FUTURE ASPECTS SOLAR PANEL INSTALLATION ON CLOSED LANDFILLS

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ABSTRACT

A landfill site is a site for the disposal of waste materials by burial and is the oldest form of waste treatment. This paper presents an examination of the current complications to placing solar systems on closed landfills while also providing applications for additional study in the area of landfill and contaminated lands development. The recent push to develop renewable energy resources has already led to a few conflicts, as plans for large-scale solar installments raise concerns about impacts to wildlife habitat. Development of contaminated lands in general and closed landfills in particular for the placement of renewable energy is a relatively new and growing practice. This paper examines the current nature of solar energy developments on closed landfills using the following focal areas: (1) solar power system considerations with respect to landfill applications, (2) landfill technical and engineering considerations. The U.S. Environmental Protection Agency (EPA) Office of Solid Waste and Emergency Response (OSWER) Center for Program Analysis is encouraging the reuse of contaminated lands, including properties with closed landfills, for siting clean and renewable energy facilities. Contaminated lands encompass sites that are undergoing remediation or have completed remediation under various cleanup programs, such as Superfund and brownfield sites.

KEYWORDS: *Solar panel, Landfills, EPA, geomembrane,*

I. INTRODUCTION

Historically, landfills have been the most common methods of organized waste disposal and remain so in many places around the world. Landfills may include internal waste disposal sites (where a producer of waste carries out their own waste disposal at the place of production) as well as sites used by many producers. A landfill also may refer to ground that has been filled in with rocks instead of waste materials. As demand for new land increases, landfills are becoming valuable for their development potential (EPA, 2002).

Closed landfill sites continue to receive stringent environmental monitoring and controls because of the following reasons. Leachate is a product that results from water contacting waste. A leachate collection system was constructed at the Britannia Sanitary Landfill Site in order to prevent leachate from migrating off-site. Methane is a landfill gas produced naturally as waste decomposes. Methane gas is collected through the leachate collection system, then drawn to an on-site flare for controlled burning. Litter fencing and dust control measures has been strategically placed around the site.

II. TYPICAL OPERATIONS & PROBLEMS

In non hazardous waste landfills typically various techniques are applied. Firstly the waste collection underwears in landfill operations are weighed at a weighbridge on arrival and their load is inspected for wastes that do not accord with the landfill's waste acceptance criteria. Afterward, the waste collection vehicles use the existing road network on their way to the tipping face or working front where they unload their contents. After loads are deposited, compactors or bulldozer are used to spread and compact the waste on the working face. Before leaving the landfill boundaries, the waste collection vehicles pass through a wheel cleaning facility. Typically, in the working face, the compacted waste is covered with soil daily. Alternative waste-cover materials are several sprayed-on foam products and then removed the following day prior to waste placement. Waste compaction is critical to extending the life of the landfill.

A large number of adverse impacts may occur from landfill operations. Damage occurrence can include infrastructure (e.g., damage to access roads by heavy vehicles); pollution of the local environment (such as contamination of groundwater and/or aquifers by leakage or sinkholes and residual soil contamination during landfill usage); off gassing of methane generated by decaying organic wastes; harboring of disease vectors such as rats and flies, particularly from improperly operated landfills, which are common in developing countries; injuries to wildlife; and simple nuisance problems (e.g., dust, odor, vermin, or noise pollution).This list is growing day by day. But we can easily overcome these problems by installing solar panels on closed landfils.

Figure 1: Land fill operation site

III. SOLAR POWER ON CLOSED LANDFILLS - THE NEW APPLICATION HAS BEEN TAKEN

- Renewable energy sources are expected to play a key role in initiatives for sustainable growth and development in the coming decades. Using closed landfills to generate clean, renewable energy is an emerging trend that can create jobs, deliver low-cost energy, and help reduce the environmental impact of our energy production. Closed landfills have traditionally been a vastly underutilized resource, which can have a negative impact on the local tax base or be seen as a business liability. Municipalities and private industries with closed landfills now have an opportunity to capitalize on this untapped resource by siting revenue-generating, clean, renewable energy facilities on these properties.
- Closed landfills often offer the right characteristics for a solar installation: plenty of open space and good sun exposure. Many incentives have emerged to make developing solar power facilities an attractive and affordable option.
- Building a solar facility on a closed landfill brings an underutilized land resource back into productive use, can provide low-cost renewable energy, and reduces a community's carbon footprint. On the other hand, there are certainly important technical challenges to overcome when developing this type of facility. In particular, site stability and impacts to the landfill cap must be carefully considered.
- Policy and funding support for siting solar installations on closed landfills is increasing. This includes initiatives from the EPA Office of Solid Waste & Emergency Response, and financial incentives from many state governments that can offset a substantial portion of the capital costs of these projects.
- An increase in regulations for the production of fossil fuels and environmental concerns have helped renewable energy sources. 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. 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. 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.

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

- Solar collectors with mirrored surfaces that reflect sunlight to heat liquid, generating electricity through steam power.

- 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:

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

IV. LANDFIL CHARACTERISTICS

The design and operational characteristics of a landfill that may affect PV system installation and efficiency include the site area, topography, location, post closure 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.
- **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.
- **Post closure plans**: This project evaluated the post closure use of well-maintained landfill sites. It is necessary to reevaluate the implementation of the post closure 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 requirement of 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.

V. 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 system. Generally speaking, most large-scale solar developments have employed the use of PV systems. PV solar energy systems have a number of different attributes that are relevant to installations on landfill caps, including energy output ratings and weight characteristics of the different cell types and support components available. Both fixed tilt and single and double axis sun-tracking mounting structures are available for PV ground installations. Fixed tilt mounting structures consist of panels installed at a permanent angle that maximizes receipt of solar radiation throughout the year, based on the site's latitude.

Figure 2: Fixed tilt PV solar array at Fort Carson, CO

- **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.

VI. PLACEMENT OF SOLAR ENERGY SYSTEMS ON CLOSED LANDFILLS

Following Table 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. 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. 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. . 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.

Table: 1 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 regarding 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	
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	

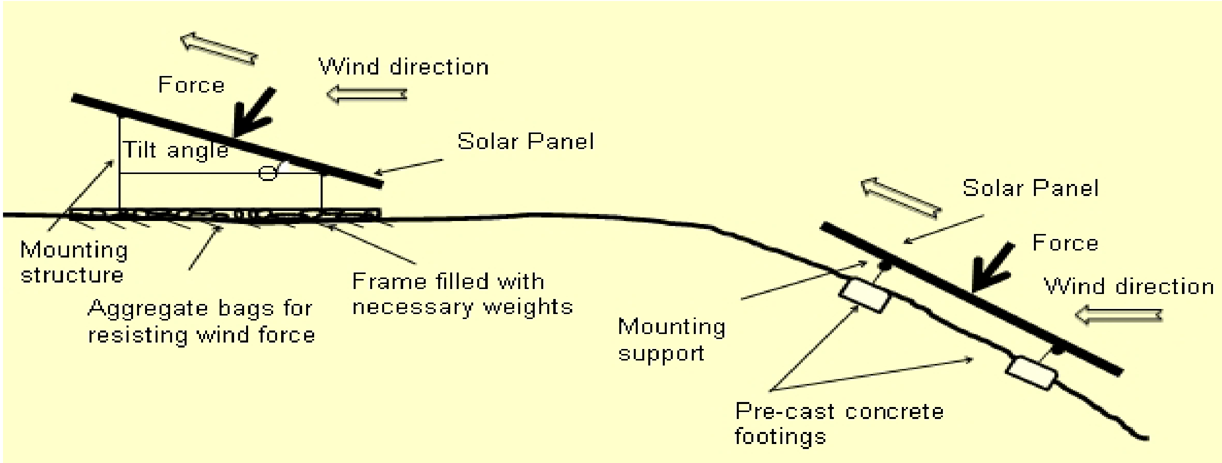

Figure 3: Placement of solar panels on top and sloped surfaces of landfill

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.

VII. 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. Because of the output advantage of the rigid panels over thin film panels, rigid panels are preferred when there is limited space. Amorphous (i.e. UniSolar model PVL flexible laminate amorphous thin film cells) 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. These are 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. The landfill cap depth needed to support the PV system depends on the deadweight loads contributed by the piers and footings. 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. 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.

VIII. SHADING EFFECTS IN SOLAR CELL

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 component.

IX. 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. 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. 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. 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.

X. ENVIRONMENTAL SUITABILITY

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. 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.

XI. SOLAR POWER PARKS AS ROLE MODEL ON CLOSED LANDFILS

Figure 4: Solar power Parks set up

Most recently, citizen groups in Colorado's San Luis Valley have challenged plans for a large solar facility and associated power lines, saying that solar facilities should be located closer to the areas where the power is used. Redeveloping brownfields in urban areas as renewable power sites could help address such concerns. EPA has met with state and local governments, stakeholders from the renewable energy sector and others to get feedback on potential obstacles. A partial answer to this dilemma may come from the EPA, which is trying to find ways to use brownfields as sites for renewable energy development. Abandoned industrial areas, closed landfills and former gas stations polluted by oil are among the locations under consideration. The agency has issued a draft plan that's open for public comment. The draft builds on the work that's been done with stakeholders since Sept. 2008. According to the EPA, there is at least anecdotal evidence to suggest that siting projects on brownfields can help cut the length of time it takes to get project permitted. Land costs are often lower, and there may be less public opposition. Part of the draft plan includes public outreach to show communities some of the potential advantages of brown field sites.

XII. CONCLUSION

Renewable energy, while viewed similar to any other redevelopment on a contaminated site, has practical differences from other types of reuse. Unlike many traditional reuses for contaminated sites, renewable energy can be sited on some sites even with cleanup work ongoing. While some at EPA have been encouraging this practice, there is no guidance for employees or the public to help them decide if this is appropriate at a particular site. Additionally, practical guidance for EPA employees and the public on siting renewable energy on previously contaminated sites would also help encourage this practice. The strategy of developing clean and renewable energy on formerly contaminated lands is a recent and growing movement. Closed landfills in particular encompass substantial potential to meet EPA's Re-Powering America's Lands Initiative by virtue of their size in both absolute numbers and acreage. EPA's campaign to site renewable energy systems on formerly contaminated lands has a number of well-established benefits across various valuation matrices (environmental, economic, and socioeconomic).

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