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Introduction

Renewable energy sources are expected to play a key role in initiatives for sustainable growth and development in the coming decades. An increase in regulations for the production of fossil fuels and environmental concerns have helped renewable energy sources gain acceptance. Table 1 presents a comparison of energy costs from nonrenewable and renewable resources.

Table 1. Energy Costs from Nonrenewable and Renewable Resources

Energy Source	Type	Cost ($/KWh)
Coal	Nonrenewable	0.03 - 0.04
Hydro	Renewable	0.02 - 0.03
Wind	Renewable	0.04 - 0.06
Biomass	Renewable	0.08 - 0.11
Geothermal	Renewable	0.05 - 0.12
Central Solar Systems	Renewable	0.12 - 0.18
Photovoltaic Systems	Renewable	0.20 - 0.30

Source: PNM Speakers Bureau, 2009.

The average price of electricity in the United States is expected to increase to about 16 cents per KWh by 2015. Even with substantial lifestyle changes, conservation, and improvements in energy efficiency, global energy demand is likely to more than triple within the next

50 years. The two main types of systems used for harnessing solar energy are:

1. Solar collectors with mirrored surfaces that reflect sunlight to heat liquid, generating electricity through steam power
2. Photovoltaic (PV) cells that absorb direct sunlight

Although solar energy is free, harnessing solar energy requires investment. Some factors that should be considered in the selection of solar harvesting systems include the following (Miggins, 2008):

1. Type of solar harvesting system to be used for a specific application (mono, poly, amorphous, ribbon, concentrated, silicon- or copper-based)
2. Solar density (watts per square foot)
3. Efficiency (conversion of light to energy)
4. Durability (ability to withstand environmental factors)
5. Physical properties of the surface and the solar system (heat tolerance, mounting, wiring, grounding, spacing requirements)
6. Appearance, form and function, and dual-use deployment
7. Manufacturer and availability, warranty, maintenance requirements, and useful life

Closed landfill sites generally are developed as open areas and public parks, but some sites have been developed for active uses such as sports complexes and shopping malls (Tansel, 1998). Recently, a number of closed landfills have been considered as potential sites for renewable energy generation (i.e., capturing energy from wind or sun). The city of Houston was awarded $50,000 from the U.S. Environmental Protection Agency (EPA) to develop a solar energy plant on a closed landfill to revitalize a 300-acre site near downtown (Barry and Tillman, 2008). Florida Power & Light (FPL) developed a solar energy project about half the size of a football field on a Sarasota County landfill, fulfilling a promise to customers (Mayk, 2006). The New Jersey Meadowlands Commission (NJMC) is planning to generate approximately 5 megawatts of energy from solar harvesting on a landfill to produce renewable energy and encourage businesses to take advantage of the state's growing green economy (Aberback, 2008). The Tessman Road Landfill in San Antonio, Texas, will be capped with a flexible solar energy–capturing cover consisting of more than 1,000 strips with photovoltaic silicon cells (Herrera, 2009). The placement of solar covers can reduce inspection and maintenance costs at the site while providing effective odor control and storm water management.

Landfill Characteristics

The design and operational characteristics of a landfill that may affect PV system installation and efficiency include the site area, topography, location, postclosure plans, cap system, and runoff control:

- **Area**: Closed sites are suitable to be developed as power parks if they have a large area with suitable orientation (i.e., south-facing).
- **Topography**: Evenness and symmetry in the landfill shape are important factors for the layout of a solar power–harvesting system. The shape of the landfill may affect the wind load and panel layout configuration. It is necessary to optimize the use of the topography in relation to wind load and panel layout for improved performance. The design and development of a site can be configured on the basis of the degree of compatibility of the finished site topography with solar energy–harvesting potential.
- **Urban and rural location**: Urban sites are closer to the power grid and the distribution system; hence, the losses during distribution are relatively small. Rural areas with high customer potential could be considered for solar systems. However, PV systems can provide a sustainable alternative to help meet the increasing demands in urban areas.
- **Postclosure plans**: This project evaluated the postclosure use of well-maintained landfill sites. It is necessary to reevaluate the implementation of the postclosure care plan and maintenance needs at the candidate sites for installation of the PV system for compatibility of the existing infrastructure with the installation and maintenance requirements of the PV system.
- **Geographical orientation**: Site slopes and orientation are important because of the path of the sun during the day and sun/earth rotation during the year. The angles at which the surfaces receive sunlight are critical for the efficiency of a PV system. Sites with larger areas facing south, flat areas, and slopes between 0.2 m/m and 0.4 m/m are more suitable for installation of solar harvesting systems.
- **Cap system**: In the solar energy interaction with the PV system, it was seen that photovoltaic systems follow the most efficient angle by which the sun's rays strike the solar panel. This angle is called the angle of incidence. A good angle of incidence produces more energy. For this reason, solar panels have to be tilted to benefit from the best range of the solar incidence. The tilted panels must be mounted on foundation systems that can withstand wind loads while being compatible with the stability of the cap.
- **Runoff control**: Runoff management in landfills is achieved by infiltration of water first through a vegetative support layer and then through a soil layer where the water is conveyed to surface water ditches and ponds. Placement of the solar panels on the landfill may affect the runoff quantity and patterns. Control and maintenance of the vegetative cover must be evaluated so that suitable vegetative cover that requires less maintenance can be utilized to minimize site access.

Solar Energy Capture Systems

Although solar energy is a freely available renewable resource, its utilization to generate electricity involves either photovoltaic or solar thermal technologies.

- **Photovoltaic technology**: Photovoltaic technology utilizes solar panels consisting of solar cells constructed with semiconducting materials such as silicon. When sunlight hits the panel, a chemical reaction (a photovoltaic effect) takes place, resulting in electricity generation. The generated electricity then is collected through proper wiring systems (http://www.epa.gov/cleanenergy/energy-and-you/affect/non-hydro.html#solar). Photovoltaic systems can be either fixed tilt or tracking. Each type requires a suitable foundation that varies with the panel weight, wind loads, and other environmental factors.
- **Solar thermal technology**: Solar thermal systems collect solar energy through the use of mirrors or concentrators to heat a liquid and create steam, which then is used to generate electricity (http://www.epa.gov/cleanenergy/energy-and-you/affect/non-hydro.html#solar). Low-temperature solar thermal systems (<100°C/212°F) involve low concentration of sunlight and generally are used for space heating or hot water preparation in homes and industrial applications. High-temperature solar thermal systems (>100oC/212oF) use various mirror configurations to concentrate the sunlight and convert the energy into high-temperature heat and then to steam. Steam is used to generate electricity through the use of a turbine generator or by running chemical reactions.

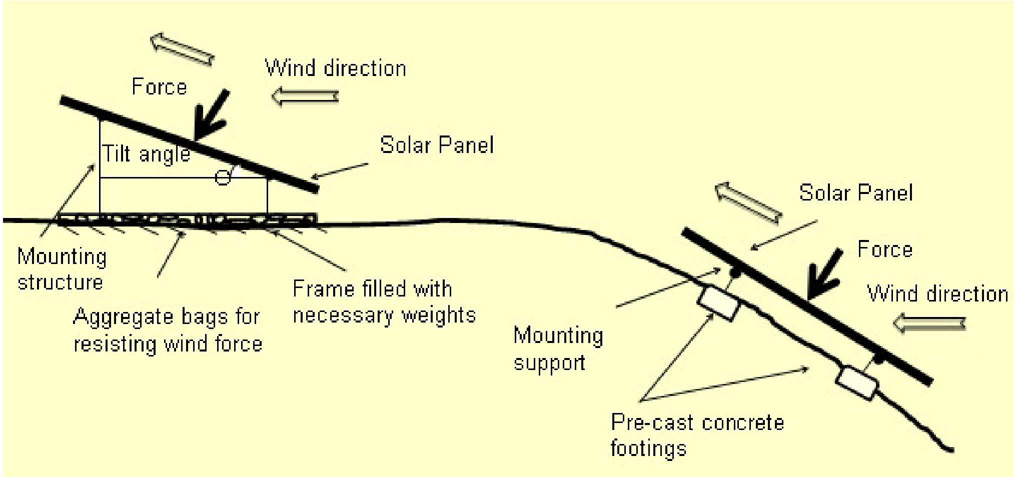
Placement of Solar Energy Systems on Closed Landfills

Table 2 summarizes the potential challenges and remedies at landfill sites for the installation of solar panels. For example, the Tessman Road landfill employed flexible PV laminates side slopes (18 degrees) directly attached to an exposed geomembrane cover. Combining exposed geomembrane covers with lightweight panels (flexible PV strips) was a remedy for problems associated with steep side slope. In the case of the Pennsauken landfill project in New Jersey, shallow precast concrete footings were used to provide a strong foundation for the PV system on the sloped surfaces, overcoming complications of side slope installation. This facility used a ballast foundation with crystalline panels on top for maximum energy production. In general, solar panels are fixed to aluminum or steel frames by using stanchions, and the frames are supported by concrete foundations by ballasted frames, concrete slabs, or precast concrete footings. Among these alternatives, concrete slabs are generally heavier than concrete footings and ballasted frames. They are also subject to cracks resulting from settlement and may be problematic on landfills because of concerns about settlement and side slope stability. Differential settlement may be a concern with array piers and footings. Ballast systems are the lightest and are preferred for flat surfaces of landfills. Foundation selection depends on factors such as the bearing capacity of the soil, landfill settlement, cap depth, and the weight of the PV system. Figure 1 shows the placement of solar panels on the top and side slopes of a landfill.

Table 2. Potential Challenges and Remedies at Landfill Sites for Installation of Solar Panels

Challenge	Impact	Potential Remedy	Example
Steep slopes	Storm water Erosion intensity High wind loads Foundation stability for anchoring solar panels	Flexible PV laminates Other lightweight solar systems with secure foundations Regrading Use of soil amendments	Tessman Road landfill Pennsauken landfill
Cap system and final cover	High maintenance needs of cap Need for regrading to increase thickness of final cover Integrity of cap system	Lightweight, noninvasive foundations Ballasted solar platforms and shallow footings	Fort Carson army base
Settlement	Uneven surface Structural stress at settlement areas Infiltration and water ponding Foundation integrity Integrity of gas system Integrity of leachate piping Integrity of underground utilities	Fixed tilt mounting structures Lightweight shallow footings and ballasts Preclosure mitigation Geogrid reinforcement Selective placement locations (i.e., older waste, construction, and demolition waste)	Pennsauken landfill, Holmes Road landfill
High wind and snow loads	System connections Foundation stability	Mounting structures with high mechanical load ratings Avoidance of side slopes	NA
Cap and site maintenance needs	Settlement surveys Gas extraction activities Erosion inspections Vegetation management	Placement of solar array around monitoring well heads Panel height to allow routine landscaping needs Existing permanent access roads	NA

Figure 1. Placement of solar panels on top and sloped surfaces of landfill



Power tower and linear concentrating solar power systems require large areas for optimal operational capacity. Hence, they are best suited for large-scale production plants with a capacity of at least 50 megawatts (MW). Large-scale power production capability is also required to optimize linear concentrator and power tower solar systems. Among the available concentrating solar power systems, dish/engine systems can be used on landfills for smaller-scale production. Currently, PV solar systems have been the most commonly used solar energy–harvesting systems that have been implemented and tested on landfills. The technical feasibility of solar energy harvesting on landfills depends on compatibility of the PV systems with the existing landfill components. Important design and operational compatibility considerations are described below.

Wind and Snow Loads

Wind loads increase the stress on the supporting structures by adding weight to the solar panels and components, resulting in failure of the solar energy system. Accumulation of ice and snow imposes additional weight on the system, increasing the stress on the foundation. Typically, panels in the crystalline and amorphous thin film cell categories are certified for wind speeds of 105 miles per hour (i.e., mechanical loading of 50 pounds per square foot) (Sampson, 2009). Hence, for hurricane-prone regions such as Florida and regions affected by heavy snow, mounting systems certified to resist higher mechanical loadings must be considered. Some landfills require regular top surface maintenance and the placement of mounting structures high enough to allow for site maintenance activities such as mowing grass. Taller systems are affected by increased weight and stress as a result of high wind loads and longer pier lengths and should be supported by stronger foundations (Sampson, 2009).

Side Slope Stability

Placement of panels on sloped surfaces (especially south-facing slopes at higher altitudes) can achieve maximum solar radiation (Sampson, 2009). Installation of panels on side slopes can be challenging in terms of ensuring good foundation support, protection from erosion, storm water control, shading, and settlement effects. Regular operation and maintenance activities could increase the need for side slope repairs, resulting in additional costs. Remedial measures such as vegetative surfaces and engineered retaining walls can reduce erosion effects (Sampson, 2009). For landfills with steep slopes, regrading and the use of additional topsoil can help achieve suitable slopes capable of supporting solar system placement (Sampson, 2009). In general, steep slopes require strong foundations (poured concrete or precast concrete footings) with lightweight solar components. Hence, lightweight solar components of appropriate mechanical loading rates with strong foundations that can resist wind loads and any additional load requirements produced by snow or ice are preferred for sloped surfaces. It is also necessary to assess slope stability before starting construction activities to ensure the integrity of the cap and maintain adequate slope stability (Sampson, 2009).

Landfill Settlement

Physicochemical, mechanical, and biochemical processes change the properties of disposed waste over time and cause settlement. Landfill settlement over time could result in the formation of surface cracks to the final cover; damage to the leachate, gas collection piping, water drainage systems, and underground utilities; and formation of water-holding depressions (Sampson, 2009).

Shading Effects

Maximum energy generation from solar energy harvesting systems can be achieved by minimizing the shading of the panels. Solar system arrays should be placed with adequate spacing so that they do not shade one another and to balance the placement of system components (inverters, wiring, and combiner boxes). For instance, the Holmes Road landfill adopted a layout of 15 acres/MW to avoid shading effects and allow for the necessary balance of system components (SRA, 2008).

Solar System Weight and Foundation Considerations

The weight of the solar panels and mounting structures selected for a project is of great significance in deciding which solar harvesting system to install on a landfill cap. Monocrystalline, polycrystalline, and amorphous thin film cells are available with varying weights, efficiency levels, and costs. Mounting and foundation structures supporting the solar panels vary depending on the weight of the panels, additional loads resulting from wind or snow or ice, side slope stability, and settlement effects. Both monocrystalline and polycrystalline panels (rigid panels) require rigid frame mountings to prevent cracking (Sampson, 2009). Because of the output advantage of the rigid panels over thin film panels, rigid panels are preferred when there is limited space. Amorphous thin film cells (flexible panels) are generally lighter and lower in cost but have lower efficiency for power production per unit area. These panels are preferred when weight is a concern or there is a need to provide a strong foundation because of side slope conditions. Amorphous thin film cells (i.e., UniSolar model PVL flexible laminate amorphous thin film cells) have been used on sloped surfaces by attaching the PV strips directly to the geomembrane of the landfill cap. Since PV strips are capable of producing high output per unit weight and do not require mounting structures or foundations, they were used successfully on slope surfaces (18 degrees) at the Tessman Road landfill and reduced side slope erosion. Tracking systems weigh more than fixed systems as a result of their increased need for mounting structures and foundations. Tracking systems require foundations with deeper piers and footings, sometimes supported by precast concrete footings. Deeper piers, if used as foundation support, could increase the weight on the landfill, increase settlement, or subject the installation to problems with side slope stability (Sampson, 2009). The landfill cap depth needed to support the PV system depends on the deadweight loads contributed by the piers and footings (SRA, 2008). Selection of a suitable PV system depends on the weight of the system (tracking systems are heavier than fixed tilt systems), the type of waste and its properties, and side slope stability (Sampson, 2009). In general, flat surfaces have fewer foundation requirements than sloped surfaces and are the preferred locations for installing heavy crystalline silicon solar cells with suitable foundations (i.e., ballast systems) for maximum energy production. For sloped surfaces, lighter panels with strong foundations should be considered (precast or poured concrete footings) and generally are preferred (Sampson, 2009).

Maintaining the Integrity of the Cap System

Clearing, filling, grading, and compaction activities generally are performed during the development of a landfill for PV system installation. During installation of solar panels, extreme care must be taken to avoid damaging the landfill cap or exposing the waste. If the site is heavily vegetated, thinning of vegetation may be necessary (Sampson, 2009). Installation of solar systems on landfills requires good foundations for system placement, which depends on landfill cap characteristics to support the footings. Generally, during the planning stage, it is necessary to consider the cap design and the anticipated loads by the PV system and its components. For most cases, prefabricated concrete piers or concrete slabs should be sufficient to support a solar system. Existing or future landfill gas-to-energy recovery infrastructure also should be considered (Sampson, 2009). An adequate soil layer should exist for trenching activities (a minimum of 14 inches of soil is required to trench for electrical line placement) with no or minimal impact on clay or geosynthetic liner (Messics, 2009; Sampson, 2009). If the landfill requires regular top surface (cap) maintenance (e.g., mowing of grass), placement of structures high enough for the operation of mowing equipment beneath the structures should be considered. Using short grasses for vegetation may be preferred to decrease the mowing activities and avoid disturbance to the panels.

Environmental Suitability

In the United States, a flat or south-facing slope is optimal for solar energy capture. The solar capture depends on the latitudinal location of the site. Placement of panels on sloped surfaces (especially south-facing slopes at higher altitudes) can achieve maximum solar radiation and benefit the project. However, it is necessary to provide a strong foundation, account for erosion and storm water control, and minimize shading effects (Sampson, 2009). Side slopes of 3:1 (18-degree slope) are preferred in landfills. Slopes greater than 5 degrees are affected by erosion effects, shading, and storm water, which have to be considered in solar system installation. Engineered retaining walls or vegetative surfaces can improve slope stability, and additional soil may be required to improve slope characteristics. Because of slope stability limitations, lightweight panels with strong foundations (poured or precast concrete footings) generally are recommended.

Environmental considerations for developing closed landfills as power parks include reducing greenhouse emissions, encouraging environmental sustainability, bettering the aesthetics of the site, and adding a renewable energy system for power production. One of the most important aspects of the use of solar systems is the reduction of greenhouse emissions. For each KWh of solar energy installed in the United States, about 7.18×10^{-4} metric tons of CO_2 are avoided.

References

Aberback, B. NJMC to Generate Solar Power on Landfill. NJMC news release, October 2, 2008.

Barry, D., and Tilman, T. Houston Awarded $50,000 from EPA for Solar Project. U.S. EPA, news release, July 29, 2008.

Herrera, T. Solar Power Landfill Cover Goes Live in Texas. greenbiz.com news release, April 6, 2009.

Mayk, L. FPL Has Sunny Spot for Solar Panel Project. Herald Tribune, Sarasota, FL, March 18, 2006.

Messics, M. Case Study: Pennsauken Landfill Solar Project. Presented at Renewable Energy at Closed Landfill Workshop, Mansfield, MA, June 17, 2009.

Miggins, J. Harvesting Solar Energy Overview of Systems: Options and Benefits of Solar Energy Systems. Seminar presentation, 2008. http://files.harc.edu/Projects/CultivateGreen/Events/20070212/HowHarvestSolarEnergy.pdf.

PNM Speakers Bureau. Customer Solar Energy Program Brochure, 2009.

Sampson, G. Solar Power Installations on Closed Landfills: Technical and Regulatory Considerations. Prepared for U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Office of Superfund Remediation and Technology Innovation Washington, D.C., September, 2009. http://www.clu-in.org/download/studentpapers/Solar-Power-Installations-on-Closed-Landfills-Sampson.pdf.

SRA International. Solar Power Analysis and Design Specifications: Technical Assistance to the City of Houston, 2008. http://www.epa.gov/brownfields/sustain_plts/factsheets/houston_solar.pdf.

Tansel, B. Land Use and Development Experiences with Closed Landfills. Journal of Solid Waste Management and Technology, vol. 25, no. 3–4, pp. 181–188, 1998.

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1. *ecd.fan* Says:
   March 9th, 2011 at 2:54 am

   Those industry-leading light-weight thin-film solar laminate panels used in both the Tessman Road landfill project in San Antonio as well as here in the Hickory Ridge project in Atlanta are made by Uni-Solar Ovonics, a subsidiary of the Michigan company Energy Conversion Devices [ticker symbol ENER].

   The E.P.A estimates there are approximately 100,000 closed landfills {ideally suited for similar solar laminate panel projects}.

   The story as aired on FoxNews… http://www.youtube.com/watch?v=sXkTLKhGLY0

   Uni-Solar's website: http://www.uni-solar.com/products/

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