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# Green Remediation Best Management Practices: Waste Cover Systems and Integrated Site Reuse Planning

*A fact sheet about the concepts and tools for using best management practices to reduce the environmental footprint of activities associated with assessing and remediating contaminated sites*

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The U.S. Environmental Protection Agency (EPA) *Principles for Greener Cleanups* outline the Agency's policy for evaluating and minimizing the environmental footprint of activities involved in cleaning up contaminated sites.[1] Best management practices (BMPs) of green remediation involve specific activities to address the core elements of greener cleanups:


- Reduce total energy use and increase the percentage of energy from renewable resources.
- Reduce air pollutants and greenhouse gas (GHG) emissions.
- Reduce water use and preserve water quality.
- Conserve material resources and reduce waste.
- Protect land and ecosystem services.

BMPs focused on the core elements involving use of renewable energy, green infrastructure or carbon sequestering vegetation during site cleanup and restoration also may help mitigate and adapt to ongoing climate change.

## Overview

Remediation at thousands of sites across the United States involves addressing hazardous waste from former industrial landfills, aged municipal landfills, illegal dumps or waste piles. A final cover system is commonly installed in these areas as part of proper closure to serve as a surface barrier that contains the source material, reduces contaminant exposure pathways or migration, and manages associated risk. A cover (cap) is typically used where:

- A hazardous, municipal or co-disposal landfill is being reclaimed under the Resource Conservation and Recovery Act (RCRA).
- An existing unit such as a closed impoundment has been designated as a consolidation area or a decision is made to build a new onsite landfill.
- Direct contact with the waste or its leaching to groundwater poses a risk.

Landfills built to contain hazardous wastes are governed by Subtitle C of RCRA while those constructed for non-hazardous waste such as municipal solid waste (MSW) and industrial waste are covered by RCRA Subtitle D.[2] In addition to RCRA requirements, closure and capping of a landfill or former waste area may be subject to requirements of the Clean Air Act, Clean Water Act and other federal, state or local regulations. In programs such as Superfund, these regulations may be considered applicable or relevant and appropriate requirements (ARARs).

For closed landfills and other areas where waste is consolidated or otherwise left in place, conventional RCRA cover systems consist of multiple layers of impermeable materials serving as biobarriers. Controls for a conventional cover system are typically built into the system to manage contaminated liquids percolating through the disposal area (leachate) and to monitor local groundwater. Covered landfills also require controls to manage landfill gas (LFG) containing methane, carbon dioxide ($CO_2$) and other organic compounds that are natural byproducts of organic material decomposition. Post-closure care of a covered waste disposal unit is commonly required for 30 years; however, covers for certain types of waste may be required for much longer periods.

An ET cover was constructed on more than 500 acres where mining-related waste rock remains in place at the Ballard Mine Superfund site near Soda Springs, Idaho. The cover system was designed to slow the flow of stormwater runoff and limit soil erosion. Its vegetation layer enables significant sequestration of atmospheric carbon.

Alternatives to the conventional cover design may be used if they show equivalent performance in infiltration reduction and erosion resistance. One alternative design involves covers composed of asphalt or concrete. Another involves evapotranspiration (ET) covers, which rely on a thick upper layer of soil with vegetation capable of storing water until it is transpired or evaporated.

Green remediation BMPs can help meet sustainability and in some cases climate resilience goals associated with site cleanup projects. When properly designed and maintained, a final cover system could provide opportunities to reuse a site for purposes such as renewable energy production and greenspace preservation. Such land use may greatly benefit communities experiencing the negative impacts of environmental contamination from local sources such as aged landfills and illegal dumps.[3]

## Cover System Design and Construction

Broad BMPs for designing a conventional cover system include:

- Plan to mimic rather than alter the site's natural landforms and topography wherever feasible, to preserve natural drainageways and to minimize grading that disturbs land and ecosystem services such as potable water, wildlife habitat and carbon storage.
- Integrate green infrastructure such as infiltration basins and grassed swales that filter and absorb stormwater where it lands, to bolster the site's capacity to manage stormwater.[4]
- Identify onsite sources of uncontaminated soil or sediment required for the cover's erosion control and frost prevention layers, to avoid shipping needs and associated fuel use and vehicle emissions. Similarly, uncontaminated sand, gravel and rocks from onsite instead of offsite areas can be used for drainage systems.
- Integrate onsite solar and wind resources to power the cover system's maintenance equipment such as leachate pumps and LFG flaring units.
- Account for potential effects of future climate scenarios, which could include altered site conditions such as increasing soil desiccation, water salinity, water table elevation, vulnerability to flooding, and wildlife risk.[5]

Fuel consumption by nonroad vehicles and associated emission of air contaminants typically account for a major portion of the environmental footprint of constructing a waste cover system.

Green remediation BMPs applying to site preparation include:

- Maximize use of available satellite imagery to define boundaries of waste units and operate field machinery with high "surgical" precision.
- Retrieve native, noninvasive plants existing within the waste unit boundaries and staging areas for later replanting.
- Rescue and relocate wildlife that rely on habitat within the waste unit and staging areas. Many environmental, academic or community groups offer help in conducting wildlife rescues and compiling wildlife or plant inventories.
- Substitute temporary silt fences with biodegradable erosion controls such as straw wattles and compost socks. Such devices capture sediment transported by stormwater runoff from or to adjoining slopes while building substrates for future vegetation.[6]
- Lay synthetic barriers and fluid collection systems on ground surfaces of staging areas to avoid introducing toxic materials to underlying groundwater.

BMPs applying to field activities include:

- Deploy bulldozers, graders and other nonroad vehicles or mobile equipment that meet Tier 4 emission standards.[7] This can be achieved by using newer vehicles or engines meeting the most recent emission control standards, using newer emission control components to rebuild engines, or retrofitting diesel engines with exhaust aftertreatment devices.[8]
- Implement an engine idle reduction plan to avoid fuel consumption when vehicles are not actively engaged. Options include manual shutdown after a specified time such as five minutes, engagement of automatic shutdown devices, or use of auxiliary power units to heat or cool vehicle cabs.
- Limit the speed of trucks and other onroad vehicles traversing the site to 10 miles per hour to minimize dust generation and prevent mobilization of airborne contaminants.
- Use graywater that may be available from onsite or nearby sources for purposes such as washing or steam-cleaning field vehicles or irrigating plants temporarily held outside the work zones.
- Use biobased rather than petroleum-based lubricants to operate construction vehicles. Selection of suitable biobased products may consider variables such as biomaterial sourcing, percentages of petroleum-based ingredients, and shelf life.[9]

Remediation at the 34-acre Raymark Industries, Inc. site in Stratford, Connecticut, has included constructing several waste caps above consolidated waste or waste left in place. Capping work at this National Priorities List (NPL) site currently focuses on a 14-acre area formerly used for disposal of industrial wastes. Contaminated sediment and waste excavated from other onsite locations is being consolidated at the area, and a low-permeability cap will be constructed above the consolidated material. The cap is designed to support redevelopment of the site for commercial, industrial, municipal or recreational uses.

Tier 4 emission-compliant vehicles and equipment pieces are deployed for waste excavation and capping preparation. During a representative month, the machinery included:

- Five excavators.
- Two compaction rollers.
- Two skid steers.
- One mini articulating dumper.
- Two mobile air compressors.
- Two water trucks.
- One portable generator.
- Four diesel pumps.

Green remediation BMPs applicable to cover system components and installation techniques include:

- Choose geotextile fabric and tubing composed of a high percentage of recycled materials rather than virgin materials for lining, erosion control and drainage.
- Use consumer/industrial waste such as recycled tires or ground granulated blast-furnace slag as a partial substitute for virgin materials in the construction mix required for asphalt, cement or concrete layers in a cover system.
- Choose uncontaminated crushed concrete instead of natural rock for the biobarriers or capillary breaks required in an ET cover.
- Select native drought-resistant plants for the upper vegetative layer to reduce maintenance such as irrigation.
- Preserve biodiversity by using a mix of native grasses, shrubs, and forbs in the vegetative layer.
- Install perimeter tree canopy that provides ecosystem services such as cooling, shading and enhanced stormwater control.

## Integration of Site Reuse Plans

Cleanup planning and implementation can incorporate plans for future reuse of the site or selected parcels where remedial actions have been completed. Upfront integrated planning can provide economies of scale and avoid later retrofitting of remedial components if site conditions or administrative goals change over time. EPA encourages owners or operators of sites requiring waste cover installation to work closely with states and other agencies or organizations responsible for current or future oversight of the system and any site reuse. Project partners often include nonprofit groups or specialized companies.

Communities located near sites with covered waste units increasingly choose reuse options focused on increasing the site's sustainability and resilience, such as:

- Developing waste gas-to-energy systems.
- Producing electricity from onsite solar or wind resources.
- Establishing greenspace.[10]

Conventional LFG management strategies involve its destruction by way of combustion (flaring) or release to the atmosphere, depending on its content. For example, LFG from a recently closed MSW landfill with a properly operated gas collection system likely contains 40-60% methane as well as $CO_2$. Both are GHGs that significantly contribute to climate change. As the landfill ages, its methane generation decreases at a rate depending on the volume and type of organic waste content and site conditions such as average rainfall. In contrast, an industrial landfill or a construction and debris landfill typically emits little LFG throughout its life. Additional characteristics to consider when evaluating feasibility of waste gas-to-energy development include depth of the waste and impermeability of the cap and liner.

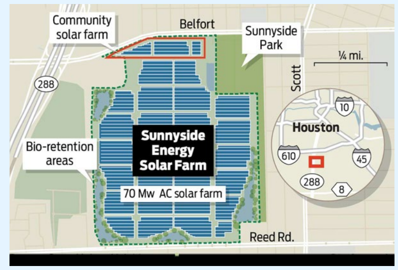
Cover system design and construction techniques can enhance current or future beneficial use of recovered LFG through BMPs such as:

- Route the LFG to power another long-term remedial operation, such as a groundwater treatment system requiring a source of heat. LFG with a relatively low BTU value may provide about 50 percent of the heating value of natural gas.
- Route the LFG to internal combustion engines, turbines or microturbines that generate electricity for various applications. Internal combustion engines are typically the choice for LFG projects sized at 800 kilowatts (kW) and larger, while microturbines are used for smaller projects (as little as 30 kW). For example, one 30 kW microturbine can typically power one 40-hp motor. Unlike most internal combustion engines, microturbines can operate with low LFG flow or methane content.
- Divert the LFG to power non-remedial activities occurring onsite or offsite. For example, medium BTU gas could be piped to an onsite or nearby commercial facility to operate an industrial boiler.
- Use the LFG to generate combined heat and power (CHP), which can provide heat for buildings, water usage or industrial processes while producing steam to power electric generators.

Alternatively, the LFG could be processed onsite to produce high-BTU gas that can be used to fuel vehicles or injected into a gas pipeline.[11] EPA's Landfill Methane Outreach Program provides tools for exploring the recovery and beneficial use of biogas generated from organic municipal solid waste.[12]

The 154-acre Central Landfill site is located within the Central Landfill, an active municipal solid waste disposal facility in Johnston, Rhode Island. This NPL site encompasses an area formerly used to dispose of hazardous industrial wastes. Site cleanup has involved constructing a multi-layer cap and hydraulically containing and treating underlying groundwater. A gas-to-energy plant has operated at the landfill since 2013, with a current capacity of about 33 MW. The capped area, a portion of which is now buried by newer waste, has contributed up to 12 percent of the total LFG collected at the landfill.

When properly designed, waste covers can provide significant opportunities to host economic enterprises such as power production from solar and wind resources. EPA, other government agencies and developers continue to investigate the potential for reusing formerly contaminated lands and mining properties on a large-scale basis. EPA's RE-Powering America's Land initiative has tracked this potential at sites across the United States.[13] The initiative's online tools include state and national maps of renewable energy resources and feasibility studies conducted by the U.S. Department of Energy (DOE) National Renewable Energy Laboratory. Additionally, DOE technical assistance may be available to state, local and tribal governments interested in pursuing clean energy demonstrations or development projects on mine land.[14]




Sites that hosted landfills in the past but remain underutilized can significantly benefit from renewable energy development projects. The Sunnyside Solar Farm project in Houston, Texas, involves converting a 240-acre former landfill into a utility-scale solar farm. A community solar array also was incorporated into the project to help lower electricity costs for low-income residents in the neighborhood. The project design included bioretention areas that store and filter stormwater and help reduce local flooding.
[image credit: Houston Chronicle]

Utility-scale renewable energy production (typically rated above 1 megawatt (MW)) is often administered through a third-party power purchase agreement among the site owner, an independent developer and a utility. As with other site redevelopment efforts, the site owner may issue a request for proposals as a means to receive competitive bids on a renewable energy project meeting specific criteria. The site owner also may collaborate with partners such as local government agencies or nonprofit organizations wishing to build or expand community solar or wind projects.[15]

Integrating the designs for a cover system and a renewable energy project will help increase efficiency of each effort and conserve the natural resources directly or indirectly used for construction and later maintenance. BMPs may include:

- ♦ Account for the weight of anticipated ground-mounted photovoltaic (PV) modules, wind turbines and associated infrastructure, which could alter specifications regarding thickness of the final cover or estimates of the future settlement of waste.
- ♦ Configure underground components of the cover system, such as leachate collection or gas monitoring piping and electrical conduits, in manners that readily enable testing or potential repair of pieces in proximity to ground mountings.
- ♦ Account for maintenance activities required for the renewable energy systems, such as periodic inspections or intermittent snow removal.
- ♦ Specify low-maintenance substrates to be used in the top layer of the final cover, to minimize activities such as mowing around ground mountings.
- ♦ Account for potential effects on stormwater management due to surface grading and introduction of impervious concrete ballasts and pads.
- ♦ Provide for grid interconnection that allows temporary disconnection from the grid and direct use of the energy output during emergencies such as grid outages.
- ♦ Include infrastructure for onsite storage of electricity that may be routinely or intermittently accessed for onsite use or routed to a local microgrid.

Waste covers also can provide significant opportunities to host greenspace that offers:

- Wildlife and habitat preservation and biodiversity.
- Recreational opportunities such as trails for hiking or centers for outdoor athletics.
- Environmental education or nature initiatives such as native seed harvesting.


Cleanup at the Hidden Lane Landfill NPL site in Sterling, Virginia, includes landfill cap repair; excavation and offsite disposal of contamination source material; and in situ bioremediation and chemical reduction of source material in bedrock. To inform site cleanup and redevelopment planning, a survey was taken during site investigations to gauge community interest in potential reuse of the property after remedy construction is complete. Options based on site suitability and local land use include passive recreation as well as light use such as solar energy development or nature conservation.

Collaborative consideration of anticipated greenspace during design and construction of a cover system helps avoid later reconstruction activities and associated natural or financial resource expenditures by the site owner or a designated sponsor. Relevant green remediation BMPs commonly include:

- ♦ Specify contiguous swaths of vegetated areas to be reestablished without structures such as service buildings that can present physical barriers to natural plant propagation, site drainage and wildlife passage.
- ♦ Use pervious rather than impervious materials to surface required access roads and walkways, which fosters natural infiltration of rain or snowmelt.
- ♦ Incorporate plant species that promote colonization of bees and other pollinators.
- ♦ Integrate cobble biota barriers to prevent burrowing animal damage to synthetic liners or low permeability layers.
- ♦ Seed or install native rather than non-native plant species, which typically increases the rate of plant survival and minimizes the need for soil or plant inputs.

## Cover System Maintenance and Monitoring

A final cover typically requires monitoring and maintenance of any liners, leachate collection and removal systems, leak detection systems, and gas collection systems to protect the surrounding environment and population from releases of hazardous constituents. Green remediation BMPs applicable to cover system maintenance and monitoring may include:

- Use remotely controlled or non-invasive techniques to avoid cover damage and minimize field visits. For example, open path spectroscopy can be used to periodically check for escaping LFG.
- Install onsite structures to capture rainfall as a source of water for work such as rinsing field equipment.
- Install small-scale solar panels to power auxiliary equipment such as weather stations.
- Minimize the frequency of grass mowing, to protect ground-nesting birds, avoid noise pollution, and reduce fuel consumption and associated air emissions.
- Conduct periodic prescribed burns, which help maintain a site's native vegetation, prevent growth of invasive plant species, and reduce fuel for potential wildfires.
- Use controlled animal grazing to eliminate woody growth and control vegetation height while adding organic matter to the soil.
- Substitute chemical fertilizers, herbicides or pesticides with non-synthetic soil and plant inputs such as compost.
- Use integrated pest management methods such as removing overgrown vegetation and standing water.[16]

Six ET covers across 450 acres and two landfill covers across 84 acres were constructed at the Rocky Mountain Arsenal in Commerce City, Colorado. Maintenance of the covers and surrounding prairie grasslands of the Rocky Mountain Arsenal National Wildlife Refuge includes periodic prescribed burns. About 100 acres of the site were deeded to Commerce City for use as a stormwater retention area and open space. An associated conservation easement reserves the acreage's conservation values in perpetuity.[17]

Information about additional BMPs that can help reduce the environmental footprint of long-term monitoring is available in EPA's companion fact sheet, *Green Remediation Best Management Practices: Site Investigation and Environmental Monitoring*.[18]

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This fact sheet provides an update on information compiled in the December 2011 "Best Management Practices: Landfill Cover Systems & Energy Production" fact sheet (EPA 542-F-11-024), in collaboration with the Greener Cleanups Subcommittee of the U.S. EPA Technical Support Project's Engineering Forum.

To view BMP fact sheets on other topics, visit CLU-IN Green Remediation Focus: www.clu-in.org/greenremediation.