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Green Remediation Best Management Practices: Integrating Renewable Energy

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 emissions.
- Reduce water use and preserve water quality.
- Conserve material resources and reduce waste.
- Protect land and ecosystem services.

BMPs 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

Renewable energy provides a significant opportunity to minimize energy- and air-related contributions to the environmental footprint of cleaning up hazardous waste sites. Use of renewable energy during site cleanup also can decrease burdens on local power grids and provide a backup supply of power. Vastly different scales and configurations of renewable energy systems may be used for site assessment, remediation or monitoring activities. The sources of renewable energy and the technologies used to capture and apply it for diverse purposes commonly involve:

- Solar energy captured by photovoltaic (PV), solar thermal or passive solar technologies.
- Land-based wind energy gathered by turbines that generate electricity or windmills that generate mechanical energy.

Additionally, geothermal energy may be captured from the earth by systems dedicated to certain heating and cooling purposes. Available sources of renewable energy at some sites also may include landfill gas or low-impact hydropower.

When exploring the use of renewable energy to power site cleanup activities, consider BMPs such as:

- Use onsite sources of renewable energy to generate off-grid power for operating remediation or monitoring equipment and maintaining associated buildings or other required infrastructure.
- Use onsite sources of renewable energy to generate power that feeds into utility grids, which offsets the use of grid power to operate remediation equipment or infrastructure.
- Develop a flexible infrastructure for renewable energy systems that can meet varying energy demands of cleanup activities over time.
- Incorporate energy storage capacity to enable continued operation of critical remediation or monitoring equipment during grid outages.
- Coordinate with parties responsible for integrating renewable energy systems that support ongoing or anticipated site activities. Joint efforts may reduce the environmental footprint associated with installing or maintaining the systems and achieve economies of scale.
- Purchase renewable energy via green power programs, renewable energy credits or community collaboratives.

At the 42-acre Solvents Recovery Service of New England site in Connecticut, a 53 kilowatt PV system directly powers pumps that extract contaminated groundwater. An infiltration gallery and green infrastructure such as vegetated swales help manage the site's stormwater and prevent onsite erosion. Remedy design and construction considered the site's anticipated use as an open-space area. Plantings of approximately 2,700 native trees and shrubs helped restore onsite biodiversity and wildlife habitat while alleviating flooding along banks of the bordering Quinnipiac River.[2]

Assessing and Optimizing Energy Use

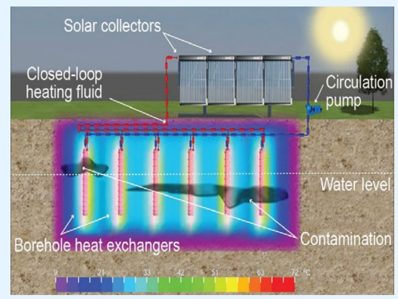
Integration of renewable energy relies on a thorough understanding of the anticipated or existing energy load associated with extracting or treating contaminated environmental media. It also relies on taking upfront steps to lighten the energy load by optimizing energy efficiency and conservation. Energy usage is typically considered during selection, design and construction of a site remedy and when planning operation and maintenance (O&M).

Use of EPA's Power Profiler can help project teams understand the type and amount of air emissions associated with electricity generation in specific U.S. subregions.[3] This knowledge can inform site-specific decisions about meeting renewable energy and air quality goals.

An energy audit will help project teams understand how energy is used in a particular extraction or treatment system and identify opportunities for improvement. A preliminary walk-through audit uses readily available data to find opportunities for energy efficiency. Use of thermographic equipment, for example, can quickly reveal air loss from heating or cooling equipment. A more detailed diagnostic audit involves collecting measurements and additional data on energy-intensive components of a remedy. Such components frequently include pumping systems, aeration blowers, compressed air networks, steam applications, heating processes and certain building operations.

Results of an energy assessment may prompt implementation of BMPs such as:

- Replace aged equipment with newer models meeting higher energy conservation standards.
- Downsize compressors and other energy-intensive equipment that have become oversized over time.
- Replace air-operated pumps with electric pumps, which are typically more efficient.
- Equip motors with variable frequency drives that automatically adjust energy use to meet real-time energy demand.
- Insulate all pipes connected to heating equipment.
- Convert an active pumping process to a gravity-flow process if a pressurized system is no longer required due to changes such as reconfiguration of equipment used for groundwater treatment or surface water collection.
- Integrate a heat exchange system to capture and beneficially use waste heat generated by equipment such as diesel generators.
- Install ground- or water-source heat pumps to extract and apply the site's natural geothermal energy for purposes such as water and space heating or cooling.
- Install an open-loop heat exchange system to capture the thermal mass in groundwater extracted from one or more wells for the purpose of aboveground treatment.[4]



Low-temperature subsurface heating was used to address hydrocarbon-contaminated groundwater at Fort Drum, New York. The application involved ground-mounted solar thermal units and borehole heat exchangers in a closed-loop system. Within six weeks, groundwater temperatures near the heat exchangers increased from about 54°F to 70°F. Sampling indicated that the elevated temperatures accelerated removal of volatile organic compounds.[5]

Site-wide usage of electricity and natural gas should be actively tracked and recorded through utility-provided meter readings and commercial or open-access software such as the U.S. Department of Energy (DOE) Energy Footprint Tool.[6] In addition, use of submetering instruments enables assignment of energy consumption to distinct portions of an extraction or treatment process, which will aid energy optimization.


An offsite closed-loop heat exchange system uses groundwater that is extracted and treated at the Phoenix-Goodyear Airport Area Superfund site in Arizona. Approximately 197 million gallons of the treated groundwater are conveyed to the heat exchange system each year, which reduces building heating and cooling costs at the offsite property by an estimated 40 percent. An additional 81.5 million gallons of the treated water are reclaimed each year to irrigate a 105-acre onsite area now used for recreational purposes.[7]

Assessing Renewable Energy Potential

A renewable energy assessment estimates the anticipated output of one or more sources of renewable energy based on site-specific attributes such as average daily solar radiation and average wind speed. The assessment also considers energy application aspects such as energy storage options, system O&M, installation permanence, tolerance of power interruptions, and peak energy demands.

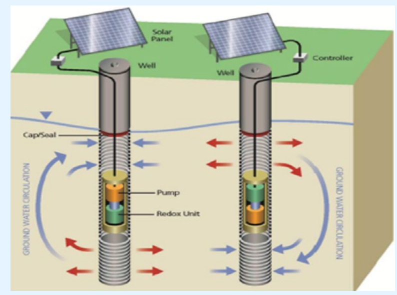
Estimates of payback periods for capital expenses are typically documented in a supporting economic study, which could range from a simple desktop evaluation to a comprehensive independent evaluation. The study should consider the anticipated duration of energy usage required to complete site remediation and the costs for alternatively using fossil fuel-derived energy. For example, ex situ treatment of contaminated groundwater at a large or remote site could incur significant expenses associated with extending a utility grid or transporting diesel fuel.

A renewable energy assessment also examines potential use of the generated power. Integration of solar and wind energy could involve multiple applications at varying scales:

- Use solar panel kits to operate monitoring or remediation equipment with low energy demands.
- Deploy mobile systems that can be easily transported and quickly assembled. Mobile systems typically comprise pre-integrated PV modules or small wind turbines (or both) and auxiliary equipment carried on trailers or in custom vehicles.
- Install small off-grid systems (below 10 kilowatts (kW)) that can power selected components of an energy-intensive remediation process or fully power remediation activities with a low or moderate energy demand.
- Construct medium- or large-scale systems connected to the grid and meeting much or all of the energy demand over time. Scaling should account for potential reduction in the energy demand and future re-purposing of the system as cleanup progresses.
- Partner with other stakeholders to develop utility-scale facilities (typically rated above 1 megawatt (MW)) that fully offset the use of grid power. Utility-scale renewable energy production is often administered through a power purchase agreement among the site owner, an independent developer and a utility.
- Diversify the sources of renewable energy to increase power generation capacity and reduce single-source reliance.
- Use a phased approach to constructing renewable energy systems, which can help manage related capital expenses.

A mechanical windmill directly powered the compressor required for biosparging at an underground storage tank site.[8]

Onsite meteorological data collected over a 12-month period can significantly inform renewable energy-related decisions supporting a new remedy or optimization of an existing remediation system. An array of tools such as the PVWatts® Calculator and the Renewable Energy Potential (reV) model are available from the U.S. DOE National Renewable Energy Laboratory (NREL) to further assess, analyze, optimize and model renewable energy and energy efficiency technologies. NREL also offers extensive open-access data relevant to site cleanup applications.[9]



The Northeastern University Superfund Research Program Center is researching solar-powered technologies to remediate contaminated groundwater. One approach involves use of a two-electrode system that can be placed inside a well to dechlorinate trichloroethylene in karst aquifers.[10]

EPA's RE-Powering America's Land initiative identifies the potential of renewable energy development on currently or formerly contaminated land and mine sites. The initiative's online tools include state and national maps of renewable energy resources and completed NREL feasibility studies.[11] Exploration of renewable energy applications to support site cleanup also may be facilitated through partnerships with academic institutions or environmental technology business incubators or accelerators.[12]

Design, Construction and Maintenance

Integration of renewable energy in each phase of project planning and implementation helps maximize and optimize renewable energy use throughout the project's life. Design of a new extraction, treatment or monitoring system, for example, may include BMPs that concern sourcing, applying and maintaining renewable energy systems:

- Identify processes not requiring a continuous supply of power. Use of off-grid renewable energy systems to intermittently operate such processes reduces the demand for fossil fuel-derived energy and can avoid storage battery usage and associated efficiency loss.
- Treat air emissions containing low contaminant concentrations through use of devices equipped with micro-scale renewable energy units. Examples include solar-powered vent flares to treat landfill gas and solar-powered fans or vent stack-mounted wind turbines to mitigate soil vapor intrusion.
- Use a solar thermal collection system to supply hot water required for building operations or selected treatment processes.
- Site new buildings to meet requirements of feasible renewable energy sources. For example, south-facing orientation of a building enables use of passive solar energy to provide direct or indirect natural light in work and storage areas. Southern exposure also will enhance capacity for a potential roof-top PV system in the future.

A 560 watt passive PV system provided power to extract contaminated groundwater for ex situ treatment at the Busy Bee's Laundry in Rolla, Missouri. The PV system was scaled to meet the expected energy demand of one 400-watt surface-mounted piston pump, which was rated at 9.1 gallons per minute at 140 feet of total dynamic head. Use of the PVWatts tool estimated a potential pumping period of 55 to 89 hours per month. The PV system included a passive tracking mechanism to maximize solar energy capture throughout the day.[13]

- Include specifications that reduce vulnerability of the renewable energy system to extreme weather conditions or events such as prolonged precipitation and intense wind force.
- Consider the need for grid interconnection capability, which allows disconnection from the grid and direct use of a renewable system output during certain times such as grid outages.[14]
- Account for renewable energy system maintenance in project budgets. This may require early negotiations with a state agency or other party responsible for future O&M.
- Identify and evaluate options to reuse the renewable energy system after it is no longer needed for its original purpose. Common options for solar- or wind-generated electricity include rerouting it to a newly constructed remediation system or to an existing building that supports ongoing site activities.

The environmental footprint of installing a renewable energy system may be minimized by BMPs addressing common construction activities. For example:

- Remove and reserve obtrusive shrubs and forbs prior to construction, for later replanting or transplanting. Preserving such small vegetation helps maintain the site's biodiversity while aiding sequestration of atmospheric carbon.
- Use backhoes, drill rigs or trenchers with emission control technologies such as diesel oxidation catalysts and diesel particulate filters.
- Use a surgical approach to excavation or trenching when installing a borehole heat exchanger or the subsurface pipe network required for a geothermal system, thereby avoiding unnecessary digging and land disturbance.
- Choose hydraulic fluids that are biodegradable.
- Implement an engine idle reduction plan to avoid fuel use when machinery is not actively engaged. For example, the plan could entail manual shutdown after a specified time or engagement of automatic shutdown devices.

BMPs specific to constructing a solar or wind energy system include:

- Build to relevant standards such as ASTM *Standard Practice for Installation, Commissioning, Operation, and Maintenance Process (ICOMP) of Photovoltaic Arrays* (ASTM E3010-15(2019));[16] *IEEE Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for Photovoltaic (PV) Systems* (IEEE 937-2019);[17] or *Power Performance Measurements of Electricity Producing Wind Turbines* (IEC/ANSI 61400-12-1:2017).[18]
- Use two strings of batteries rather than a single string to store excess electricity so that one string may be taken out of service for maintenance while the other continues to provide power.
- Use multiple microinverters rather than a large central inverter for AC/DC conversion to prevent full-system shutdown if an individual component fails.
- Allow sufficient access space around and below PV panels for maintenance activities such as removing snow or mowing vegetation.
- Allow sufficient space to raise and lower a wind tower requiring repair.
- Provide elevated pads to prevent flooding of ground-mounted equipment.
- Include proper drainage controls to minimize flooding potential and associated soil erosion, which can undermine ground-mounted equipment pads or racks.
- Use low- or no-maintenance construction techniques and materials, such as choosing tie-down wires made of coated metal rather than less durable plastic.
- Revegetate construction areas with native low-growth flowering species such as white clover to promote rainwater and snowmelt infiltration, foster natural pollination, and minimize mowing. Using gravel as ground cover at the base of PV mounts or wind turbines often creates uneven work surfaces, increases stormwater runoff, and insufficiently controls weeds.
- Consider the need for third-party inspection and commissioning of the constructed system prior to its startup.

Renewable energy was used to collect offgas from air sparging equipment operating over 10 months at the Rainbow Valley Citrus Maintenance Yard Facility in Goodyear, Arizona. The system consisted of two solar fan assemblies, each containing a 2.5 watt PV module, a 1.8 watt fan inside louvered housing, and a 1.8 watt motor. The louvers in the fan housing provided a passive wind flow. Deployment of the two assemblies avoided use of an electrical air blower predicted to consume 20,000 kilowatt hours of electricity over the same period.[15]

At the Continental Steel Corp. site in Kokomo, Indiana, up to 60 percent of the grid electricity powering a groundwater extraction system is offset by operating three 2.4 kW grid-tied wind turbines. About 9.1 million kilowatt hours of energy is additionally generated onsite each year by a 7.2 MW solar farm administered through a 20-year power purchase agreement. The site's solar energy is also captured on a small scale; a single PV panel powers a pump that intermittently extracts contaminated groundwater and fuel oil from a concrete-lined sump installed along an onsite stream.[19]

BMPs to reduce the environmental footprint associated with solar and wind system O&M include:

- Use O&M checklists based on guidelines or standards such as the IEC standard for maintenance of grid-connected PV systems.[20]
- Incorporate data loggers to collect real-time information that informs schedules for routine preventive measures and averts corrective maintenance problems.
- Conduct detailed inspections on an established schedule. A wind turbine inspection, for example, should include examining and testing the power controls, foundation, tower and guy wires, tower mechanics, blades and generator parts.[21]
- Equip inverters with telemetry that enables remote testing, software reconfigurations or updates, and resetting as needed.
- Use biobased rather than petroleum-based products to lubricate moving parts such as gears and bearings.
- Standardize preferred products to avoid mismatch of replacement parts.
- Incorporate security measures to prevent damage or theft of system components.

Detailed PV-related practices regarding design, construction or operation as well as energy storage are described in NREL guidance such as *Best Practices for Operation and Maintenance of Photovoltaic and Energy Storage Systems*.[22]

A mobile solar-powered vapor extraction unit was set up within one day for a soil vapor extraction pilot study at Vandenberg Air Force Base, California. The unit consisted of one 3 kW PV array, a converter, one 4.6-horsepower regenerative blower, manifold piping and a knock-out tank. During operation, the integrated system modulated air vacuum blower speeds according to the available solar energy. The system achieved a maximum airflow of 200 cubic feet per minute and vacuum of 100 inches of water column over two months of deployment.[23]

Mobile Energy Systems and Energy Storage

Deployment of autonomous or towable renewably energy systems can help increase a remediation project's resilience to utility power outages or fuel supply reductions while reducing the environmental footprint of cleanup activities. Mobile systems available for rental or purchase in today's commercial market generate useable energy from solar energy, wind energy or a hybrid of both resources. Hybrid systems also may include supplies of compressed natural gas or diesel fuel. In addition to providing a backup power supply, mobile systems can provide energy to:

- Power equipment temporarily engaged in remedy construction.
- Operate a field laboratory.
- Conduct remediation activities at remote sites or discrete areas with no existing access to utility grids or posing challenges to fuel hauling.
- Perform activities confined to certain seasons or site conditions.
- Conduct pilot studies of remediation technologies such as soil vapor extraction, dual-phase extraction or in situ thermal treatment.
- Treat contamination hot spots in soil, sediment or groundwater.
- Repair, modify or decommission field equipment.
- Respond to emergencies such as severe weather events, wildfires or releases of hazardous substances.

Mobile energy rigs may provide power via a mix of resources such as wind energy, solar energy and gasoline or diesel generators. On-board equipment typically includes inverters, battery storage and internet devices.[24]

Resilience to grid outages or reduced fuel supplies can be further increased by using transportable units that store excess energy produced from onsite sources of renewable energy. Such a unit typically consists of a towable, insulated metal container that holds battery banks and ancillary equipment. The container can be maintained onsite indefinitely and dispatched when and where needed. When not deployed for intermittent needs, the unit can provide power for routine site activities such as maintaining telecommunications and recharging electric vehicles.[25]

Sizes and capacities of energy storage units considerably vary. This 20-foot unit can store up to 1 MW of energy.[26]

Purchasing Green Power

Procurement of green power provides another approach to integrating renewable energy into site remediation projects. Through market-based instruments, green power purchasers gain a portion of property rights to the environmental, social and other non-power attributes of offsite projects dedicated to renewable electricity generation. BMPs concerning green power procurement commonly include:

- Buy renewable energy certificates (RECs) from a selected power-generation or energy-commodity company.[27] Renewable energy resources comprising the REC market include solar electric, wind, low-impact hydropower, geothermal and biomass (primarily landfill gas). In some states, RECs specific to solar energy (SRECs) also are available.

- Participate in green energy programs offered by local utilities, which enable electricity and natural gas providers to offer pricing structures based on bundles of RECs derived from qualified energy projects. A list of U.S. utilities with green pricing programs is available from NREL.[28] Also, many states allow electricity or natural gas to be purchased from sources other than utility companies, some of which offer clean energy options that include REC bundles.
- Enroll in community solar or wind projects.[29,30] Through subscription- or ownership-based enrollment, participants share the environmental benefits of a solar or wind energy project regardless of its location.

Comprehensive information about green power, including its onsite generation through power purchase agreements, is available in the *Guide to Purchasing Green Power*.[31] The Database of State Incentives for Renewables and Efficiency (DSIRE®) provides frequently updated information about renewable energy and energy efficiency incentives offered by state agencies.[32] Certain incentive structures allow green power tax credits to be transferred from ineligible purchasers to eligible project partners.

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This fact sheet provides an update on information compiled in the April 2011
"Best Management Practices: Integrating Renewable Energy into Site Cleanup" fact sheet (EPA 542-F-11-006),
in collaboration with the Greener Cleanups Subcommittee of the U.S. EPA Technical Support Project's Engineering Forum.

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