Solar Installations on Closed Landfills: Technical and Regulatory Considerations

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1

Goal

- Summarize the findings from 2009 research, including the following:
  1. The opportunity for solar energy on landfills
  2. Relevant solar power system technologies
  3. Technical challenges
  4. Regulatory complications
  5. Case evidence

Problem Statement

- Thousands of closed landfills across US[1]
- EPA OSWER OCPA currently encouraging placement of clean energy on contaminated lands
- Recurring challenges:
  - Technical (e.g. cap integrity and site remedy)
  - Regulatory (state and local)

3

Solar Power Systems

- Ground mounted system components
  - Stanchions
  - Footings
    - Shallow concrete pillars;
    - Slab;
    - Ballasted frames;
    - Driven pile

Solar Power Systems

5

Solar Technologies

- Photovoltaic
  - Panels
    1. Thin film/amorphous
    2. Polycrystalline
    3. Monocrystalline
  - Mounting structures
    1. Fixed tilt
    2. Single axis tracker
    3. Double axis tracker

Solar Technologies

- Concentrating Solar Power (CSP)
  1. Linear concentrators
     1. Parabolic trough
     2. Fresnel reflector
  2. Power towers
  3. Dish/Engine Systems

Large scale[2] production

Small scale production

Weight Considerations

- PV panel weight
  - Thin film
    - Generally light weight
    - Flexible
    - Less efficient per unit area
  - Crystalline
    - Heavier
    - Rigid
    - More efficient (monocrystalline > polycrystalline)

Weight Considerations

Brand	Model	Watts	Weight (lbs)	Watts/ Pound	Dimensions (inches)	Cell Type*
Kyocera	KC 50T	50	10	5.00	25x26	P
	KC 130GT	130	26.8	4.85	56.1x25.7x2.2	P
	KD 180GX-LP	180	36.4	4.95	52.8x39x1.4	P
Mitsubishi	MF120EC4	120	25.4	4.72	56.1x25.4x2.2	P
	MF185UD5	185	43	4.30	65.3x32.6x1.81	P
Sanyo	190BA3	190	33	5.75	52x35x1.8	P
	HIT Power N 215N/HIP-215NKHA5	215	35.3	6.10	63.2x32x72.8	P
REC Solar	SCM 210WP	210	48.4	4.33	66.55x39.01x1.69	P
Sharp	Sharp 140	140	32	4.38	49x39	P
SunWize	SW150	150	44	3.41	66.61x30.27	M
SolarWorld	SW175	175	40	4.38	63.9x32x1.6	M
Uni-Solar	PVL-68	68	8.7	7.82	112.1x15.5x0.2	A
	PVL-144	144	17	8.47	216x15.5x0.2	A
Kaneka	G-SA060	60	30.2	1.99	39x39x1.6	A

Table 1 – Weight specifications for various solar PV panels. www.wholesalesolar.com

P=polycrystalline, M=monocrystalline, A=amorphous thin film

9

Weight Considerations

Courtesy of Tony Walker, Republic Services
twalker@republicservices.com

10

PV Weight Considerations

- System mounting
  1. Single and double axis sun trackers
  2. Fixed tilt
- Foundations
  1. Ballasted platform;
  2. Concrete footings (poured and pre-fabricated);
  3. Slab

Wind and Snow Loading

- IEC standards ~ 50 pounds per square foot mechanical loading (wind speed of ~105 mph)
- Consider how wind loading is impacted by operations and maintenance activities
- Snow loading and side slope stability

Technical Challenges: Landfill Settlement

- Processes
  1. Biochemical degradation;
  2. Physiochemical changes;
  3. Raveling;
  4. Any combination of 1-4[3]
- Dependent on waste
  1. Age;
  2. Depth;
  3. Type;
  4. Method of placement

Technical Challenges: Landfill Settlement

- Differential settlement
  - Impacts on site remedy
    1. Surface cracks;
    2. Water drainage system;
    3. Leachate and gas piping;
    4. Surface depressions;
    5. Underground utilities
  - Impacts on solar system structures
    1. Piers and footings;
    2. Aspect of solar panels

Technical Challenges: Landfill Settlement

- When settlement is a concern
  1. Tracking vs. fixed mounting structures
  2. Foundation materials
  3. Weight of solar array
- Mitigation
  1. Simultaneous closure and development
  2. Previously closed landfills

Technical Challenges: Cover Material Integrity

- Clearing and grading activities
- Cover thickness and risk to cap performance
  1. Redistribute or import new soil
  2. Support foundation
  3. Trenching for electrical lines
- Regulatory restrictions

Technical Challenges: Slide Slope Stability

- Slope instability generally decreases with time[4]
- Constructing on steep slopes
  1. Increased erosion and stormwater control
  2. Increased O&M costs
  3. Foundation considerations
- Snow and ice loading

Technical Challenges: Future Site Remedy Management

- Consider
  1. Settlement surveys;
  2. Landfill gas surveys;
  3. Gas extraction activities;
  4. Erosion inspections;
  5. Cap maintenance
- Access roads

Technical Challenges: Review

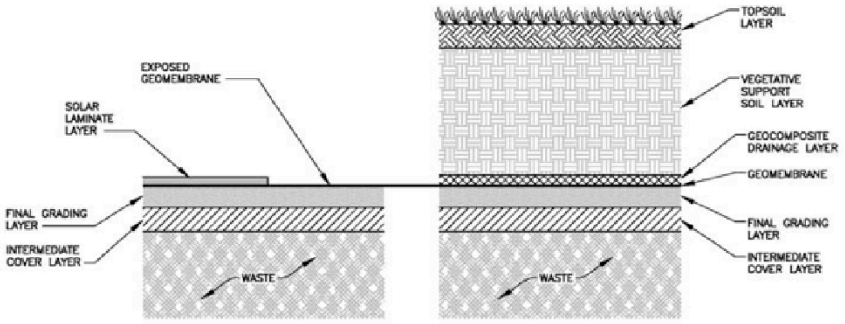
Complication	Challenges	Potential Remedy	Example
Steep side slope	• Anchoring solar panels • Stormwater • Erosion • Snow & wind loading	• Flexible PV laminates • Other light weight solar system that provides secure foundations • Re-grading and soil amendments	Tessman Road Landfill case study
Thin landfill cap cover	• Puncturing landfill cap	• Light weight, non-invasive foundations • Ballasted solar platforms and shallow footings	Fort Carson Army Base case study
Settlement	• Depressions • Infiltration • System foundations • Gas and leachate piping • Underground utilities	• Fixed tilt mounting structures • Light weight shallow footings and ballast • Pre-closure mitigation • Geogrid reinforcement • Selective placement (older waste, construction and demolition waste)	Pennsauken Landfill, Holmes Road Landfill
Wind and snow loading	• System connections • Foundation stability	• Use solar panels and mounting structures with high mechanical load rating • Avoid side slope placement	Not available
Routine cap maintenance	• Settlement surveys • Gas extraction activities • Erosion inspections • Vegetation management	• Plan solar array placement around monitoring well heads • Design panel height to allow for routine landscaping practices • Existing permanent access roads	Not available

19

Regulatory Complications: Permitting

- RCRA Subtitle D
- State and local government responsible
- 2008 survey[5]
  - 13 states responded
  - No ordinances against landfill development
- Permitted closure?
- Alternative cover design

Regulatory Complications: Permitting



Roberts, M., Perera, K., Alexander, T., Walker, T. "Alternative Landfill Closure: Solar Energy Cover System." 2008. Engineering design paper provided by Tony Walker, Republic Services, twalker@republicservices.com

21

Regulatory Complications Permitting

- Solid waste site assignment;
- Landfill property deed;
- Environmental site assessment;
- Closure permit and certification;
- Site plan;
- Landfill capping design plan;
- Post-closure use design plan;
- Storm waster drainage/Run-off control plan;
- Storm water erosion control plan;
- Landfill gas control and monitoring plan;
- Geotechnical stability and settlement analysis;
- Capping system interface;
- Utilities description;
- Environmental monitoring description;
- Qualitative health and environmental risk assessment;
- Post-closure monitoring and maintenance plan;
- Financial assurance;
- Wetlands protection plan;
- Documentation that the site is in compliance with state environmental protection statutes[6]

Regulatory Complications: Zoning and Land Use

- Refer to local government ordinances
- Notify local planning department and enforcement agencies
- e.g. Minnesota
  - MPCA owns 25 of 112 landfills under CLP
  - MPCA has right to limit land use on all sites[7]

Regulatory Complications: Environmental Site Investigations

- Environmental site investigation
  - Previously conducted ESI
  - Refer to local regulator
- Confirm location of well heads
  - Plan placement accordingly

Regulatory Complications
Liability

- CERCLA
- Brownfields Law
- EPA tools
- State liability protection

Regulatory Complications
Liability

State	Liability Protection
Massachusetts	Parties that complete a site cleanup have liability protection against Commonwealth claims for response action and natural resource damage costs once cleanup is complete.
Michigan	The Michigan Natural Resources and Environmental Protection Act of 1994 exempts landowners from liability for contamination if they perform an environmental investigation and submit it to state authorities within 45 days of purchasing the land.
New Jersey	New Jersey offers limited covenants not to sue, innocent land purchaser defenses, and Prospective Purchaser Agreements.
Oregon	Oregon offers a Prospective Purchaser Agreement.
Pennsylvania	Parties may be excluded from liability for state approved cleanups.
Wisconsin	The Wisconsin Remediation and Redevelopment program consolidates many state and federal programs into a single program to assist in the redevelopment of contaminated lands. Certain parties may be found to have limited liability through the state's Voluntary Party Liability Exemption.

National Association of Local Government Environmental Professionals, Northeast-Midwest Institute. " Unlocking Brownfields: Keys to Community Revitalization." Retrieved online from http://www.resourcesaver.com/file/toolmanager/CustomO93C337F65023.pdf on August 4, 2009.

Case Evidence:
Fort Carson

- **Site Name:** Fort Carson, SWMU 9
- **Location:** Fort Carson, CO, Region 8
- **Site Type:** Construction debris landfill
- **Size:** 2 megawatt
- **Panels**: First Solar FS-272 72.5 watt amorphous thin film
- **Inverters**: 500 kilowatt SATCON, 408 volts DC power to 200 volt AC, 2400 amps
- **Transformers**: 500 kilovolt-amps 200 volts/12,470 volts
- **Footings**: 30” wide x 30” deep, 120” long, 6” above grade, 24” below grade, 24’ on center spacing, anchor bolts for front and rear stanchions;
- **Stanchions**: 4” 60 gauge steel, 101” height in rear, 25” height in front;
- **Beams and supports**: 12 gauge steel C-channels, 287” long, 10” deep, slots cut into beams to allow for side-to-side adjustment, rails are 16 gauge z-channels, rails support module clips and are secured to the beams in front and rear.
- Vince Guthrie, Utility Programs, Fort Carson, Vincent.guthrie@us.army.mil

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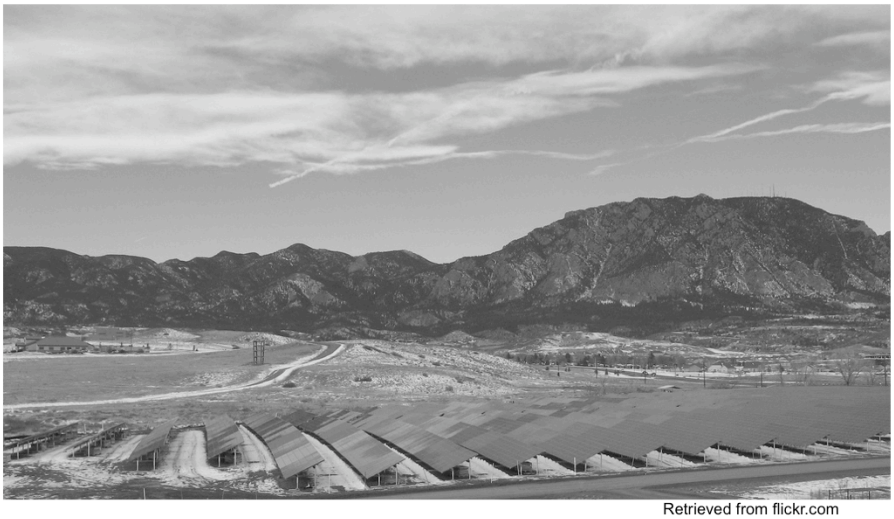
28



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Case Evidence:
Holmes Road Landfill

- **Site Name:** Holmes Road Landfill
- **Location:** Houston, TX, Region 6
- **Site Type:** Municipal solid waste landfill
- **Size:** 10 megawatt (projected)
- **Status:** Under review
- Fixed tilt single axis mounting structures;
- Poured concrete footings;
- Amorphous thin film solar photovoltaic panels;
- 500 kilowatt inverters;
- 21,740 AMAT line.
- Rob Lawrence, Senior Policy Advisor, US EPA Region 6, Lawrence.rob@epa.gov, 214-665-6580
- SRA International. “Solar Power Analysis and Design Specifications: Technical Assistance to the City of Houston.” Retrieved online from http://www.epa.gov/brownfields/sustain_plts/factsheets/houston_solar.pdf on July 30, 2009.

Case Evidence:
Nellis Air Force Base

- **Site Name:** Nellis Air Force Base
- **Location:** Nellis Air Force Base, NV, Region 9
- **Site Type:** Municipal solid waste landfill
- **Size:** 14.2 megawatts
- **Panels**: 72, 416 - SunPower Corporation, SANYO, SunTech Power Holdings, and Evergreen Solar, Inc. crystalline panels.
- **Mounting Structure**: 5,821 - SunPower T20 and SunPower Tracker single axis sun tracking systems;
- **Foundation**: Concrete footing foundations;
- **Inverter**: 54 - Xantrex Technology, Inc.
- Nellis Air Force Base Internal and Media Relations, 702-652-2407
- SunPower. “Nellis Air Force Base Case Study Fact Sheet.” Retrieved from http://us.sunpowercorp.com/business/success-stories/success-story-pdfs/federal-government/SPWRNellis_CS.pdf on August 4, 2009.
- Nellis Air Force Base. “Nellis Air Force Base Solar Power System Fact Sheet.” Retrieved from http://www.nellis.af.mil/shared/media/document/AFD-080117-043.pdf on August 6, 2009.

31

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Case Evidence:
Tessman Road Landfill

- **Site Name:** Tessman Road Landfill
- **Location:** San Antonio, TX
- **Site Type:** Municipal Solid Waste Landfill
- **Size:** 182 megawatt hours
- **Geomembrane**: Firestone 60 millimeter thermoplastic polyolefin.
- **Panels**: 1,050 Uni-Solar photovoltaic laminates (PVL) flexible panels positioned parallel to the landfill grade. Dimension for the panels is 15.5”x216”x0.25”.
- **Adhesive**: SikaLastomer-68 ethylene propylene copolymer.
- Tony Walker, Republic Services, 480-627-7088
- Solar Cap Project. Republic Services, Inc. 2008. Retrieved from http://www.fhsanantonio.com/video/republic/ on August 10, 2009.
- Roberts, M., Perera, K., Alexander, T., Walker, T. “Alternative Landfill Closure: Solar Energy Cover System.” 2008. Engineering design paper provided by Tony Walker, Republic Services, twalker@republicservices.com

Photo courtesy of Tony Walker,
Republic Services 34

Case Evidence: Pennsauken, NJ

- **Site Name:** Pennsauken Landfill
- **Location:** Pennsauken, NJ
- **Site Type:** Municipal Solid Waste Landfill
- **Size:** 2.1 megawatt
- **Panels**: Crystalline photovoltaic;
- **Mounting Structures** (top deck): Concrete ballasted;
- **Mounting Structures** (side slop): Pre-cast concrete footings.
- Mark Messics, P.E., Senior Business Development Manager, PPL Renewable Energy, mcmessics@pplweb.com
- Messics, Mark. “Case Study: Pennsauken Landfill Solar Project.” Presented at Renewable Energy at Closed Landfill Workshop. Mansfield/Foxboro Holiday Inn, Mansfield, MA. June 17, 2009. Retrieved from http://www.mass.gov/dep/energy/pennsauk.pdf on August 13, 2009.

Conclusions

- New and developing practice
- A number of benefits
- Recurring challenges
- Engineering measures available
- Complicated regulatory context

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[3]Christensen, T.H., Cossu, R., Stegmann, R. *Landfilling of Waste: Barriers*. London: E & FN Spon, 1994. Electronic.

[4]Misgav, A., Perl, N., Avnimelech, Y. "Selecting a Compatible Open Space Use for a Closed Landfill Site." *Landscape and Urban Planning* 55.2 (2001): 95-111. Electronic.

[5]Masson, P.T. 2008. "Should Landfills be Redeveloped: What do Various States Think?" Presented at 2008 Solid Waste Association of North America – 23rd Annual Northwest Regional Solid Waste Symposium. McMenamins Edgefield, Troutdale, OR. April 17, 2008. Retrieved from http://www.swanaoregon.org/symposium_2008.htm on July 21, 2009.

[6]Massachusetts Department of Environmental Protection. 2009. "Landfill Post-Closure Use Permitting Guidelines." Retrieved from http://www.mass.gov/dep/recycle/laws/policies.htm#lfpcguid on July 20, 2009.

[7]Minnesota Pollution Control Agency. "Closed Landfill Program – Land Use Planning." September 2008. Retrieved online from http://www.pca.state.mn.us/publications/c-clf1-02.pdf on August 11, 2009.

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