36 million tons generated each year. While concerns remain about long-term capacity and resilience, overall hazardous waste infrastructure has significantly improved in recent years due to major investments under the Infrastructure Investment and Jobs Act (IIJA). Those investments included $3.5 billion for the Superfund program and $1.5 billion for the Brownfields program, resulting in accelerated cleanup of contaminated properties, enhanced protection of public health and the environment, and economic benefits.

However, as individual per- and polyfluoroalkyl substances (PFAS) have recently been designated as hazardous substances under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), or Superfund program,[1] addressing PFAS contamination will put significant pressure on hazardous waste infrastructure, increasing future requirements for site investigations and remediation, treatment capacity, and the development of new treatment technologies.

BACKGROUND

Two primary laws govern hazardous waste management and disposal in the U.S.: the Resource Conservation and Recovery Act (RCRA) and the CERCLA, or Superfund program. RCRA regulates the management of hazardous waste as it is generated and governs the generation and proper transport, storage, treatment, and disposal of hazardous waste. RCRA also drives the cleanup of RCRA facilities if hazardous substances have been released into the environment. Meanwhile, CERCLA governs the cleanup of abandoned hazardous waste sites, holds responsible parties accountable, and gives the Environmental Protection Agency (EPA) the funds necessary to clean up contaminated sites where there is no viable responsible party. The EPA's Brownfields program was established under CERCLA and authorizes funds for the cleanup and redevelopment of industrial and commercial properties that are unused or underused due to environmental contamination.

Photo: EPA

CAPACITY AND CONDITION

The amount of hazardous materials both generated and managed has remained relatively stable over the past decade. EPA finds that 34.8 million tons of hazardous materials were generated in 2011, increasing to 35.9 million tons in 2021.[2] In 2011, 1,395 regulated hazardous waste management facilities handled 38.5 million tons of hazardous waste, compared to just 882 facilities managing 37.6 million tons of hazardous waste in 2021. Of those 37.6 million tons of managed hazardous waste, 1.6 million tons were recovered or recycled.[3]

Moving forward, infrastructure will be increasingly stressed through deadlines for closure of out-of-compliance coal combustion residual surface impoundments, as well as further accumulation of disaster debris from wildfires, floods, and other extreme weather events.[6]

In 2019, EPA's National Capacity Assessment Report[4] indicated adequate capacity nationwide for treating and disposing of hazardous waste through the year 2044. However, the report predates the designation of several PFAS compounds as hazardous substances, a development that will increase the need for site investigations and remediation, treatment capacity, and creation of new treatment technologies. In addition, the lowering of health-based risk screening levels for lead in soil from 400 parts per million (ppm) to 200 ppm (and to 100 ppm in communities where there are multiple potential sources of lead contamination) will increase demands on cleaning up and managing sites with lead contamination. Therefore, the impacts of PFAS and more stringent cleanup of lead contamination is expected to increase the number of sites requiring cleanup, generate additional quantities of contaminated materials requiring management, and trigger further investigation and remediation work at sites where the environmental work had been considered completed.

However, EPA's economic evaluation of new PFAS rulings concluded that the impacts will not be significant primarily because PFAS contamination will generally be associated with other hazardous wastes that already require management. Industry-based assessments are ongoing, and the full impact of the recent rulings are not clear at this time.[5]

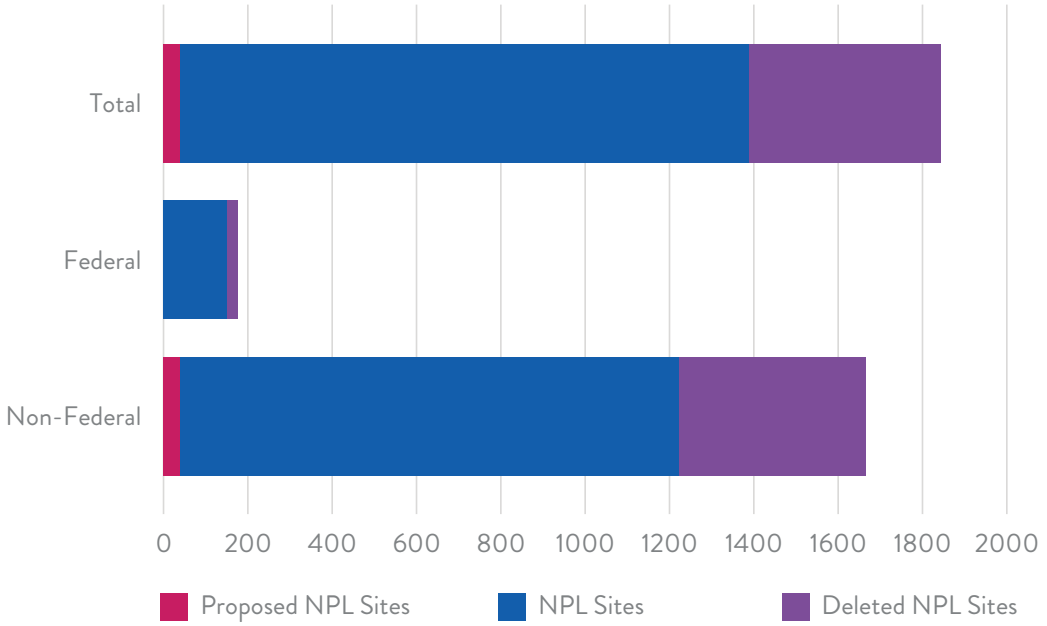
Moving forward, infrastructure will be increasingly stressed through deadlines for closure of out-of-compliance coal combustion residual surface impoundments, as well as further accumulation of disaster debris from wildfires, floods, and other extreme weather events.[6] Greater use of in-situ treatment and of remediation approaches that optimize natural systems may partially offset the regulatory and climate-related trends increasing hazardous waste generation, but it will be several years before we understand how these competing trends will "balance out."

Finally, management of hazardous materials from depleted electric vehicle lithium-ion batteries and solar panels will be required, creating the need for effective reconditioning of these items. For example, reusing retired lithium-ion batteries in energy storage systems has the potential to reduce disposal costs and help stabilize and strengthen the nation's energy grid.[7,8]

Superfund

The EPA's Superfund program has led to more responsible management practices and a significant reduction in careless disposal of hazardous materials since its passage in 1980. Superfund sites are included on EPA's National Priorities List (NPL). The NPL is routinely updated as sites are cleaned up and removed from the list, and other sites are discovered, evaluated, and added. As of September 2024, there were 1,183 non-federal Superfund sites and 157 federal sites, totaling 1,340 NPL sites and an additional 42 sites proposed for the NPL. Since the program was first created, 458 Superfund sites have been cleaned up and removed from the NPL.[9] At the end of 2023, 692 current and former Superfund sites were in reuse, supporting 10,261 businesses, employing more than 237,000 people, and generating more than $18.8 billion in employment income.[10]

Status of the National Priorities List (as of December 2024)



Source: US EPA, National Capacity Assessment Report under CERCLA Section 104(c)(9), December, 2019

Abandoned mine sites, which make up about 10% of the NPL, represent some of the most extensive and costly cleanups, with the top 25 most expensive cleanups estimated at $50 to $583 million.[11] In addition, there are over 22,000 known mines and mine features.[12] ("Mine features" include historic mining infrastructure, old adits and quarries, and piles of rock and mineral that were left behind after mining operations ceased.) The IIJA includes $11.3 billion in funding for reclaiming abandoned mine lands, treating acid mine drainage, and restoring water supplies damaged by mining.

Brownfields

Brownfield sites are properties that were previously developed for industrial or commercial use, where those past uses have resulted in contamination from hazardous substances. There are an estimated 450,000 brownfield sites across the country, which differ from Superfund sites in the degree and nature of the contamination and ability to redevelop the property. Brownfields redevelopment has resulted in significant economic and environmental benefits, with an estimated economic benefit ratio of 21:1 for every federal dollar spent.[13]

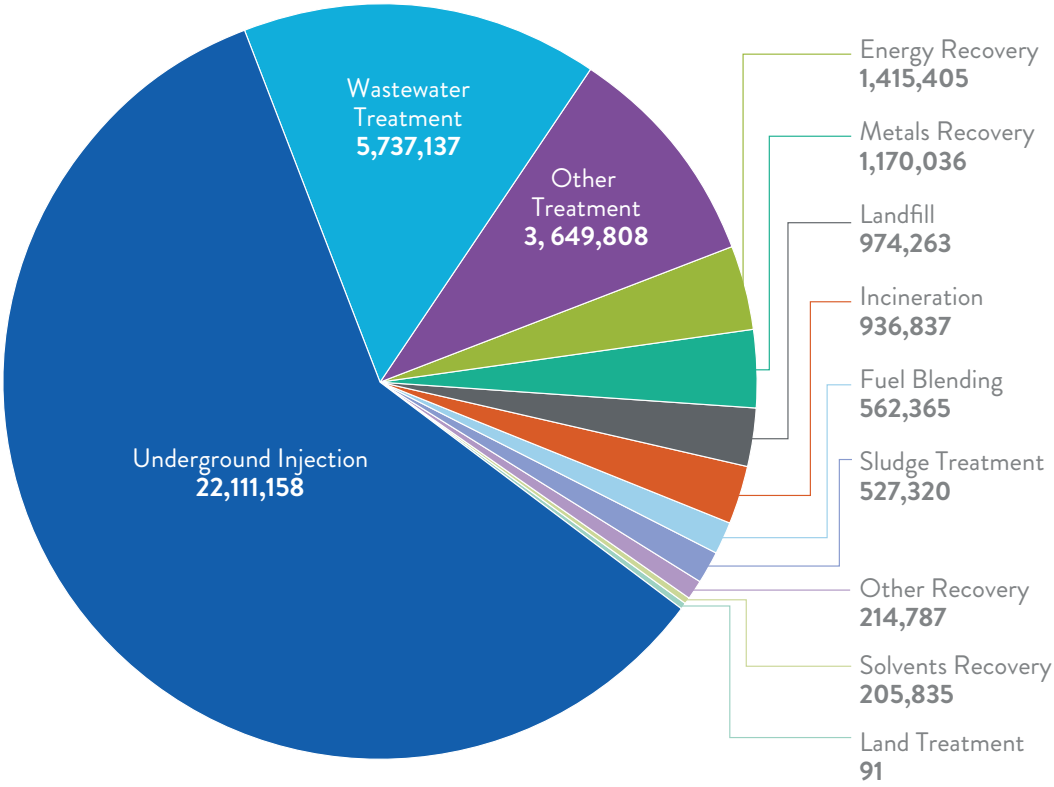
Since 2006, approximately 220,000 brownfield sites have been cleaned up, facilitating the creation of more than 270,000 jobs, with 3.7 million acres ready for reuse.[14] The supplemental investment in the Brownfields program through the IIJA expanded the number of projects and funds over 350 programs supporting the planning, construction, and operation of various public infrastructure projects.

Resource Conservation and Recovery Act

RCRA supports permitting, inspection and enforcement, program management, and corrective action to prevent pollution and facilitate cleanup of environmental problems caused by waste mismanagement. The RCRA hazardous waste program is administered almost entirely by the states (except for Alaska and Iowa) and is supported through federal grants.

Currently, 19,235 facilities are large quantity generators (LQGs) of hazardous waste. (LQGs generate 1,000 kg [2,200 lbs] or more of nonacute hazardous waste or more than 1 kg [2.2 lbs] of acutely hazardous waste per calendar month.) In 2021, those LQGs generated 35.9 million tons of hazardous waste, including eight facilities that each generated over 1 million tons of hazardous waste.[15]

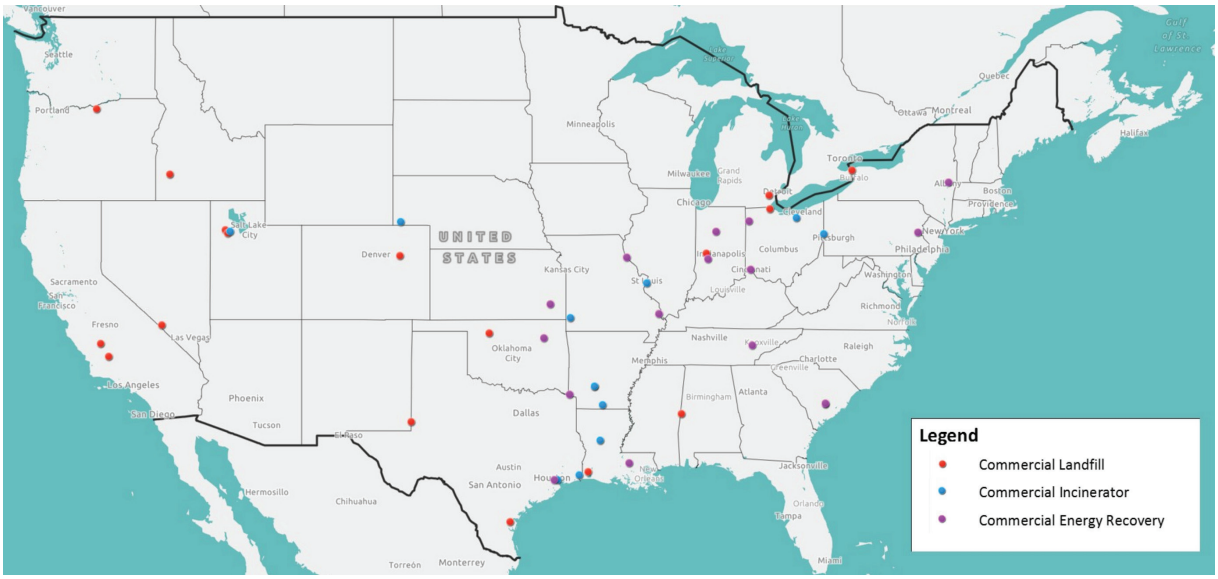
Hazardous Waste Management Methods/Tons Managed



Source: U.S. Environmental Protection Agency

Waste generation is concentrated in certain "hot spots" across the country. About 80% of all generated hazardous waste is produced by three industry sectors: chemical manufacturing, petroleum and coal products manufacturing, and waste treatment and disposal facilities. More than half the nation's hazardous waste is generated in the state of Texas.

Commercial Hazardous Waste Energy Recovery, Incineration, and Landfill Facilities



Source: U.S. Department of Energy

Our nation's ability to effectively manage its hazardous and solid waste in the future is impacted by the weakness of our recycling system under RCRA.[16] Of the 37.5 million tons of hazardous waste generated each year, only 1.6 million tons were recovered or recycled in 2021[17]; comparatively, the EPA estimates that about 32% of non-hazardous waste generated in the U.S. is currently recycled or composted.[18]

Currently, 3,924 facilities have been identified as releasing hazardous waste or hazardous constituents from a RCRA-regulated facility or have applied for treatment, storage, and disposal facility RCRA permit.

Department of Energy Environmental Management Program

The Department of Energy's Environmental Management (DOE EM) program is charged with cleaning up 107 hazardous waste sites nationwide, including some of the world's most dangerous radioactive sites that once supported defense production programs and government-sponsored nuclear energy research. Since 1989, the DOE has completed its cleanup mission at 92 of the 107 primary nuclear weapons and nuclear research sites.

US Department of Energy Active Cleanup Sites

Source: U.S. Department of Energy Office of Environmental Management

FUNDING AND FUTURE NEED

Before the passage of the IIJA, the Superfund budget had been flat for a decade at around $1.1 billion annually. Insufficient funding for the program led to a growing backlog of sites not being cleaned up. The $3.5 billion invested in Superfund through the IIJA was used to clear the backlog of 49 sites where cleanup had been on hold while also accelerating work on new Superfund sites.

In the future, the Superfund program will rely primarily on Superfund excise taxes for its funding. However, Superfund excise taxes expired more than 25 years ago. Since the taxes expired, the program has been funded through general revenues and settlement agreements with parties responsible for the pollution. The 2022 Inflation Reduction Act (IRA) reinstated a Petroleum and Oil Superfund Tax, and the IIJA reinstated the Chemicals Superfund Tax and the Hazardous Substances Tax, the latter sunsetting in 2031. Combined with contributions from general revenues, this represents a substantial increase over pre-IIJA funding levels. EPA projects that these excise taxes will bring in $2.17 billion in tax receipts to fund the cleanup program in Fiscal Year 2025 alone.19 However, there may be "start-up" issues with the initial implementation of the new taxes as revenue thus far trail projections. In FY 2024, the chemical tax collected

$472 million on a $1.7 billion estimate, and the petroleum tax generated $732 million, below the projected $858 million.20 If Superfund tax receipts continue to fall short of projections, additional general revenue or tax regime updates will be needed to sustain the program's effectiveness.

The Brownfields program also benefited from the IIJA, with supplemental funding of $1.5 billion. Prior to the IIJA, Brownfields grant funding to the states remained stagnant at just under $50 million annually for two decades. Over that period, the number of grant applicants more than doubled, resulting in more grants but smaller in size. With more sites, the states' resources were overstretched, and their ability to deliver robust brownfield development programs was compromised. With IIJA funding, the amount granted to states increased to $110 million per year, with that level of financing sustained over FY22–26. Due to this increase, states have added program capacity leading to significantly more economic, social, and environmental benefits for their residents. EPA estimates that $20 is leveraged for each $1 awarded through brownfields assessment, cleanup, and planning grants.[19] Given the return on brownfield investments,[20] the level of funding achieved through the IIJA should be sustained beyond FY26.

The RCRA program is managed by the states but is mainly funded through federal grants, with a 25% state-matching requirement. Unlike the Superfund and Brownfields programs, the RCRA program did not receive supplemental funding through the IIJA. A 2023 study by the Association of State and Territorial Solid Waste Management Officials (ASTSWMO) estimated the total national cost of the RCRA Subtitle C program for FY22 at $194 million.[21] The federal grant allocation for FY22 was $98.2 million, which has been stagnant since 1995, meaning that the program funding has been effectively cut in half due to inflation. Therefore, states have been forced to cover the funding shortfall, which totaled $63 million in FY22 alone, by "overmatching" at 48% of federal grant funding. That has strained the state RCRA management programs in processing permits, inspections, enforcement, responding to new rulemakings, and providing technical assistance, hiring, and training.[22]

For the remaining 15 active cleanup sites under the DOE EM program, the estimated life-cycle cost of cleanup is over $525 billion, with a cleanup completion date projected around 2080. A total of 11 sites have ongoing cleanup operations with a life-cycle cost of at least $1 billion each, with the Hanford Site in Richland, WA, representing the most expensive estimated cleanup at $312 billion.[23] Annual funding for the DOE EM cleanup program has been consistently around $7.4 billion, below the estimated needs.

OPERATION AND MAINTENANCE

EPA indicates that there is adequate capacity nationwide for the treatment and disposal of hazardous waste through the year 2044[24]; however, the estimate does not take into account several factors:

- The incineration of hazardous waste has trended upward for the past two decades,[25] with 937,000 tons of hazardous waste incinerated in 2021,[26] but commercially available incinerator capacity has decreased.
- Several large privately owned incinerators have recently closed, and that waste is now being sent to commercial incinerators.

In 2021, the American Trucking Association estimated a record shortage of over 80,000 qualified drivers. The shortage was most acute for the waste transport industry, where specialized permits, handling, equipment and training are required.[27]

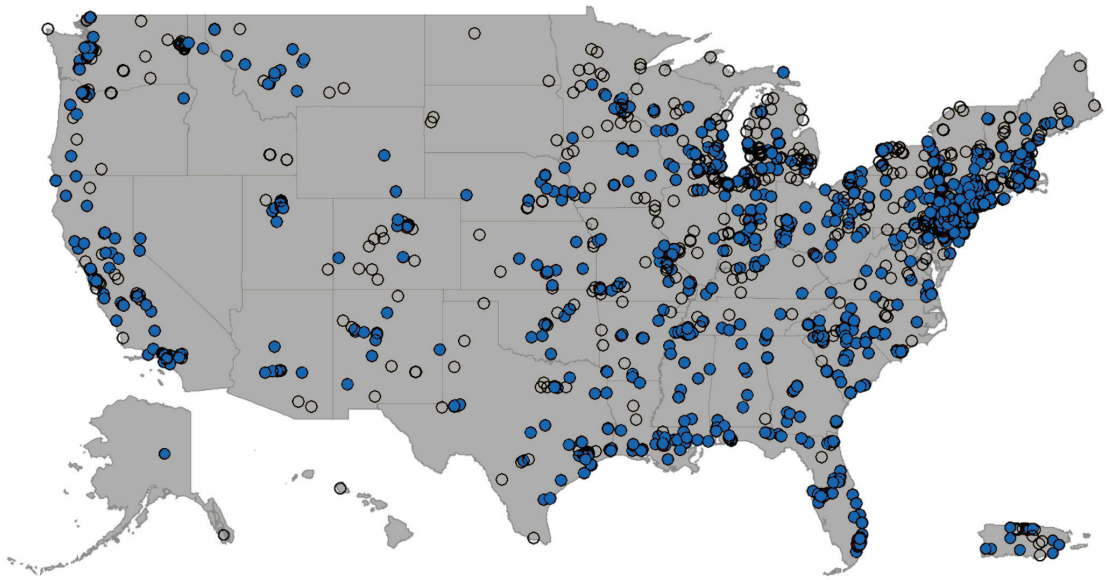
As a result of these factors, a large number of LQGs are exceeding RCRA compliance requirements for how long hazardous waste is permitted to be stored on-site.[28] In response, EPA took the unusual step in 2021 of issuing regulatory exemptions to address these capacity-related compliance issues.[29]

PUBLIC SAFETY AND RESILIENCE

The resilience of the nation's hazardous waste infrastructure is a growing concern. The core purpose of the nation's hazardous waste infrastructure is public safety—preventing the release of and exposure to dangerous and toxic substances. While the existing infrastructure is generally fit for that purpose, the resilience of the infrastructure is less certain. Since certain PFAS compounds have been designated as hazardous substances under CERCLA, addressing this type of public and environmental safety concern will put significant pressure on hazardous waste infrastructure with implications on future requirements for site investigations and remediation, treatment capacity, and the development of new treatment technologies.[30]

Currently, 945 (about 60%) of all non-federal NPL sites are in areas that may be affected by flooding, storm surge, wildfires, or sea level rise related to climate change effects.[31] However, EPA recently issued a directive incorporating climate resilience as a core factor in selecting and designing a Superfund cleanup.

Superfund Sites Potentially Impacted by Extreme Weather



Source: SUPERFUND: EPA Should Take Additional Actions to Manage Risks from Climate Change Effects, US General Accountability Office, GAO-21-555T, May 2021

INNOVATION

Remediation technologies continue to improve, and more effective site characterization and cleanup strategies are used to emphasize adaptive management and optimization of treatment systems. For example, EPA's 2023 Superfund Remedy Report indicates a shift toward greater reliance on in situ and natural systems-based remediation approaches. In situ source treatment increased from 20% to 34%, and monitored natural attenuation (MNA) for groundwater increased from 20% to 31% compared to the previous three years (2015–2017).[32] Meanwhile, EPA's PFAS Strategic Road Map[33] identifies research as a central focus of EPA's strategy, enabling greater collaboration between industry, government, and academia in developing new treatment technologies to address PFAS contamination, resulting in more rapid implementation of promising treatment innovations.

RECOMMENDATIONS TO RAISE THE GRADE

- Maintain current funding levels for the Superfund and Brownfields programs.
- Monitor and maintain the Superfund chemical tax and petroleum tax to ensure the program is adequately funded for the long term.
- Direct robust funding to the state RCRA programs to ensure resources are available to protect the public and environment through permitting, inspections, and corrective action.
- Expand hazardous waste incinerator capacity to meet growing demands.
- Invest in building capacity and resources for hazardous waste transportation.
- Accelerate and increase investment in PFAS research aimed at characterization, treatment, and analysis, and apply that research to inform a protective and scientifically sound regulatory framework for managing PFAS in the environment.
- Strengthen the nation's existing recycling system through investments and innovations in consumer education, collection systems, sorting technologies, and biochemical degradation of plastics and other areas to move forward in the direction where products reaching the end of their use are recycled and productively reused.
- Develop more reliable hazardous remediation cost estimating tools so the nation can effectively plan and budget for future hazardous waste management and infrastructure costs.
- Resolve long-standing technology and implementation problems for long-term stabilization of high-level radioactive wastes.
- Establish a geologic repository for permanent storage of radioactive waste.

SOURCES

1. U.S. EPA, "Designation of PFOA and PFOS as hazardous substances under CERCLA Release Reporting Requirements Factsheet," 2024.
2. U.S. EPA, RCRA Info Web, "Biennial Report Summary: Hazardous Waste Report Data," 2021.
3. Ibid.
4. U.S. EPA, "National Capacity Assessment Report: Pursuant to CERCLA Section 104(c)(9)," 2019.
5. Regulations.gov, "Economic Assessment of the Potential Costs, Benefits, and other Impacts of the Proposed Rulemaking to List Specific PFAS as RCRA Hazardous Constituents," 2024.
6. Federal Register, "Hazardous and Solid Waste Management System: Disposal of Coal Combustion Residuals From Electric Utilities; Legacy CCR Surface Impoundments," 2023.
7. Fan, T., W. Liang, W. Guo, T. Feng, and W. Li, "Life Cycle Assessment of Electric Vehicles' Lithium-Ion Batteries Reused for Energy Storage," *Journal of Energy Storage* 71 (November 2023): 108126.
8. The Grist, "Where Could Millions of EV Batteries Retire? Solar Farms," 2023.

SOURCES (cont.)

9. U.S. EPA, "National Priorities List (NPL) Sites," 2024.
10. U.S. EPA, "Redevelopment Economics at Superfund Sites," 2024.
11. U.S. Government Accountability Office, "Abandoned Hardrock Mines: Information on Number of Mines, Expenditures, and Factors that Limit Efforts to Address Hazards," 2020.
12. Ibid.
13. U.S. EPA, "Environmental Benefits of Brownfields Redevelopment: A Nationwide Assessment," 2020.
14. U.S. EPA, "Brownfields Accomplishments and Benefits Report: Leveraging Resources to Revitalize Communities," 2020.
15. U.S. EPA, RCRA Info Web, "Biennial Report Summary: Hazardous Waste Report Data," 2021.
16. California Management Review, "America's Broken Recycling System," 2023.
17. Ibid.
18. U.S. EPA, "National Overview: Facts and Figures on Materials, Wastes, and Recycling," 2024.
19. U.S. EPA, "FY 2025 Budget," 2024.
20. E&E News, "Superfund Tax Shortfall: Trouble for Cleanups, EPA Budget," April 15, 2024.
21. U.S. EPA, "Brownfields Program Environmental and Economic Benefits," 2021.
22. U.S. EPA, "Environmental Benefits of Brownfields Redevelopment: A Nationwide Assessment," 2020.
23. ASTSWMO, "2023 Hazardous Waste Management Program Implementation Costs Report," 2023.
24. Ibid.
25. U.S. Government Accountability Office, "Environmental Cleanup: Status of Major DOE Projects and Operations," 2022.
26. U.S. EPA, "National Capacity Assessment Report: Pursuant to CERCLA Section 104(c)(9)," 2019.
27. Association of State and Territorial Solid Waste Management, "HW & MM Capacity," 2022.
28. U.S. EPA, RCRA Info Web, 2024.
29. WTS, "Driver Shortages and the Impact on Waste and By-Product Transportation," 2022.
30. Ibid.
31. U.S. EPA, "Regulatory Options for Addressing the Temporary Backlog of Containerized Hazardous Waste Needing Incineration," 2021.
32. U.S. EPA, "Proposal to List Nine Per- and Polyfluoroalkyl Compounds as Resource Conservation and Recovery Act Hazardous Constituents," 2024.
33. U.S. Government Accountability Office, "Superfund: EPA Should Take Additional Actions to Manage Risks from Climate Change," 2019.
34. U.S. EPA, Office of Land and Emergency Management, "Superfund Remedy Report, 17th Edition," 2023.
35. U.S. EPA, "EPA's PFAS Strategic Roadmap: Second Annual Progress Report," 2023.