AGENDA

- INTRODUCTIONS & EXPERIENCE
- REGULATORY REQUIREMENTS & TIMELINE
- SOLAR ARRAY DEPLOYMENT OPTIONS & CONSIDERATIONS
- BURIED SYSTEMS FOR SOIL COMPONENT CAPS AND ADJACENT LANDS
- BALLASTED SYSTEMS FOR GOESYNTHETIC & SOIL COMPONENT CAPS
- MOUNTING SYSTEMS FOR FULL GEOSYNTHETIC CAPS
INTRODUCTIONS & EXPERIENCE
INTRODUCTIONS

Halle Doering
Project Civil Engineer

- Lansing, MI
- 5 years at Golder
- Experience with landfill sites including stormwater design, engineering, and construction quality assurance (CQA)

Dave Regalbuto
Senior Hydrogeologist

- Holland, MI
- 22 years at Golder
- Experience with hydrogeologic investigation for Part 115 permit applications; groundwater monitoring
RECENT EXAMPLES OF SOLAR AT LANDFILLS

CLOSED SITE

• East Lansing Solar Park: occupies NW portion of Burcham Park, East Lansing, operational in 2018. Site of a closed/capped but unlined landfill with protective soil cover. 1,000-panel solar array – ballasted type support; no cap penetration of solar panel mounts.
RECENT EXAMPLES OF SOLAR AT LANDFILLS SITES PLANNING CLOSURE PRESENTLY

• Mississippi CCR Landfill - to be permitted and constructed in 2020 with full geosynthetics including solar panels on ClosureTurf®

• Type III Landfills – currently facilities in northern and southern MI are considering solar applications both on and adjacent to the landfill footprint
RECENT EXAMPLES OF SOLAR AT LANDFILLS

FUTURE SITES

• Lansing, MI Type III Landfill - permitted in Michigan for the use of final cover in 2019 with the use of ClosureTurf® and solar panels

• Grand Rapids, MI MSW Incinerator Ash Landfill - permitted in Michigan for the use of final cover in 2017 with the use of ClosureTurf® and considering solar panels
REGULATORY REQUIREMENTS & TIMELINE
REGULATORY FRAMEWORK

EGLE CONSIDERATIONS

- Liner penetration: likely not an option, but design to prevent preferential CH4 and infiltrations pathways
- Load requirements on liner (~5psi – 720 psf)
- Cable height above the liner – follow local electrical codes, some systems have integrated wire, different options available
- Equipment used for installation of panels on liner
- Impacts to landfill after lifetime of solar system expires
- Settlement issues
- Financial assurance – additional maintenance costs
- Wind and snow loads
- Stormwater management
- Typical post closure inspections

EPA REQUIREMENTS

- Stormwater management
- Closure and post closure
- Permit conditions
- Penetrations of the landfill cap
- Site preparation and grading
- Community involvement and transparency
- Regulatory requirements should be part of a feasibility study or conceptual design
TIMELINE

CLOSED SITES

• 3 months engineering design, collaboration with solar manufacturer

• 1 - 5 Months for EGLE review of permit
  ▪ Submitted as modification – Part 115-18 (liner penetration) – 5 months (150 days)
  ▪ Submitted as upgrade/improvement
    • Can be approved by local regulator
    • Need to be clear and prove that it is an actual improvement with Part 115 rules
    • Prove on cap solar systems don’t damage liner
    • No public notice required

• Design- build option or additional ~2 months for design-bid–build

• Total: 4 -10 months dependent on system and design-build selections
TIMELINE

SITES PLANNING CLOSURE

• 3 months engineering design, collaboration with solar manufacturer
• 5 Months for EGLE review of permit
  • Submitted as part of landfill closure plan and permit –Part 115-7, 5 months (150 days)
• Design- build option or additional ~2 months for design-bid–build
• Total 8 -10 Months dependent on design-build selections

SITES REQUIRING FILL AND GRADING

• Sites vary on closure timeline dependent on quantity of fill and grading required to meet closure grades
SOLAR ARRAY DEPLOYMENT OPTIONS & CONSIDERATIONS
ACCEPTABLE SLOPES:

SOUTH FACING

- Optimal production on south facing slopes, greater time exposed to sunlight
- Closure plans can incorporate grading necessary to optimize solar production
- Slope orientations outside of +/- 20-30deg from due south typically result in lower annual energy production, these slopes are typically adjusted through grading or not considered useable
- Option to install longer legs on back side of panels to adjust tilt to south, locally manufactured as needed

2 - 5%

- Less dense, more space needed between panels (~5-10 feet)
- Typically ballasted system
- Minimal slopes reduce rainfall infiltration through the cap, reduce erosion, and avoid ponding
ACCEPTABLE SLOPES:

25-33%

- Denser panels and less space needed
- Installation and servicing more difficult on steeper slopes
- Steeper slopes generally require lighter-weight solar arrays and heavier foundations to anchor the system (not ideal for ballasted systems)
- Foundation/anchoring system more challenging
- Higher wind loads
- Increased erosion
- Best practices using fix tilt mounted systems
- PV integrated geomembrane (rail system with closure turf)
- Higher costs associated with difficulties installing and manufacturing for steeper slopes
OTHER CONSIDERATIONS:

WIRING FOR ELECTRICAL CONNECTION

• Wiring connecting arrays to inverters and inverters to the point of interconnection
• Generally run as direct burial through trenches
• In landfills, wiring may be required to run through above-ground conduit due to restrictions with cap penetrations or other concerns

SYSTEM MONITORING

• Consistent monitoring systems with traditional green field sites.
OTHER CONSIDERATIONS (Cont.):

MAINTENANCE

- Routine operations and maintenance of photovoltaic systems are usually minimal in cost, ranging from $10-15/kW on an annual basis.
- Following installation of solar panel system, the solar system operation, maintenance, and monitoring can be integrated with the landfill.
- Panel washing and water management plan or Natural Cleansing
- ClosureTurf® does not require mowing around the solar panels
BURIED SYSTEMS FOR SOIL COMPONENT CAPS AND ADJACENT LANDS
SOLAR ENERGY PRODUCTION OPTIONS:  
BURIED FOUNDATION SYSTEM

• This founding system likely to be used adjacent to landfills, but not on landfills
• Footers set in shallow holes in the landfill cap, if on landfill, includes penetration of the cap
• Tend to be heavier than other anchoring systems but may provide more stability compared to other anchoring systems for application on steep slopes
• Weight and size of concrete blocks is determined by weight bearing characteristics of the landfill cap, and wind and snow loading requirements
### SOLAR ENERGY PRODUCTION OPTIONS:

<table>
<thead>
<tr>
<th>System</th>
<th>Buried Foundation (liner penetration)</th>
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<tbody>
<tr>
<td><strong>Pros</strong></td>
<td>- Generally provides more stability than other systems, heavier on a psi basis</td>
</tr>
</tbody>
</table>
| **Cons** | - Penetration in liner after lifetime of solar system  
- Permitting modification – 150day review by EGLE |
| **Cost** | - Additional cost to penetrate liner |
BURIED FOUNDATION SYSTEM
BALLASTED SYSTEMS FOR GEOSYNTHETIC & SOIL COMPONENT CAPS
SOLAR ENERGY PRODUCTION OPTIONS:

BALLASTED FOUNDATION SYSTEM

• Most common type of anchoring method on landfills
• Does not penetrate landfill cap
• Provides good structural support for the PV array
• Good for flat landfill surfaces, installation more difficult as slope increases
• Design requires proper weight of ballast material to balance dead weight loading requirements of the landfill cap while protecting against wind uplift and sliding
## SOLAR ENERGY PRODUCTION OPTIONS:

<table>
<thead>
<tr>
<th>System</th>
<th>Ballasted Foundation system (above liner)</th>
</tr>
</thead>
</table>
| **Pros** | - No penetration to liner system  
- No damage to liner after lifetime of solar  
- Permitting Improvement – local regulator approval only needed  
- minimal site prep or disturbance to the vegetative cover  
- Installed quickly  
- Good structural support for the PV array |
| **Cons** | - Difficult installation on steeper slopes |
| **Cost** | - Increasing number of manufacturers are offering pre-packaged ballast and racking solutions that are designed for site specific conditions |
BALLASTED SYSTEMS

BURCHAM PARK LANDFILL – EAST LANSING

- Partners: LBWL, City of East Lansing, Michigan Energy Options, Renewable Energy Evolution
- 3 acres; 1000 panels; 144 lessees
- 465,000 kWh annually (60 homes)

- 2016: Conceptual design; community roll-out
- 2017: Engineering design; EGLE approval
- 2018: Construction; full operation 12-28-2018
BALLASTED SYSTEMS

Burcham Park Landfill – East Lansing

- Unlined old municipal landfill
- Profile: ~ 5 feet of waste, underlain by thin peat, sand, stiff glacial clay
- 24-inch clay cover; intended only to prevent direct contact. (no golf!)
- 2017: EGLE accepted design considerations/constraints:

1. Ballast loading/gravel base will not deform clay cap
2. Storm water: runoff mitigated with berms / basin
BALLASTED SYSTEMS

EXAMPLE 300 kW (1000 Panels in 2 acres) DESIGN FROM BURCHAM PARK, EAST LANSING, MI

FROM: Patriot Solar Group (www.patriotsolargroup.com)
BALLASTED SYSTEMS
EXAMPLE DESIGN FROM BURCHAM PARK, EAST LANSING, MI

Advantages: No cap penetrations, ash landfills see less settlement than MSW, more readily available, many projects in the Midwest/northeast.

Disadvantages: More area needed per MW, wind loads, slopes (~5% max.), maintenance.

FROM: Patriot Solar Group (www.patriotsolargroup.com)
BALLASTED SYSTEMS
EXAMPLE ON CAP LANDFILL PROJECTS - MASSACHUSETTS

Edison Landfill, 7.8 MW, 90 mph wind and 50 psf snow load

North Carver Landfill, 1.77 MW, 3 high Ballasted ground mount

FROM: Patriot Solar Group (www.patriotsolargroup.com)
MOUNTING SYSTEMS FOR FULL GEOSYNTHETIC CAPS
SOLAR ENERGY PRODUCTION OPTIONS:

ALTERNATIVE FINAL COVER OPTIONS

• Alternative final cover can be installed with ballasted foundation or rail systems
• Rail system has higher density of panels therefore greater production per acre
• Rail system has easier and faster installation
• Rail system can be used on slopes greater than 5%
**SOLAR ENERGY PRODUCTION OPTIONS:**

<table>
<thead>
<tr>
<th>System</th>
<th>Integrated Alternative Cover System (Closure Turf with rackless system)</th>
</tr>
</thead>
</table>
| **Pros** | - No penetration to liner system  
- No damage to liner after lifetime of solar  
- Solar included in initial permitting  
- Replaces vegetative and final cover  
- No vegetation maintenance  
- Reduced erosion and soil maintenance  
- Decreases rainwater intrusion of the landfill cover  
- Increased density and higher power/acre  
- Faster and easier installation |
| **Cons** | - Only for sites not yet closed  
- Limited information on long term maintenance |
| **Cost** | - Cost is similar to that of final landfill cover with addition of solar system  
- Reduced maintenance costs |
FULL GEOSYNTHETIC CAPS

BENEFITS OF GEOSYNTHETIC CAPS:

- Reduced maintenance / post closure care
- Reduced soil loss due to rainfall
- Increased runoff quality
- Potential reduction of downchute channels and diversion berms
- Eliminated need for clay and vegetative soil in final cover

FROM: WatershedGeo, www.watershedgeo.com
FULL GEOSYNTHETIC CAPS – OPTIONS WITH SOLAR

ClosureTurf® can be used with **ballasted ground mount or rail system** solar options
RAIL SYSTEM

Friction Strip + Embedded Rail Attachment = PowerCap™ Rackless Panels
RAIL SYSTEM

Friction Strip Installation

Panel Installation

BENEFITS:
• Faster and easier installation
• Can be installed on slopes (max 2H:1V)
• Increased Density = more Power per acre ~ 1MW: 2-3 Acres
• Long term reliability, 30-year manufacturer warranty

FROM: WatershedGeo, www.watershedgeo.com
RAIL SYSTEM

Other Considerations:
- Rail system moves with settlement
- Electrical conduits run above ground to toe of slope where they connect
- No vegetation to maintain over time
- No erosion to fix over time
BALLASTED SYSTEMS

Owner: Materials Innovation and Recycling Authority (MIRA)
Location: Hartford, CT
Completed: 2014
Closure Area: 36 acres
Solar Capacity: 1 MW over ~5 acres
THANK YOU. QUESTIONS?