Solar Power Installations on Closed Landfills

An Online Continuing Education Course for Engineers

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1. INTRODUCTION

Since 1988 the number of municipal solid waste (MSW) landfills in the U.S. has decreased from 7,924 to 1,754. Accordingly, at least 6,170 landfills have closed over the past two decades. Estimates for the total number of closed landfills in the United States are as high as 100,000 (Suflita et al, 1992). This roughly estimated number of landfills represents hundreds of thousands of acres of brownfields real property.

As demand for new land increases, landfills are becoming valuable for their development potential (EPA, 2002). Contaminated lands encompass sites that are undergoing remediation or have completed remediation under various cleanup programs, such as Superfund and brownfield sites. Through the Re-Powering America's Lands Initiative, the U.S. Environmental Protection Agency Office of Solid Waste and Emergency Response (OSWER) has identified several important reasons for siting clean and renewable energy facilities on contaminated lands, including:

- Contaminated lands offer thousands of acres of open space in areas where solar installations may be less likely to involve community concerns over aesthetic impacts;
- Contaminated lands may have lower overall transaction costs than greenfield sites;
- Development of brownfields can assuage the stress placed on greenfields to site clean and renewable energy facilities;
- Contaminated lands may have environmental conditions that are not well suited for commercial or residential zoning or otherwise have low demand for real estate development (EPA, 2008).

Electricity generated from renewable energy projects on contaminated or remediated lands can then be used onsite or sold or credited for offsite use.

While the benefits of developing contaminated lands are well established, recurring challenges complicate the practice. This course outlines the technical and regulatory challenges to placing solar systems on closed landfills, with a particular focus on system placement at Superfund and brownfield sites, and provides case evidence of successful solar system planning and construction. It 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, and (3) regulatory considerations.

2. SOLAR POWER SYSTEMS

There are a fairly wide set of considerations that are important when planning a solar system to be placed over a closed landfill. With respect to the solar technologies available, considerations include whether concentrating solar power (CSP) or photovoltaic (PV) will be best suited to site-specific conditions. Additional factors to consider during the planning process, given the constraints of building on a landfill cap, are the desired output capacity, weight characteristics, and degree of mechanical stress expected from onsite weather conditions. This section provides an introduction to ground mounted solar systems followed by a discussion of the different solar technologies available, weight characteristics, and wind and snow loading as they apply to landfill installations.

2.1. Introduction to Ground Mounted Systems

Installation of a solar energy system on a landfill cap will require the use of ground mounted solar arrays. Ground mounted solar systems often involve aluminum or galvanized steel framing that is attached to a concrete foundation. The concrete foundation can also be referred to as a pier or footing and the panel supports can be referred to as stanchions. With respect to footings, several designs are available:

- Shallow poured concrete pillars;
- Pre-fabricated concrete;
- Slab;
- Ballast frames;
- Driven pile; and
- Earth screw augers.

The simplest solar mounting structures resemble an A-frame, with vertical stanchions secured to a foundation supporting the solar panels **(Figure 1** and **Figure 2).** More elegant mounting structures have axes that move to track the movement of the sun **(Figure 3,** Section 2.2).

In **Figure 1,** the aluminum support stanchions supporting the PV panels can be seen on the right. The aluminum stanchions are secured to pillar-shaped ground penetrating concrete footings in the front and rear. The preceding discussion is relevant to PV solar systems. Comparison of PV systems to alternate solar technologies is discussed in further detail in the following section.

Figure 1. Fixed tilt A-frame style ground mounted PV system

Source: flickr.com

2.2. Different Solar Technologies

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 1** and **Figure 2).**

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

Source: flickr.com

The second type of PV mounting structure currently available is the azimuth tracking (sun-tracking) PV configuration, which provides automated adjustment of the panels on a single or double axis corresponding to the sun's position relative to the PV array. Single axis trackers are mounted on an axis horizontal to ground surface, which allows panel rotation to maximize panel exposure to the sun **(Figure 3).** Double axis trackers are able to track both the sun's altitude and east to west movement, allowing the PV panels to be directed toward the sun's position in the sky regardless of time of day or season.

Both double axis and single axis trackers have an output advantage over fixed tilt configurations. Double axis trackers have an advantage over single axis trackers in that they can maximize energy output at any given point in time. The double axis output advantage is greater during winter months, when the sun is low on the horizon. However, double axis trackers require more land than single axis trackers because of the difficulty in avoiding shading between panels. A second disadvantage to the double axis tracker is the operation and maintenance hours, cost, and parasitic energy required to keep up and power the two motors that drive the axes (Kurokawa, 2003). The disadvantages in the amount of land and operation and maintenance hours required for sun-tracking systems could complicate their application on landfill caps.

Figure 3. Single axis sun-tracking mounting structure, concrete footings, support beams, and PV panels at Nellis Air Force Base, NV

Source: flickr.com

CSP systems have different attributes than PV systems but also have the potential to be used on closed landfill sites. In general terms, CSP technologies use mirrors and reflectors to concentrate and collect solar energy in the form of heat that is transferred through fluids contained in a closed-loop network of receiving tubes and then converted to extremely high temperatures for electricity production. Three main technology systems for CSP are in use today:

1. Linear concentrator systems;
2. Power tower systems; and
3. Dish/Engine systems.

Linear concentrator systems can be broken down into two subcategories differing in reflection and reception technologies: parabolic trough systems and linear Fresnel reflector systems. Parabolic trough systems use parabola-shaped reflectors to direct solar rays to oil-filled receiving tubes placed along the focal line of the parabolic axis **(Figure 4).** In contrast, linear Fresnel reflector systems use flat mirrors that may be mounted on a tracking axis to reflect and concentrate sunlight onto water-filled receiver tubes fixed above the mirrors (DOE, 2008a).

In power tower systems, many flat sun-tracking mirrors surround a central tower equipped with a receiver at the top **(Figure 5).** Electricity is produced when fluid contained in the receivers (typically helium, nitrogen, or hydrogen gas) is heated to supercritical temperatures for generating steam, which then powers a turbine and generator system. Both power tower systems and linear CSP systems are designed to collect heated fluids that create steam at a central location. Because large areas of land are necessary for optimal operational capacity, both power tower and linear CSP systems are best suited for large-scale production plants of 50 megawatts or more (Stoddard et al, 2006).

Dish/engine technology uses a large parabolic dish of mirrors coupled with fluid-containing receiving tubes and an engine to generate mechanical power (rather than steam) for electricity production. **(Figure 6).** Dish/engine systems generally have an electricity production capability ranging 3-25 kilowatts, which is substantially lower than the other two CSP technologies. Because dish/engine systems are modular with relatively low production capacities for individual units, they may be better suited for smaller-scale operations (DOE, 2008b). Similar to linear concentrators and power towers, dish/engine systems will also require flat grades to provide adequate support.

Figure 4. Parabolic trough linear ... irrors

Source: flickr.com