

Solar Facilities on Landfills Engineering, Permitting, Construction, and Lessons Learned



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Engineering from Site Approval through Construction

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Landfill Siting – Advantages and Challenges

ADVANTAGES

- Large Open Space
- Access for Construction
- Remote Location
- Limited Shading
- Inexpensive Land
- Use of Underutilized Land
- Increased Site Monitoring

CHALLENGES

- Permitting Restrictions
- Settlement Issues
- Cap Restrictions
- Weight/Load Limits
- Interconnection Costs
- Slope Stability
- Erosion Control

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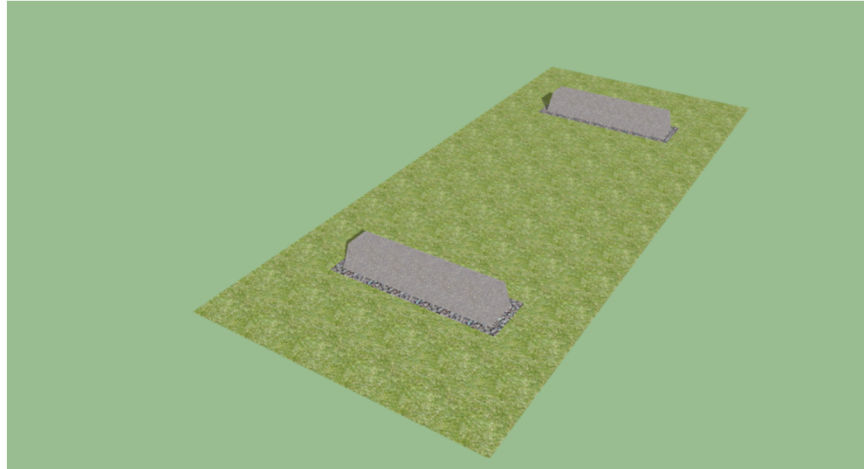
Key Design Considerations

- ELECTRIC GRID INTERCONNECTION
- NATURAL RESOURCES
- SOLAR TECHNOLOGY
- SITE TOPOGRAPHY AND SLOPE
- SITE SHADING
- SITE ACCESS, RESTRICTIONS

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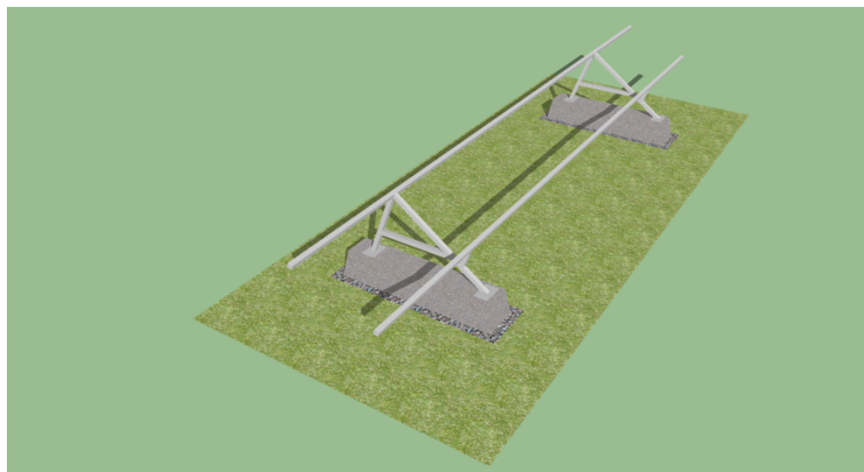
Typical Construction



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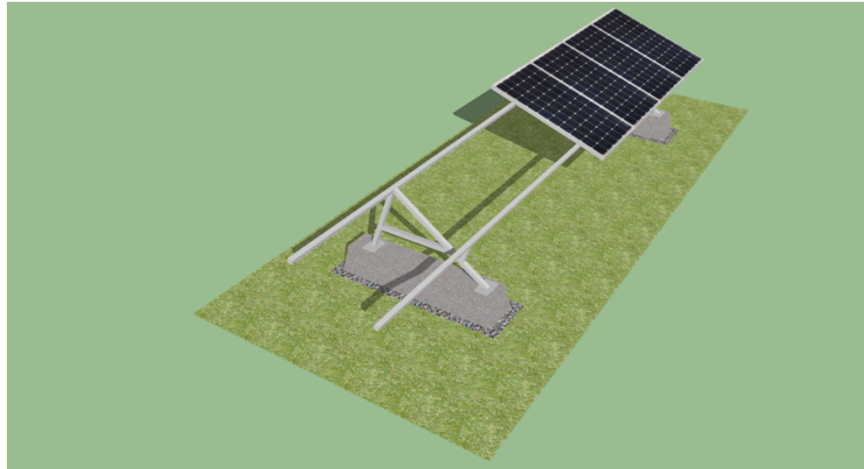
Typical Construction



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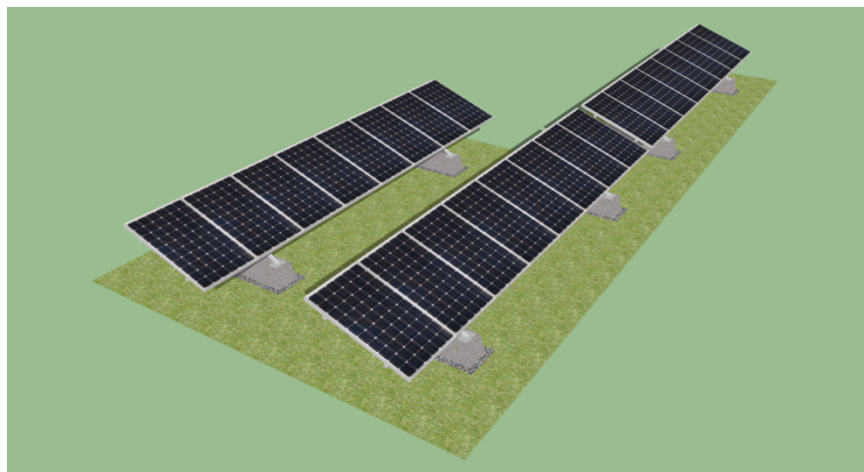
Typical Construction



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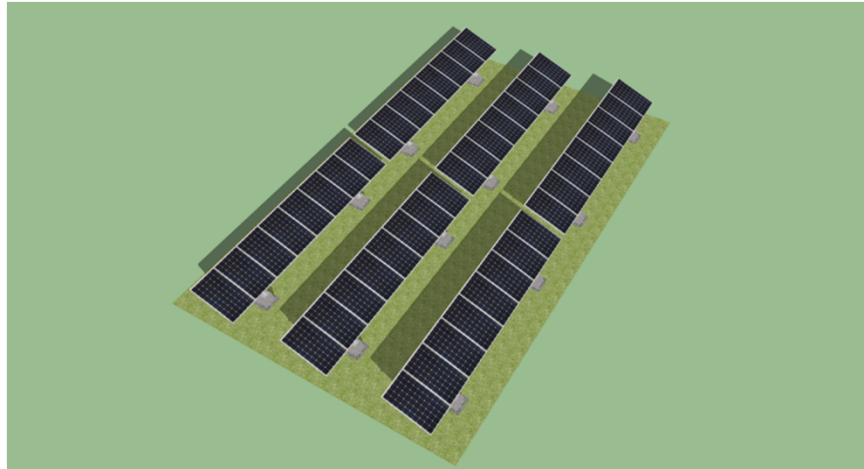
Typical Construction



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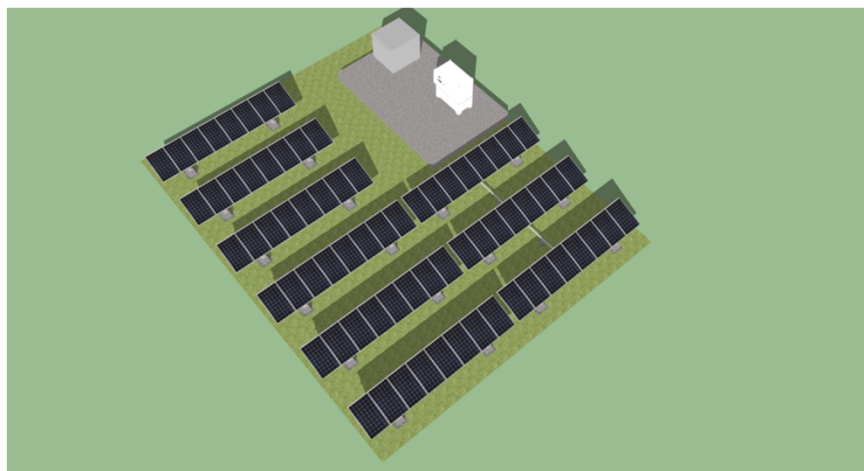
Typical Construction



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Typical Construction



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Typical Construction



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Settlement

LANDFILLS ARE GOING TO SETTLE !

- Typical magnitudes and types of settlement
 - Typical Magnitudes – several inches to several feet
 - Total Settlement – whole site settles at the same rate/magnitude
 - Differential – Different rates/magnitudes in different areas
 - Primary versus secondary compression.
 - *Primary*
 - *Large magnitudes/high rates*
 - *Rates slow after several years following closure*
 - *Secondary is long-term settlement occurring after primary*
- But how much settlement has occurred and how much settlement will occur?

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Settlement

- **Review historical documentation**
 - Types and Variability of Waste
 - Thickness of Waste
 - Thickness of cover
 - How long has the landfill been closed
 - Settlement/elevation measurements (settlement plates/topographic survey)
- **Subsurface Investigations**
 - Costly
 - May not result in useful information due to variability of waste.

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Settlement – What can we do?

- Design a system that can tolerate some differential settlement
 - Adjustable racking
 - Flexible connections
 - Row spacing to allow repair (i.e. ballast re-leveling)
- Adding more weight to the landfill will result in additional (primary) settlement
 - Minimize overall added weight of the system on the cap
 - Ballast/Racking Systems that minimize/distribute weight

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Storm Water

- A re-evaluation of the existing site storm water management system will be required to determine the impacts of the proposed development.
- Typically modules are not considered impervious
- Model for a 24-hour, 25-yr and 100-yr events.
- Design so that roads, ballast and equipment pads do not fundamentally change storm water flow.
- May require modifications to the storm water system.



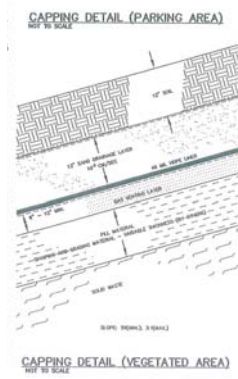
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Stormwater

Groundcover:

- Ground cover will be a major design consideration in how it impacts the landfill subgrade drainage layer, erosion and sedimentation control, and the effort required for future site maintenance. Ground cover may be gravel, or grass, or a combination of both.



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Storm Water - Groundcover

- Drip edge considerations
- Re-seeding with low growth, shade tolerant mixture and low light vegetation
- Row spacing considerations
 - Ability to mow between rows.
 - Allow sufficient light for growth
- Racking Height considerations



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Landfill Gas

- Landfills typically use combination of Engineering controls, Management controls and Monitoring to ensure gas does not pose unacceptable risk.

Solar Equipment Engineering Controls:

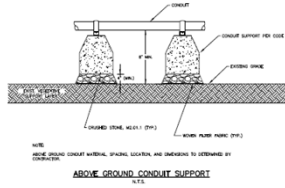
- Above grade structures designed to prevent gas accumulation
- Gas monitoring or warning systems
- Vapor barriers
- Venting systems
- Above grade conduit runs
- Any subsurface runs - gas proof fittings



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Landfill Gas – Engineering Controls



Above Grade Conduit Runs



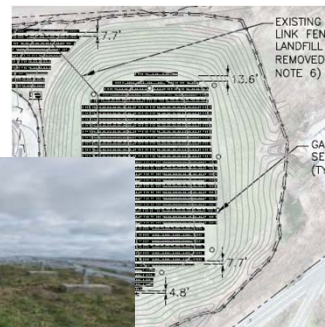
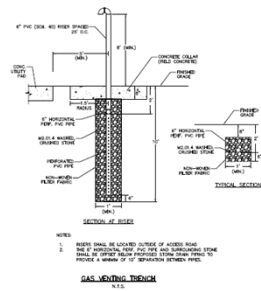
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Landfill Gas – Engineering Controls

Gas venting around equipment pads

Spacing around gas vents



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Landfill Gas – Engineering Controls

Gas well removal/relocation



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Landfill Gas

Management Controls and Monitoring:

- Do gas survey if uncertain
- Sufficient clearance from the solar arrays shall be provided for future maintenance and monitoring access.
- Any potential combustion issues between the gas wells and the solar arrays will be reviewed.
- Monitoring worker exposure during construction
- Design should keep solar equipment and conduits away from gas sources

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Geotechnical Concerns – Side Slope Stability

Challenges:

- Slope Failure
- Stability of anchoring system
- Storm water management
- Increased erosion
- Static and Dynamic Loading
- Snow and Ice loading
- Side Slope Repairs



Design Considerations:

- Maintain Existing slopes
- Remain 10 feet back of crest of slope
- Analyze geomembrane liner/soil interface friction angle (if present)
- Light weight PV module systems
- More robust footing/anchor system

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Geotechnical Concerns – Wind/Snow Loading

Challenges:

- Design for local wind speed
- Design for snow loads

While....

- Minimizing bearing pressure/dead load on capping soils and geomembrane liner



Design Considerations:

- Minimize height of array...while still providing clearance for cap mowing and vegetative growth
- Geometric design and orientation of dead load
- Light weight PV module systems
- Account for snow accumulation
- Combined loads – consider tilt angle

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Geotechnical Concerns – Sliding

Challenges:

- Sliding is a potential failure that should be considered when designing ballasted footings
- Sliding can occur due to the wind induced forces on the solar array system
- The wind not only tries to push the Solar Array system horizontally, but it also creates a lift which reduces the actual dead load
- Reduced dead load coupled with the horizontal wind force creates the possibility of a solar module and its foundation sliding horizontally

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Removal of Vegetation



Placement of Geotextile



Gravel for Leveling

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Structural Concerns – Ballast Design

Design Considerations:

- Tilt angle and tracking characteristics of the solar power system.
- Local design wind speeds where the solar power system is to be installed.
- Support and racking configuration.
- Overall solar module system size and weight.
- Local design codes and project requirements.
- Soil characteristics relative to friction, sliding, consolidation, slope stability, etc.

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Structural Concerns – Ballast Design

Types:

Precast ballasts seemed to be favored in Northeast

- No soil penetration.
- Minimal site excavation/preparation needed.
- Speed of delivery and installation
- Eliminates the need for cast in place concrete and all associated issues including forming, pouring, and dry time which can dictate the pace of the installation process.
- Accommodates most site locations and conditions



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Structural Concerns – Ballast Design

Racking solutions have emerged using approaches other than precast blocks

- Ballast trays for standard pavers
- Pour-in-place plastic forms,

These can...

- Reduce install time and racking costs.
- Provide ease of installation - *the racks are assembled first, while they are light. The weight is added after the system is lined up.*
- Some systems can reduce overall bearing pressure by spreading the load.



Solstice Mounting System

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Cap Integrity

Overall design must protect the integrity of the cap system including:

- Preventing damage to HDPE liners/low permeability soil layers
 - Designing equipment to limit bearing pressure on geomembrane liner to acceptable levels
 - Use of low ground pressure equipment during construction
- Preventing damage to subgrade drainage and gas collection systems
 - Designing equipment layout to avoid structures and lines
 - Use of low ground pressure equipment during construction



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Cap Integrity

- Preventing damage to storm water management system (*including drainage swales and vegetative cover*)
 - Designing equipment layout to avoid structures and swales
 - Design to limit alteration to existing storm water flow
 - Use of Drip edge erosion control if necessary
 - Allow adequate distance between rows to maintain vegetation
 - Raise panel height to allow for access/limit shading to cover below system
 - Maintain proper sediment and erosion controls during construction
- Preventing slope failure
 - Route/collect drainage away from slopes
 - Limit additional weight on slopes
 - Limit proximity of roads and system to slope



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Site Development Considerations & Concerns



Access Road:

- An access road will be required for both construction period and long-term maintenance access.
- Access roads must not interfere with storm water flow.
- Temporary access roads to allow construction equipment.
- Removal of temporary access roads following completion of construction

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Site Development Considerations & Concerns

Site Security:

- Prevent unauthorized access
- Protect against theft or vandalism
- Meet electrical codes

Consider if:

- A determination needs to be made on whether the entire site needs to be fenced or just the solar array system.
- What level of security is required for the solar development area in order to provide limited access and to insure liability considerations are addressed?
- The security measure should provide a mechanism to provide access for the landfill gas management system and any other monitoring required for the landfill permitting requirements.



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Site Development Considerations & Concerns

- Fencing – *Perimeter or system specific*
 - Can be very costly
 - May require specific design
 - Wind/ snow loading
 - Ballasted to prevent cap penetration
 - Allow for animal migration
- Security cameras/Motion detectors
 - Provides cost effective full-time monitoring

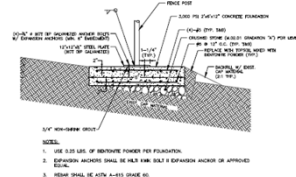


FIG. ALTERNATE #1
BALLAST FENCE FOUNDATION
NOT TO SCALE

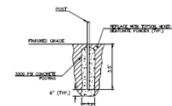


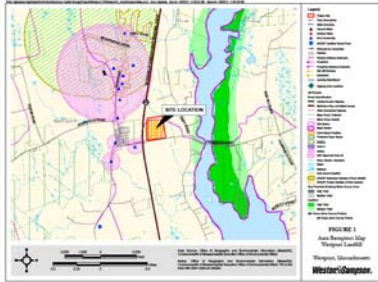
FIG. ALTERNATE #2
STANDARD FENCE FOUNDATION
NOT TO SCALE

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Site Development Considerations & Concerns

Resource Area Concerns



- Natural Resource Areas
- Wetlands
- Endangered or Threatened Species
- Aquifer Protection Areas
- Cultural Resource Areas
- Historic Landmarks
- Special Zoning Districts

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Site Development Considerations & Concerns

Example Design practices to minimize impact:

Turtle Habitat Area:

- ❖ Fence adjusted to allow Turtles to cross under fence.

Nesting Birds

- ❖ Grass mowing limited to certain times of to minimize disturbance of nesting birds.
- ❖ Construction sequencing to avoid impact

Endangered Moth Species

- ❖ Prime and subprime moth habitat delineated to allow maximize size solar array and clearing to minimize shading.

Archaeological Resources

- ❖ Visual simulations to demonstrate no significant affect on historic or archaeological resources.

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Chatham Landfill Ground Mounted Solar PV Project



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Chatham Landfill Ground Mounted Solar PV Project



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Lessons Learned - Engineering

- Importance of Interface Friction on Sliding
- Cable Trays vs. Underground Conduit
- Repairing geomembrane liners
- Separation of atmospheres around methane sources
- Differences in racking systems
- Differences in ballasts (precast vs. pour-in-place)

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Construction Design Considerations

- Limiting the depth of any excavation
- Avoid using heavy equipment on cap
- Use low ground pressure equipment on cap
- Restrictions on laydown areas
- Maintaining erosion control
- Maintaining storm water controls
- Soil reuse of excavated materials
- Health and Safety Plan – Trained workforce

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Lessons Learned - Construction

- Survey stake installation on landfill cap
- Staking erosion control into landfill cap
- Keeping heavy equipment on roadways
- Soil caps vs. geomembrane caps
- Ballast layouts and who performs them
- Expect having to make repairs to both soil and geomembrane liners
- Costs for construction oversight

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Permitting Process

Federal

Stormwater Notice of Intent (NPDES)
Federal Aviation Administration

State

Agency Landfill Post Closure Use
Natural Heritage Endangered Species
Wetlands

Local

Utility Interconnection
Planning and Zoning
Local Historical Commission
Local Conservation Commission
Site Plan Approval
Special Permit
Building/Electric

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Lessons Learned - Permitting

- Anticipate time needed for permitting and then double it
- Interconnection permit – Get an early start
- Each state has their own landfill reuse permit with specific requirements
- Wetlands and species of special concern (bats, turtles, moths, birds, etc.)
- Cultural and historical issues

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Needham, MA



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Questions?

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