MATERIALS MANAGEMENT DIVISION GUIDANCE DOCUMENT

Design and Regulatory Considerations for Developing and Installing Photovoltaic (PV) Solar Arrays on Closed Landfills

October 14, 2024

INTRODUCTION

The Michigan Department of Environment, Great Lakes, and Energy (EGLE), Materials Management Division (MMD), encourages the post-closure use of landfills for photovoltaic (PV) solar array projects provided the design, installation, operation, and removal of the PV solar array does not compromise the integrity of the closure elements or environmental monitoring systems for capped landfills.

TYPICAL CLOSED LANDFILL INFORMATION

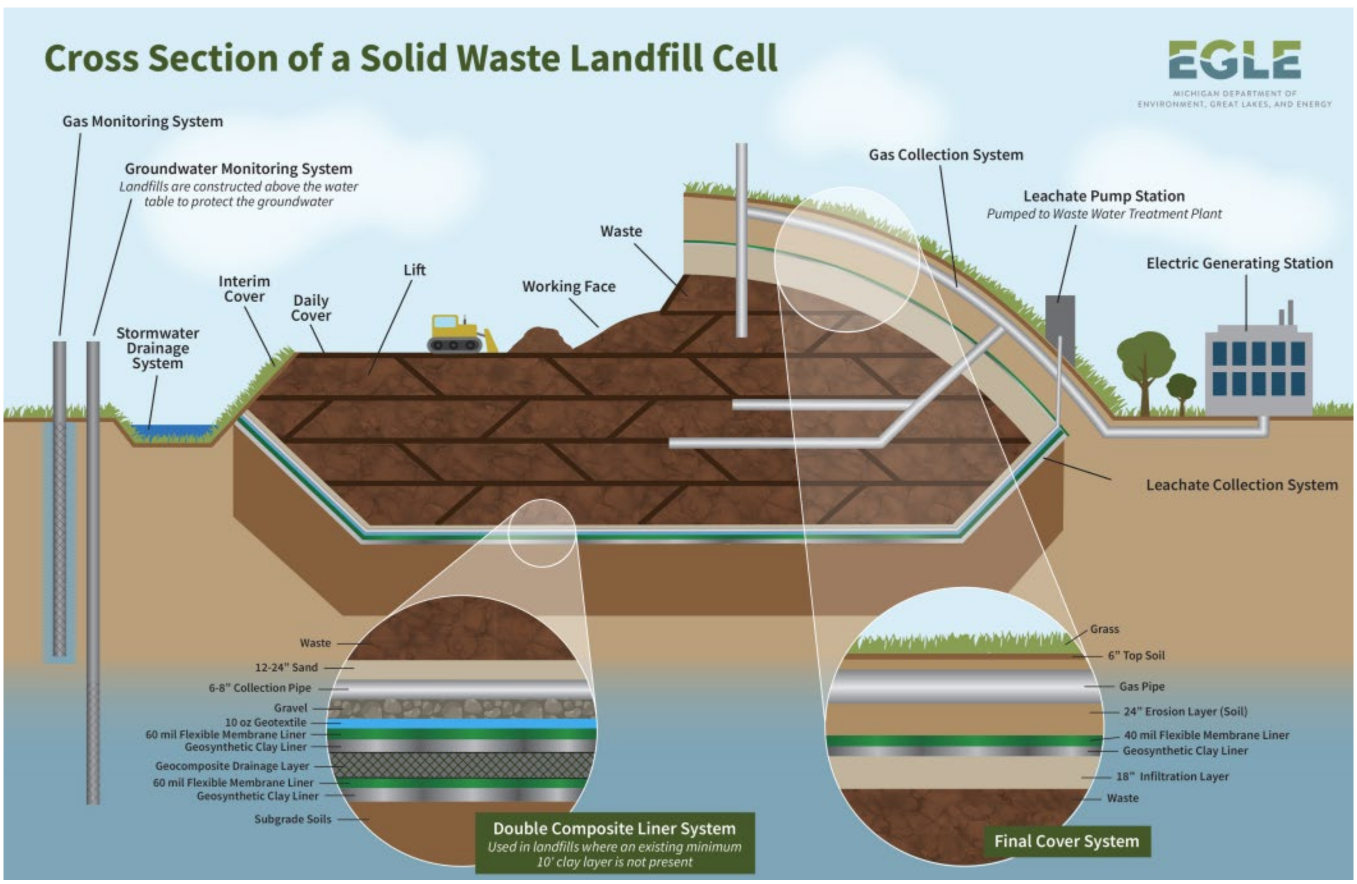
Modern solid waste landfills have been closed in accordance with the Part 115, Solid Waste Management, of the Natural Resources and Environmental Protection Act (PA), 1994 PA 451, as amended; (Part 115) and the administrative rules promulgated pursuant to Part 115 (Part 115 Rules, 'R'). Older landfills that were closed prior to January 1979, were closed under the Garbage and Refuse Disposal, 1965 PA 87, as amended (Act 87) or other authorities and may be subject to different post-closure care and land use restriction timeframes. There are also numerous remediation sites and surface impoundments that were closed as landfills in Michigan. The closure system for landfills is key to preventing migration of contamination and protecting human health and the environment.

Closure of a landfill typically consists of an engineered cap, gas and leachate extraction, and environmental monitoring systems which can include:

- a gas collection layer, if needed;
- a thick low permeability clay layer;
- a flexible membrane liner;

- a protective/erosion soil layer;
- an established grassy vegetation system;
- a stormwater drainage system;
- leachate collection risers and cleanouts;
- gas extraction wells or vents, if needed;
- perimeter landfill gas monitoring probes, if needed;
- groundwater monitoring wells; and
- other features to prevent erosion, limit settlement, mitigate stability issues, etc. as needed.

The **[Cross-Section of a Solid Waste Landfill Cell]** figure below, illustrates an example of how the cap and other closure and environmental monitoring features are integrated into a closed landfill.



CONSIDERATIONS FOR PV SOLAR ARRAYS INSTALLED ON CLOSED LANDFILLS

EGLE, MMD, may consider allowing PV solar arrays to be installed on closed landfills if the proposed project is protective of the existing capping, leachate and gas extraction systems, and environmental monitoring systems. Penetrations of the landfill cap are not encouraged but may be considered with a detailed demonstration of equal or greater protection from infiltration for the proposed penetration design. Lightweight, ground mounted systems that are not anchored into the existing cap are preferred to avoid creation of preferential pathways for escape of landfill gases through the existing cap and stormwater infiltration into the existing cap. A proposed project must also consider site security, deed restrictions and other existing safeguards that are used to protect human health and the environment from the landfill.

EGLE MMD will take the following considerations into account:

- Existing restrictive covenant or deed restrictions;
- Consistency with the existing post-closure plan;
- Surrounding community preferences and needs;
- Licensing and financial assurance requirements;
- Landfill slopes, orientation, and cap elements;
- Settlement and slope failure potential;
- Type of PV solar array anchoring system;
- PV solar array system weight and dynamic load considerations;
- Lightning protection and grounding;
- Cables, boxes, and other appurtenance placement;
- Cover vegetation management;
- Post-closure inspection ability;
- Stormwater management;
- Integration with existing landfill gas and leachate extraction, environmental monitoring, and production systems;
- Installation and construction methods;
- Site security;
- Closure, removal, and proper disposal of the PV solar panels and equipment after end of life; and
- Site restoration.

The following table describes the design considerations that EGLE MMD will examine and consider for allowing a proposed PV solar array installation project on a closed landfill. This table does not consider every possible challenge or approach and each project should evaluate the challenges specific to the landfill site. Professional design engineers shall regard human health and safety and the environment as the most important considerations when designing PV solar array projects on closed landfills.

TABLE 1 – LANDFILL PV SOLAR ARRAY DESIGN CONSIDERATIONS

Design Considerations and Regulatory Reference	Challenges	Suggested Approach
Restrictive Covenants or Deeds Part 115 324.11518	Although the post-closure period for landfills is generally 30 years, restrictive covenants/deeds can be 50 years following EGLE MMD's approval of the landfill's closure certification. Post-closure may be longer than 30 years if there is corrective action or other environmental concern (i.e. leachate or gas generation). Some restrictive deeds do not allow any future disturbance of the cap (i.e. hazardous waste landfills).	Research the applicable restrictive covenant/deed for the proposed site and request waiver approvals from EGLE MMD, if allowed, for installation of PV solar arrays on closed landfills. Copies of the restrictive covenants and deeds may be obtained, if available, by sending a request to the EGLE MMD Solid Waste Section. Solid Waste Section Staff contact information can be found at this website: https://www.michigan.gov/egle/about/organization/materials-management/solid-waste/solid-waste-disposal-areas Copies of the restrictive covenants and deeds may also be obtained, if available, by performing a Title search with the County's Registrar of Deeds. A list of the Registrar of Deeds for each county can be found at this website: https://www.michigan.gov/taxes/collections/register-of-deeds
Existing Obligations Part 111, 115 and 201	If a developer intends to purchase or lease a closed landfill site, it is possible that the landfill owner may have existing obligations for corrective action under the Hazardous Waste Rules (Part 111), Solid Waste Rules (Part 115) or the Environmental Remediation Rules (Part 201).	Research the applicable obligations for the proposed site and request approvals from EGLE, if allowed, for installation of PV solar arrays on closed landfills with corrective action obligations.

Design Considerations and Regulatory Reference	Challenges	Suggested Approach
Community Preferences / Environmental Justice Part 111, Part 115 and Part 201	Some communities may not want a closed landfill to have activity again. Some communities may have renewable energy goals that could be considered. Existing corrective action or consent orders on a closed landfill may require any development proposal (including for PV solar) to include significant public input.	Involve the community early on in the project. Include the surrounding community's preferences and needs in the PV solar project designs (i.e. Environmental Justice communities, community solar garden needs, etc.). Ask EGLE MMD for procedures for public input, if needed.
Permitting or Licensing Part 115 324.11510(2)(d) and 324.11517 R 299.4304 and/or R299.4425	Installing PV solar arrays on an existing landfill cap may require a post-closure operating license from the operator of the PV solar array or consent order modification depending on the nature and rule applicability of the original closure. PV solar array designs may be added to future closure designs for active landfill sites, and must follow the Part 115 rules for thickness, layer types, and permeability requirements.	A regulatory requirement review from EGLE MMD should be part of a feasibility study or conceptual design for all proposed landfill PV solar array installation projects. Permit, consent order and/or license conditions may be added to account for altered maintenance requirements, inspections, restoration and financial assurance.

Design Considerations and Regulatory Reference	Challenges	Suggested Approach
Financial Assurance Part 115 324.11517, 324.11523, and 324.11523a	EGLE MMD may require a form of additional financial assurance as part of an agreement or post-closure operating license to account for additional maintenance costs associated with PV solar arrays. EGLE MMD would also have a focus on the owner/operator’s custodial care duties (per 324.11517(4)) if the site is abandoned prior to proper closure of the PV solar array project.	Work with EGLE MMD to determine the appropriate financial assurance mechanism for the project, if required. If the site is still in the post-closure period, EGLE MMD will evaluate the need for additional financial assurance. If the site is past the post-closure period, EGLE MMD would evaluate site conditions to determine if financial assurance is needed. For example, if the cap was disturbed as part of the PV solar array installation, a new financial assurance mechanism, or an addition to an existing mechanism may be needed. The site may also pursue a legally enforceable agreement with EGLE MMD to include financial assurance for PV solar array maintenance and removal costs.

Design Considerations and Regulatory Reference	Challenges	Suggested Approach
Landfill Slope and Orientation Part 115 324.11517 R 299.4304 or R 299.4425	Flatter (slopes less than 5-percent) areas on landfills are usually not suitable. Installation and maintenance is more difficult on steeper slopes (greater than 5-percent). These slopes experience higher wind loads, decreased slope stability, and run the risk of erosion. As a result, steeper slopes generally require lighter-weight solar arrays and heavier foundations to anchor the system.	Work with EGLE MMD to determine the slope stability history and existing slope maintenance challenges for the project. Rail-type PV solar arrays, anchored on geosynthetics with artificial grass may be an option for steeper slopes, if allowed by Part 115.

Design Considerations and Regulatory Reference	Challenges	Suggested Approach
Cap Protection Part 115 324.11517 R 299.4304, R 299.4317, R 299.4425, R 299.4433, R 299.4447, R 299.4449, and/or R 299.4915	Closed landfills have restrictions on cap modifications that require them to remain in compliance with Part 115, permitted post-closure use and other federal, state, tribal and local laws. PV solar array designs that need foundation or ancillary equipment (cables, boxes, etc.) penetration into the existing cap surface layers are not encouraged but may be considered with the proper demonstration of equal or greater protection from infiltration. Need to prevent preferential landfill gas escape pathways, water infiltration pathways, disturbance to the existing stormwater management system on the cap, and damage to established vegetation.	Work with EGLE MMD to understand restrictions and options for modifying a landfill cap in post closure. Consider lightweight anchoring systems (for example ballasted systems) that can be installed on the landfill surface and do not have to penetrate the cap. Design requires proper weight of ballast material to balance PV solar array and foundation weight loading requirements of the landfill cap while also protecting against wind uplift and sliding. Work with EGLE MMD to determine the appropriate cable, box, and other appurtenance locations for the project, based on existing infrastructure. Cable wires and equipment will need to be placed above the landfill cap. In some cases, cover penetration may be allowed, such as for older landfills with only clay caps, in monofils with minimal settlement expected (ash, foundry sand, etc.), where no landfill gas generation is expected, and where proper booting is proposed. However, these design requests will be reviewed by EGLE MMD on a case-by-case basis and will require a demonstration of equal or greater protection from infiltration with the design proposal.

Design Considerations and Regulatory Reference	Challenges	Suggested Approach
Settlement Potential and Slope Stability Part 115 324.11517 R 299.4304, R 299.4419, R 299.4425, and/or R 299.4910	Newly closed Municipal Solid Waste (MSW) landfills will have differential settlement for many years, and therefore may not be suitable for PV solar array installations. Differential settlement during the PV solar array life can be expected for most landfill types. Adding weight to a cap system with geosynthetics may disturb the veneer stability of the cap.	Work with EGLE MMD to determine the slope stability history and existing settlement challenges for the project. Older landfills that have essentially stopped settling are more desirable for PV solar array installations. Landfills that have waste types that do not have large settlement issues (i.e. coal combustion residuals or contaminated soils) are more desirable for PV solar array installations. The landfill cap weight bearing capacity must be considered in all proposed PV solar array foundation designs. Loading requirements (including during installation) on geosynthetics should be less than 5 pounds per square inch (psi) at the cap surface, and will be less for exposed geomembrane surfaces. Designs need to include settlement and stability effects on the landfill cap from the added wind and snow loads. Conduct a slope stability assessment and avoid excessive weight and dynamic wind/snow loads that could affect slope stability.

Design Considerations and Regulatory Reference	Challenges	Suggested Approach
Subsurface leachate and landfill gas piping infrastructure and system integration Part 115 324.11517 R 299.4433	Compatibility with landfill gas, lateral drainage and leachate system locations should be considered. Compatibility with load bearing capacity of landfill gas and drainage piping should be considered. Some landfills may have existing landfill gas production (energy, pipeline) systems that would need to be protected.	Work with EGLE MMD to determine the locations and extent of the subsurface infrastructure for the project. A crushing analysis of the existing piping infrastructure should be included in the proposed PV solar array foundation design. The PV solar array and appurtenances should be designed and spaced to allow free access to landfill gas and leachate piping infrastructure. Explore opportunities to operate the landfill gas production and PV solar array generating units as one system, utilizing existing electric connection systems.
Lightning protection and grounding Part 115 324.11517	Landfills, even capped ones, emit landfill gasses (i.e. methane and hydrogen sulfide gas). There are limited areas to ground the electrical wiring.	Work with EGLE MMD to determine the best locations for grounding protection for the project. The PV solar array installation and electrical set up must be designed to prevent sparking to prevent potential fires. Any enclosed areas should be designed with landfill gas detection meters and maintenance staff should be aware of inhalation and explosion hazards. Do not ground PV solar array wiring systems in waste material beneath the landfill cap.

Design Considerations and Regulatory Reference	**Challenges**	**Suggested Approach**
Post Closure Inspection Part 115 324.11517 R 299.4317 or R 299.4449	PV solar array installations cannot impede the ability to perform regular maintenance, landfill gas monitoring, leachate monitoring, and observance of any settlement or stability issues with the landfill or landfill cap.	Work with EGLE MMD to determine the existing inspection and maintenance challenges for the project. The PV solar arrays must be spaced to allow equipment access to repair areas of the cap that were observed to be damaged during regular inspections. PV solar arrays should be designed to allow access for inspection of the cap elements.
Vegetation Management Part 115 324.11517 R 299.4317 or R 299.4449	Mowing the grass between the panels may be difficult. Vegetation needs access to sun and rain. Vegetation on top of a closed landfill must be maintained for inspection purposes and to prevent woody vegetation growth and erosion.	Work with EGLE MMD to determine the existing vegetation maintenance challenges for the project. Space the PV solar array panels to maximize the area for mowing, sunshine and rainwater needed to maintain proper vegetation. Plantings of pollinators or other plants that are ecologically sustainable should be considered. Grazing animals could be used to “mow” (sheep, goats, etc.). Aggregate placed around and under PV solar arrays may be considered.

Design Considerations and Regulatory Reference	Challenges	Suggested Approach
Stormwater Management Part 115 324.11517 R 299.4304, R 299.4317, R 299.4425, and/or R 299.4449	PV solar array installations may impede the proper flow of stormwater to the landfill's existing stormwater management system. Existing stormwater systems on closed landfills may need to be upgraded to suit the project. Increased erosion around the PV solar array foundation can be expected and increased flows may result from removed vegetation or impermeable areas. Some sites may have an active National Pollutant Discharge Elimination System (NPDES) permit with requirements for outfall discharges.	Work with EGLE MMD to determine the existing stormwater challenges for the project. Coordinate with state and local permitting officials. Erosion must be managed around the PV solar array foundations and other equipment. Layout of the PV solar array should accommodate the existing stormwater management system. A redesign of the stormwater management system may be needed to accommodate changes in flow rates and velocity of stormwater runoff.
Site security Part 115 324.11517 R 299.4317 or R 299.4449	Closed landfill sites require security as part of the restrictive covenants, cap protection and safety. Given that the PV solar array systems are a protected power source, they may require more security than the closed landfill required.	Work with EGLE MMD to determine the required site security elements for the landfill. Provide adequate controls (i.e. fences, cameras, lighting, guards, etc.) to limit access to the landfill cap components and the PV solar arrays and appurtenances. Safety of the public should also be considered given the risks from landfill gas and electrocution.

Design Considerations and Regulatory Reference	**Challenges**	**Suggested Approach**
Construction Part 115 324.11517	Site preparation and grading may be limited to only materials that can be placed on top of the existing cap and won't affect inspections, stormwater runoff, erosion, settlement, or stability. Equipment used for installation of panels on the landfill cap shall not penetrate or damage the existing cap, underlying pipe structures, or stormwater features. Need to assure the prevention of nuisance odors and dust during construction. Need to prevent erosion and sediment loading.	Work with EGLE MMD and local authorities to determine required permits for cap modification fill placement and grading and construction documentation requirements. Use low ground pressure equipment for site preparation, grading, dust control, materials hauling, etc. on the landfill cap and avoid heavy loads on existing landfill gas and leachate piping. Minimize grading where possible. Project timing should consider growing seasons for restorative vegetation. Consider use of low maintenance vegetation using native species or other pollinator type vegetation. Apply water, not chemicals, to control dust during construction. Implement soil erosion and sediment control measures in disturbed areas of site. Minimize damage to the stormwater management system during construction and comply with NPDES permit and landfill post-closure care requirements.

Design Considerations and Regulatory Reference	Challenges	Suggested Approach
Ongoing environmental monitoring Part 115 324.11517 R 299.4317 or R 299.4449	Closed landfills have structures in place for groundwater, leachate, and landfill gas monitoring post-closure. These structures can get damaged if not properly protected. The use of chemicals to clean the PV solar array panels may affect the groundwater monitoring at the site or increase the potential for groundwater contamination.	Work with EGLE MMD to determine the location and purpose for all existing environmental monitoring features at the site. Locate and clearly mark all existing groundwater monitoring wells, gas probes, leachate piping and manholes to avoid damage during construction or operation of the PV solar arrays. Avoid use of chemical cleansers to clean the PV solar array panels.
PV solar array maintenance and cleaning Part 115 324.11517 R 299.4317 or R 299.4449	PV solar array monitoring and maintenance may be difficult at remote landfill locations. Post-closure landfill groundwater monitoring may be affected using chemicals for cleaning or maintenance.	Work with EGLE MMD to determine the environmental monitoring constituents for the landfill. Avoid using chemical cleansers to clean the PV solar array panels. Take advantage of natural cleaning from storm events. If needed, use low ground pressure water trucks to bring water on the cap to clean the PV solar array panels.

Design Considerations and Regulatory Reference	Challenges	Suggested Approach
PV solar array disposal	PV solar array panels that have been damaged or have reached end of life should be properly recycled or disposed of per the requirements in place at the time of disposal. Solar panels may be considered a hazardous waste, depending on the materials used in manufacturing.	Follow the United States Environmental Protection Agency (USEPA) instructions on solar panel disposal as these regulations may change frequently. Here is a useful website for solar panel disposal information: https://www.epa.gov/hw/end-life-solar-panels-regulations-and-management

LINKS TO ADDITIONAL INFORMATION

The Part 115 Statute and Rules are referenced in this document and can be found on EGLE's website: https://www.michigan.gov/egle/about/organization/materials-management/solid-waste/solid-waste-statutes-and-rules

General landfill cross section information website: https://www.michigan.gov/egle/-/media/Project/Websites/egle/Documents/Programs/MMD/Landfills/Anatomy-of-a-Landfill-with-Glossary.pdf

In addition to the EGLE MMD specific information listed in this document, the United States Environmental Protection Agency's document titled "Best Practices for Siting Solar Photovoltaics on MSW Landfills," should be referenced (United States Environmental Protection Agency (USEPA), 2022). Website: https://www.epa.gov/re-powering/best-practices-siting-solar-photovoltaics-municipal-solid-waste-landfills

Looking for a potential Michigan landfill site for renewable energy projects?

- Head to USEPA's RE-Powering Mapper at https://www.epa.gov/re-powering/re-powering-mapper.
- Contact the EGLE MMD Solid Waste Section Staff for a list of closed landfills.
- Search for remediation sites closed as landfills on the Remediation Information and Data Exchange (RIDE) Database at https://www.egle.state.mi.us/RIDE/home.

EGLE MMD LANDFILL CONTACTS

Any questions or concerns regarding this policy and procedure should be directed to:

EGLE MMD Solid Waste Section Staff: Solid Waste Disposal Areas (michigan.gov)
https://www.michigan.gov/egle/about/organization/materials-management/solid-waste/solid-waste-disposal-areas

or

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REFERENCES

United States Environmental Protection Agency (USEPA). (2022, May). *Best Practices for Siting Solar Photovoltaics on Municipal Solid Waste Landfills.* Retrieved from https://www.epa.gov/re-powering/best-practices-siting-solar-photovoltaics-municipal-solid-waste-landfills