United States Environmental Protection Agency
Solar Screening Study for the Lee's Lane Landfill in Louisville, Kentucky

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A Solar Screening Study Prepared by the Environmental Protection Agency, Region 4 for Siting Renewable Energy on Contaminated Lands

Team Consisting of:
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This report is to be used for screening purposes only.

Additional evaluations will need to be conducted to fully characterize the feasibility and economics of the Lee's Lane Landfill Site. Third party solar developers and local utility companies may have technical and financial interests to pursue potential solar renewable energy projects and perform additional solar assessments to determine if projects are economically viable.

This study does not assess the environmental conditions at the site.

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I. Executive Summary

An analysis of solar photovoltaics was performed for the Lee's Lane Landfill Site in Louisville, Kentucky. The Lee's Lane Landfill site appears to have somewhat favorable site conditions to support solar PV generation and economically viable reuse, especially since the site has nearby businesses that could potentially use the electricity generated from PV, transmission lines, accessible roads, somewhat flat and open area, and minimal shading issues once the site is cleared.

The annual energy output, annual energy value, and various economic results are listed in the two tables below along with the annual emissions reductions. Table 1 lists the results assuming the 30% Federal Investment Tax Credit (ITC) is not captured and Table 2 lists the results assuming the 30% Federal ITC is captured. Results are also presented for assuming both the wholesale electric rate of $0.0323/kWh and the commercial electric rate of $0.0869/kWh.

As shown, capturing the Federal ITC has a big impact on the financial viability of a PV project. Furthermore, the buyback electricity rate also has a big impact on the financial viability of a PV project. The economics are most favorable for the utility-scale PV system (i.e., 12.2 megawatts (MW)) due to the reduced installed cost of this system. The economics are least favorable for the PV system on the capped landfill due to the increased installed cost related to building on a capped landfill. It is important to note that the economics for building on the capped landfill could be more favorable when compared to the larger site when the cost of tree clearing and site preparation is accounted for (note, assessing the cost of tree clearing and site preparation is beyond on the scope of this project). A system of approximately 500 kW could be implemented on the site, offering a positive redevelopment option that could power the equivalent of approximately 60 homes[1].

[1] Assuming average American home uses 11,000 kWh/yr.

Table 1. Lee's Lane Landfill Site PV System Simulation Results without Federal ITC

PV System	Potential Area for PV (Acres)	PV System Size (MW)	Current Electricity Rate (¢/kWh)	Annual Energy Output (kWh/year)	Annual Energy Value ($/year)	Estimated Initial Cost without 30% ITC ($)	Simple Payback without ITC (years)	Annual CO_2e Emissions Reductions (metric tons/year)
3-Acre Sample Size	3.0	0.5	Wholesale 3.23	667,645	$21,565	$1,075,000	49.8	407
6.5-Acre Capped Landfill	6.5	1.1		1,468,821	$47,443	$2,838,000	59.8	895
73.4-Acre Site	73.4	12.2		16,290,535	$526,184	$21,653,000	41.2	9,931
Entire Site (79.9 Acres)	79.9	13.3		17,759,356	$573,627	$24,491,000	42.7	10,826
3-Acre Sample Size	3.0	0.5	Commercial 8.69	667,645	$58,018	$1,075,000	18.5	407
6.5-Acre Capped Landfill	6.5	1.1		1,468,821	$127,641	$2,838,000	22.2	895
73.4-Acre Site	73.4	12.2		16,290,535	$1,415,647	$21,653,000	15.3	9,931
Entire Site (79.9 Acres)	79.9	13.3		17,759,356	$1,543,288	$24,491,000	15.9	10,826

Table 2. Lee's Lane Landfill Site PV System Simulation Results with Federal ITC

PV System	Potential Area for PV (Acres)	PV System Size (MW)	Current Electricity Rate (¢/kWh)	Annual Energy Output (kWh/year)	Annual Energy Value ($/year)	Estimated Initial Cost with 30% ITC ($)	Simple Payback with ITC (years)	Annual CO_2e Emissions Reductions (metric tons/year)
3-Acre Sample Size	3.0	0.5	Wholesale 3.23	667,645	$21,565	$752,500	34.9	407
6.5-Acre Capped Landfill	6.5	1.1		1,468,821	$47,443	$1,986,600	41.9	895
73.4-Acre Site	73.4	12.2		16,290,535	$526,184	$15,157,100	28.8	9,931
Entire Site (79.9 Acres)	79.9	13.3		17,759,356	$573,627	$17,143,700	29.9	10,826
3-Acre Sample Size	3.0	0.5	Commercial 8.69	667,645	$58,018	$752,500	13.0	407
6.5-Acre Capped Landfill	6.5	1.1		1,468,821	$127,641	$1,986,600	15.6	895
73.4-Acre Site	73.4	12.2		16,290,535	$1,415,647	$15,157,100	10.7	9,931
Entire Site (79.9 Acres)	79.9	13.3		17,759,356	$1,543,288	$17,143,700	11.1	10,826

There are a multitude of ways which a project could be developed including: public private partnership, power purchase agreement, enhanced use lease, on site off-taker, or community solar. The next steps to move the site forward include:

- Compile all historical and investigative information on the site, from EPA and KDEP;
- Verify ownership information;
- Determine whether pre-construction activities described in Appendix A are applicable;
- Refine notion of land available for a potential PV installation (for example, impacts of state specific incentives and limitations; more detailed shading analysis, etc.);
- Identify the off-taker for the power. This could be the adjacent businesses, members of the community, the tenants of a potential redevelopment, or the utility;
- Finalize the project implementation pathway, and assemble the stakeholders; and,
- Engage the utility and offer full transparency into project plans, technology sizes, and partner organizations.

Developing solar at the Lee's Lane Landfill site is an opportunity to re-invigorate the neighboring community with job opportunities, and blight reduction. Brownfield sites such as this site offer unique redevelopment prospects, and developing renewables on the site is an opportunity to leverage synergies between the industrial nature of the site's former use (e.g., electrical infrastructure, level topography, limited alternative use) and site preparation required for clean power systems. By implementing RE on this site, the emissions would be reduced which meets the community's goals around sustainability.

Background

The Lee's Lane Landfill is a 112-acrea parcel of land with potential areas for PV that totals 79.9 acres, which includes the landfill area covered by an engineered cap (6.5 acres), as well as the parts of the site with only a soil cover (73.4 acres). The site is located approximately 8 miles to the southwest of downtown Louisville, Kentucky. The site was formerly a quarry during the 1940's and 1950's and then operated as a landfill until 1975. Currently the Lee's Lane Landfill site is owned by the Hofgesang Foundation which does not have the funds or organizational capability to redevelop the site, and is interested in divesting its ownership. The Foundation has had little involvement in the site. The Lee's Lane Landfill site was designated an EPA Superfund site in 1983 due to contamination in the water, ground, and air, and the site was deleted from the Superfund program's National Priorities List in 1996. Because waste was left in place, EPA continues to review site conditions to ensure protectiveness.

Through the RE-Powering America's Lands initiative (see Appendix B for more information), a desktop analysis of the Lee's Lane Landfill site was conducted to screen for solar development potential. Given the location of the Lee's Lane Landfill and the renewable energy (RE) resources at the site, solar was determined to be the best suited RE technology for the site given that there is no noise associated with the system, and there is no requirement to ship materials into the site on a regular basis when compared to other RE technologies (e.g., wind power or biomass). A team of stakeholders including the Kentucky Energy and Environment Cabinet, the Environmental Protection Agency (EPA), and the National Renewable Energy Laboratory (NREL), began discussions regarding the site in the summer of 2016.

Former Superfund sites typically have limited redevelopment potential and solar PV installations can be a viable reuse. Blighted properties often are particularly well-suited for solar development because they are often:

- Located near critical infrastructure including electric transmission lines and roads;
- Located near areas with high energy demand (e.g., large population bases);
- Have minimal grade (0-2 percent) which allows for optimal siting of solar photovoltaic (PV) structures;
- Offered at lower land costs when compared to open space; and may be adequately zoned for RE;
- May have environmental conditions that are not well suited for commercial or residential redevelopment;
- Can provide job opportunities in urban and rural communities;
- Are able to accommodate net metered or utility scale projects; and,
- May reduce the environmental impacts of energy systems (e.g., reduce greenhouse gas emissions).

Each solar PV system represents a standalone system that can be sized to use the entire available site area. The viability of implementing a solar PV system on a site is highly impacted by the available area for an array, solar resource, distance to transmission lines, distance to major roads, favorable economic conditions, and community support.

This solar screening report provides critical information to assist the Lee's Lane Landfill site officials in determining the site's potential for solar PV electricity generation. In addition, the report will outline various incentives (Section VI - Incentives) that could assist in financing the implementation of a solar PV system.

While there is no perfect fuel or generation technology some of the benefits of solar PV include:

- Air quality benefits and other pollutant reductions compared to other distributed power options;
- Provides long-term stabilization of electrical costs;
- When combined with a battery backup system, a PV unit can provide power when utility power is not available, and,
- Availability of additional grants and tax incentives.

If the Lee's Lane Landfill Solar Project Team decides to further pursue the installation of solar PV, then Louisville Gas & Electric (LG&E) should be consulted early in the planning stages so that the municipality can be alerted of any potential distribution interconnection issues that might exist or equipment upgrades needed to facilitate the solar project, in addition to applicable tariffs and utility requirements.

While financing the Lee's Lane Landfill Solar Project is beyond the scope of this report, the Project Team should work with the local utility company who could be willing to discuss all of the various options such as a Power Purchase Agreement (PPA). To learn more about PPA structures, please go to the following PPA Checklist for State and local Governments:

http://www.nrel.gov/docs/fy10osti/46668.pdf

II. PV Ground Mount Systems

The solar array has to be secured and oriented optimally to maximize system output. The structure holding the modules is referred to as the mounting system. For ground mount systems, the mounting system can be either directly anchored into the ground (via driven piers or concrete footers) or ballasted on the surface without ground penetration. Mounting systems must withstand local wind loads, which range from 90–120 mph range for most areas or 130 mph or more for areas with hurricane potential. Depending on the region, snow and ice loads must also be a design consideration for the mounting system.

Typical ground-mounted systems can be categorized as fixed-tilt or tracking. Fixed-tilt mounting structures consist of panels installed at a set angle, typically based on site latitude and wind conditions, to increase exposure to solar radiation throughout the year. Fixed-tilt systems are used at many contaminated sites. Fixed-tilt systems have lower maintenance costs but generate less energy (kWh) per unit power (kW) of capacity than tracking systems.

Tracking systems rotate the PV modules so they follow the sun as it moves across the sky. This increases energy output but also increases maintenance and equipment costs slightly. Single-axis tracking, in which PV is rotated on a single axis, can increase energy output up to 25% or more.

The selection of mounting type is dependent on many factors including installation size, electricity rates, government incentives, land constraints, soil conditions, alignment and latitude requirements, and local weather. The mounting system design will also need to meet applicable local building code requirements with respect to snow, wind, and seismic zones. Selection of mounting types should also consider frost protection needs especially in cold regions. Contaminated land applications may raise additional design considerations due to site conditions, including differential settlement. Selection of the mounting system is also heavily dependent on anchoring or foundation selection.

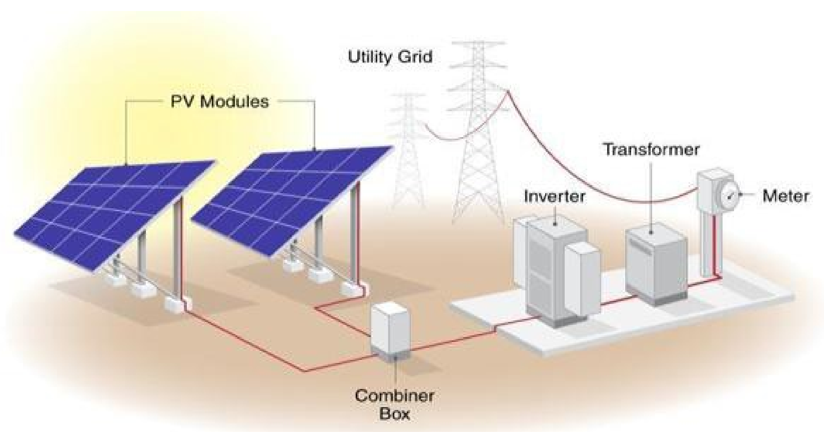

Figure 1. Ground Mount PV Array
Source: NREL

Major System Components

A typical PV system is made up of several key components including:

- PV modules
- Inverter
- Balance-of-system components - includes mounting racks, hardware for the panels, and

wiring for electrical connections. Electrical connections, including wiring, disconnect switches, fuses, and breakers are required to meet electrical code (e.g., NEC Article 690) for both safety and equipment protection.

In most traditional applications, wiring from the arrays to inverters and inverters to point of interconnection is generally run as direct burial through trenches. On contaminated site applications, this wiring may be required to run through above-ground conduits due to restrictions with cap penetration or other concerns. Therefore, site developers should consider noting any such restrictions, if applicable, in requests for proposals in order to improve overall bid accuracy. Similarly, it is recommended that PV system vendors reflect these costs in the quote when costing out the overall system. See Appendix C for additional information on PV Systems Overview and Appendix D for a Glossary of Terms.

A number of brownfield sites that are municipally owned and operated have expressed interest in potential revenue flows from PV systems. In some cases, revenue can be generated by the use of PV on a contaminated site pending actual site conditions, financial incentives, economic conditions, and support from the utility companies.

III. Lee’s Lane Landfill Site PV System/Siting Considerations

The Lee’s Lane Landfill Site is located approximately 8 miles to the southwest of downtown Louisville, Kentucky. Louisville has a favorable solar resource of 4.71 kWh/m^2/day on average over the course of a year at tilt equal to latitude (i.e., 38 degrees). Solar PV in Louisville is capable of generating power in all months of the year. The following resource maps shows how the solar resource differs across the United States.

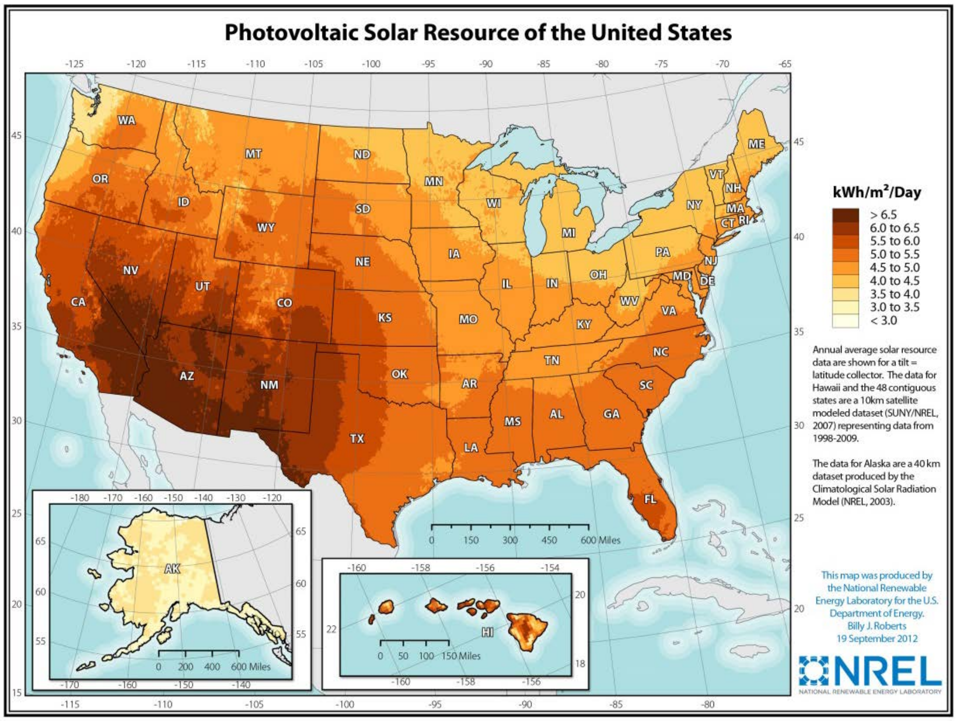

Figure 2: Solar Resource Map USA[2]
Source: NREL

[2] http://www.nrel.gov/gis/solar.html

Figure 4 shows an aerial view of the Lee's Lane Landfill site. With the addition of soil fill, the site has a relatively large area that can potentially be used for PV.

Figure 3; Lee's Lane Landfill

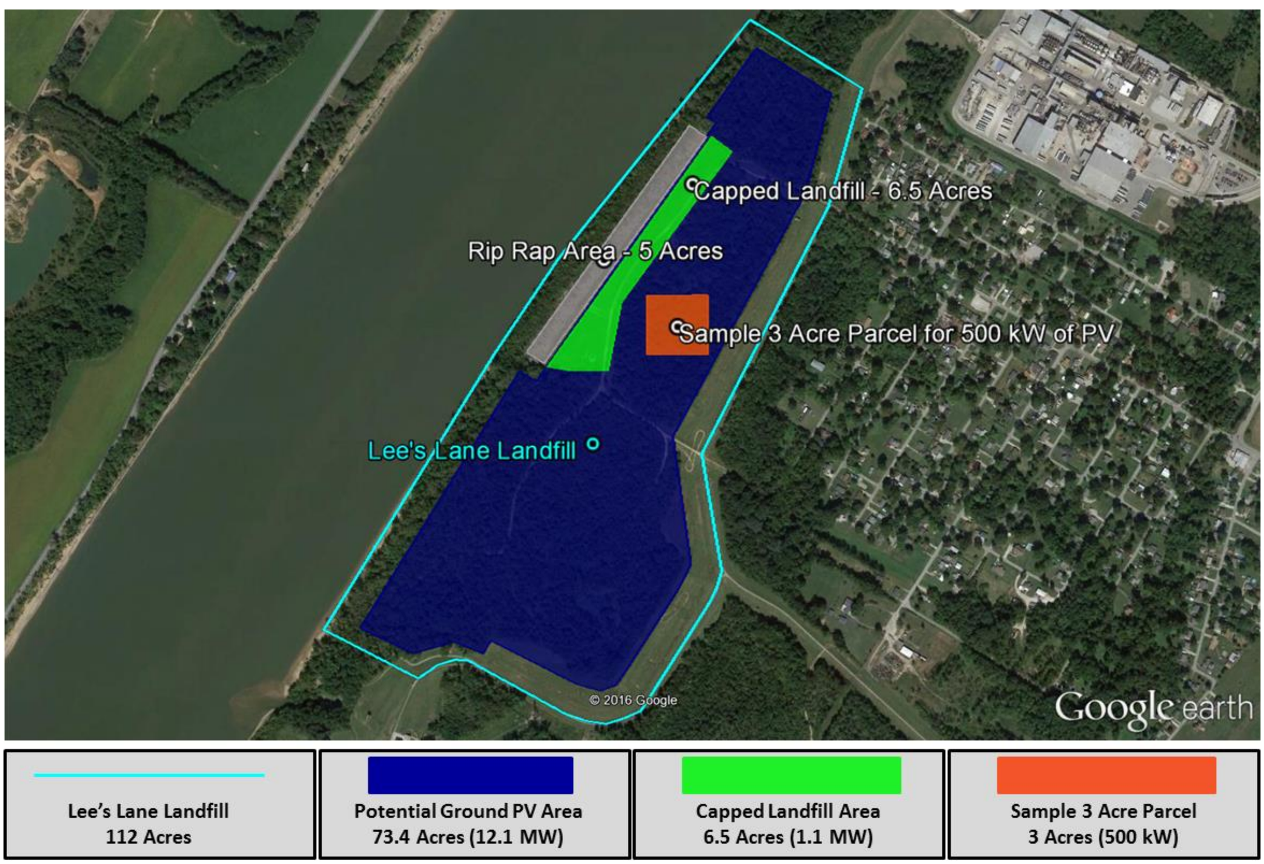

Figure 4. Current Potential Areas for PV at Lee's Lane Landfill Site
Source: Google Earth

Useable Site Acreage

There are three potential areas for PV considered that include:

1.) The current total potential area for PV at the Lee's Lane Landfill site, excluding the capped landfill area and the rip-rap area, is approximately 73.4 acres (shown in blue), which allows for a 200-foot buffer around the site boundary to accommodate for the earthen dam to the east of the site and the Ohio River to the west of the site.

2.) The capped landfill area (shown in green) is 6.5 acres and can also be considered for PV, but there is typically a 20% premium for building PV systems on capped landfills due to various factors (e.g., ballasting the PV system so there are no cap penetrations, designing around storm water pathways, etc.). One clear advantage the capped landfill area has over the larger 73.4-acre area is that the area is already leveled and clear of trees, so the cost of removing trees does not have to be factored in (note, the cost of tree removal in any of the areas is not considered in this analysis).

3.) A sample 3-acre area (shown in orange) that would accommodate 500 kW of PV. The 500 kW PV system size corresponds to the current LG&E shared solar project of building out 4 MW of PV in 500 kW increments.

In general, the available site area will impact the potential PV system size and the cost of PV systems. The economics of the PV system will also vary according to the entities developing solar PV at the site (e.g., municipally funded system or a power purchase agreement funded system). Typically, a minimum of 2 useable acres of the site area is recommended to site PV systems. Useable acreage is typically characterized as flat to gently sloping southern exposures that are free from obstructions and get full sun for at least a 6-hour period each day. A majority of the area at the Lee's Lane Landfill site can be considered available, but tree and vegetation clearing, as well as the addition of soil fill, would have to be carried out throughout most of the site to make the land suitable for PV. The cost of this preparatory work is not considered in this study. Although considering the nonnative species and presence of invasives at the site, site preparatory work for a solar array could provide co-benefits of providing for more native habitat supporting more biodiversity. See Appendix E for more information on the vegetation at the site.

Figure 5: Lee's Lane Landfill site illustrating vegetation and tree cover.

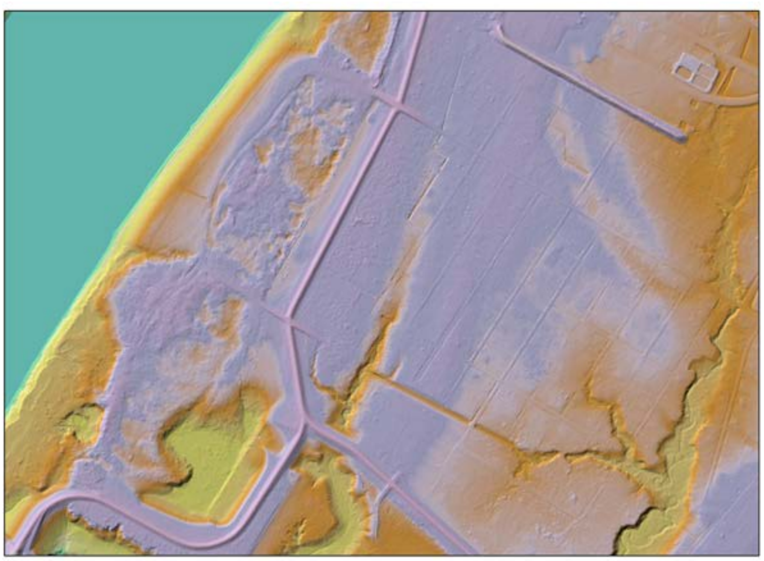

Figure 6: Topography of the site illustrating potential issues with site leveling and vegetation.

Transmission/Utility Resources

As indicated earlier, if the Lee's Lane Landfill officials decide to pursue PV solar generation on the site, a high level preliminary interconnection transmission study from LG&E is highly recommended early in the process. The interconnection study will allow LG&E to determine the feasibility of interconnecting to the electric grid, assess potential electrical upgrades, and estimate the potential costs. All technical pertinent information about the proposed solar PV system should be provided to LG&E in accordance with the application requirements.

In general, the distance from the proposed solar PV system to the point of interconnection with electrical transmission should be within a ½ mile distance in order to yield more viable economic conditions. The following aerial image shows the locations of the nearest utility substations. The 69 kVA substation with the name unknown is located approximately 0.18 miles from the Lee's Lane Landfill boundary.

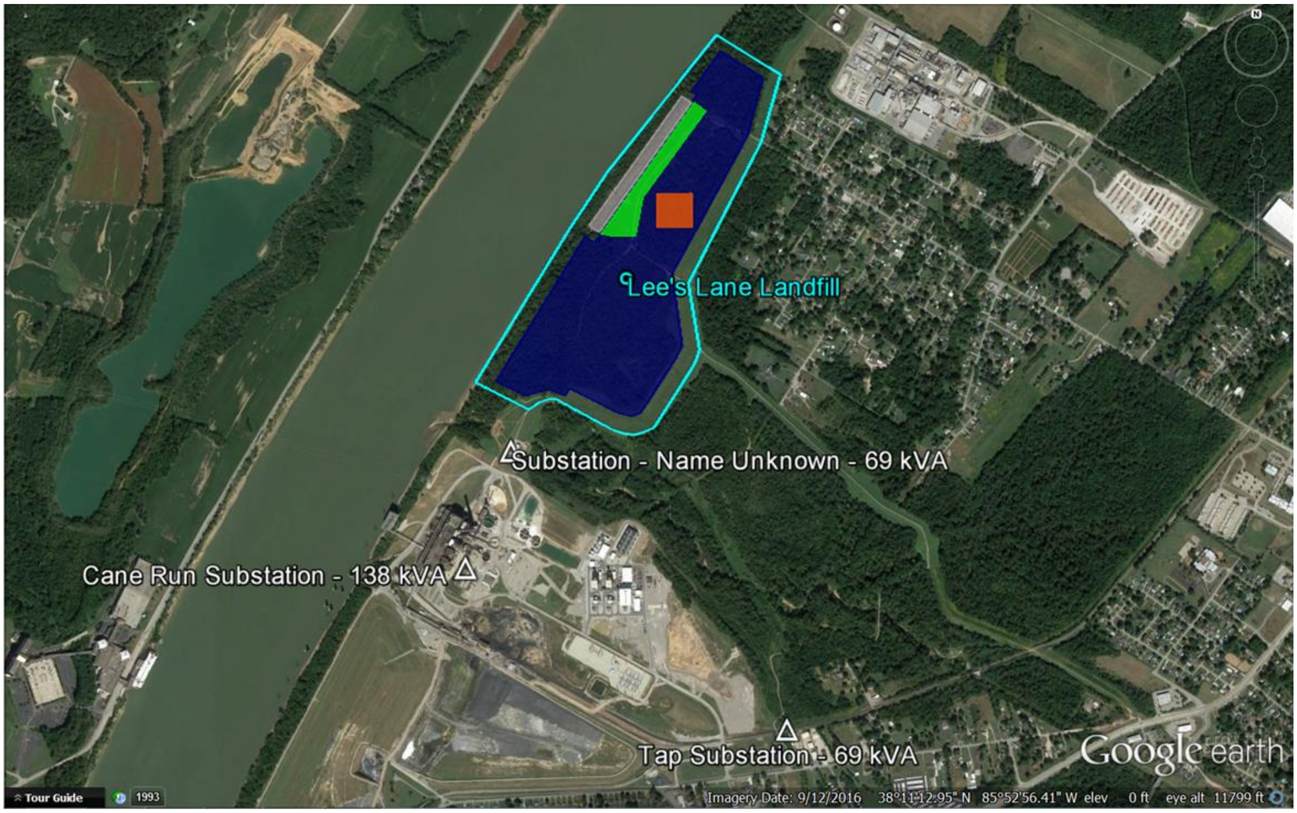

Figure 7. Utility Substations Near Lee's Lane Landfill
(Photo Credit: Google Earth)

IV. Solar Assessment

PV modules are very sensitive to shading. When shaded (either partially or fully shaded), the panel is unable to optimally collect the high-energy beam radiation from the sun. PV modules are made up of many individual cells that all produce a small amount of current and voltage. These individual cells are connected in series to produce a larger current. If an individual cell is shaded, it acts as resistance to the whole series circuit, impeding current flow and dissipating power rather than producing it. By finding the solar access, it can be determined if the area is appropriate for solar power generation.

It is recommended that the team perform a shading analysis on the site, to ensure that the panels can operate free of shading in order to maximize the production from the system. Any areas that have substantial shading should be removed from the available area. An annual solar availability of 90% or higher is recommended for siting PV to assure that there is minimal shading of the PV panels throughout the year. Areas that have obstructions that cause the annual solar availability to drop below 90% should not be considered for PV.

The following key and site related information was collected to aid in the solar assessment for the Lee's Lane Landfill.

Table 3. Lee's Lane Landfill Site Information

Brownfield/Site Name	Lee's Lane Landfill
Physical Address	Lee's Lane @ the Ohio River, Louisville KY 40216
Property Operator/Owner (private/public)	Hofgesang Foundation
Local Contacts (phone number/emails)	Kenya Stump Kenya.Stump@ky.gov 502-782-7083
Other relevant contacts	Donna Seadler Seadler.Donna@epa.gov 404-562-8870
Site Physical Characteristics:	
Property Size (total)	112 acres
Potential Usable for Solar PV	79.9 acres
Known Contamination?	The landfill at the site stopped operating in 1975, when it was closed, covered, and vented. Since that time, it was listed on the Superfund National Priorities List. EPA removed waste, installed a cap on a portion of the former landfill, and installed rip-rap on the river slope. The landfill receives regular inspections and maintenance.
Has there been a site assessment performed (Phase I or Phase II)	No Phase I or Phase II have been conducted. However, EPA and KDEP have conducted soil, soil gas, and groundwater sampling within the last several years and this data is publicly available, in addition to EPA risk evaluations of the results.
Physical Conditions - surface area, terrain conditions/soil erosion?	A majority of the area is vegetated (grass, brush, and trees). The previous waste fill was not leveled at the time it was covered so additional fill would be necessary to level the site.
Known Shading Concerns (existing trees/buildings/structures)	Existing trees and vegetation
Any available site maps, including topos?	Google Earth images
Utility Information:	

Utility Company serving the Area (contacts)	Louisville Gas & Electric (LG&E)
Distance to major highways (provide highway information)	Close proximity to major roads and highways 3.3 miles to Interstate 264.
Distance to Electrical Transmission Lines Closer distance will minimize interconnection cost.	0.18 miles to transmission
Location of the Substations	The site is 0.63 miles from the LG&E and KU Cane Run Power Plant that has a 138 kVA substation 0.18 miles to the 69 kVA unnamed substation
Identified off-taker?	A number of potential off-takers include: Louisville Metro Community solar participants Custom build for a designated industrial customer through a utility facilitated PPA or special contract
Other	
Any previous solar or interconnection studies done at the site?	No
Nearest critical Infrastructures from the site? (Hospitals, police stations, school/shelters, fire house, waste treatment plants, water treatment facilities, municipal facilities, cell towers, or others).	1.3 miles to the nearest school (Farnsley Middle) 1.7 miles to the nearest fire station 3.7 miles to the nearest wastewater treatment plant (Morris Forman) 4.9 miles to the nearest hospital (Saint Mary & Elizabeth Hospital)
Are there any neighboring industries or businesses that could be an off-taker of the power generated by solar?	The industrial area just north of the site, including the Rubbertown facilities.
Community vision for reuse and development at the site? Is there municipality support?	The Louisville Sustainability Council projects include the Solar Over Louisville 2 MW solar challenge. The City of Louisville has also been recognized as a 4 STAR community. The STAR Community Rating System is the nation's first comprehensive framework and certification program for evaluating local sustainability, encompassing economic, environmental and social performance measures. However, the city rating on climate and energy is recognized as an area for improvement and greening the energy supply is a category to focus efforts. The immediate community currently has no formal organization or stance but would be interested in EPA assistance toward a redevelopment vision. The municipality supports redevelopment but is unable to commit resources.
Can the Load Bearing Capacity of the LF accommodate the additional loading of a Solar PV system?	How would we get this information?
Any on-going remediation at the site	Minor issues identified in the most recent Five Year Review of the remedy are being addressed. The landfill gas collection system was determined to be unnecessary and methane is no longer a threat.
Any existing site liens/bankruptcy status?	Unknown.
Price of Solar per Watt Installed	Three scenarios: (1) $1.77/watt; $2.15/watt; and $2.58/watt (first two numbers taken from the U.S. Photovoltaic Prices and Cost Breakdowns: Q1 2015[3]; third number represents 20% more than second)

[3] http://www.nrel.gov/docs/fy15osti/64746.pdf

PV Watts Site Identification

The predicted array performance was found using PVWatts[4] for the Lee's Lane Landfill site. NREL's PVWatts™ calculator determines the energy production and cost savings of grid-connected photovoltaic (PV) systems throughout the world. It allows homeowners, installers, manufacturers, and researchers to easily develop estimates of the performance of hypothetical PV installations. The PVWatts calculator works by creating hour-by-hour performance simulations that provide estimated monthly and annual energy production in kilowatt-hours and energy value. Users can select a location and choose to use default values or their own system parameters for size, electric cost, array type, tilt angle, and azimuth angle.

The PVWatts Grid Data Calculator is another NREL tool which was utilized to calculate estimates of kWh and MWh energy performance for the system based on the number of acres available. Table 4 below shows the identification information, PV system specifications, and energy specifications for the three potential areas for PV that include:

1.) The entire 73.4-acre potential area for PV that can accommodate 12.2 MW of PV

2.) A sample 3-acre potential area that can accommodate 500 kW of PV

3.) The 6.5-acre capped landfill area that can accommodate 1.1 MW of PV.

Table 4. PVWatts Site Identification Information and Specifications

Location and Station Identification	
Requested Location	Lee's Lane Landfill
Weather Data Source	(TMY2) Louisville, KY
Latitude	38.18° N
Longitude	85.73° W
PV System Specifications *(Commercial)*	
DC System Size	500 kW, 1.1 MW, and 12.2 MW
Module Type	Standard
Array Type	Fixed (open rack)
Array Tilt	20°
Array Azimuth	180°
System Losses	14%
Inverter Efficiency	96%
DC to AC Size Ratio	1.1
Initial Economic Comparison	

[4] http://pvwatts.nrel.gov/pvwatts.php

Electricity Buyback Rates	**0.0323 $/kWh wholesale electricity rate** **0.0869 $/kWh commercial electricity rate**
Initial Cost	**2.15 $/Wdc for the 500 kW commercial-scale PV system** **2.58 $/Wdc for the 1.1MW commercial-scale PV system (2.15 $/Wdc + 20% premium for building on a landfill)** **1.77 $/Wdc for the 12.2 MW utility-scale PV system**

Direct current (dc) is one directional current and is the type of electricity that is produced by a PV system. Alternating current (ac) is current that alternates direction many times a second at regular intervals and is the electricity that is commonly found at electrical outlets in homes, offices, businesses, and so on. Table 5 shows the theoretical performance results for a 500 kW, 20-degree fixed tilt PV system at the Lee’s Lane Landfill site as calculated by PVWatts assuming both the wholesale and commercial electric rates

Table 5. Lee’s Lane Landfill Site PVWatts Results for the 500 kW PV System

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value Assuming the Wholesale Electricity Rate ($)	Energy Value Assuming the Commercial Electricity Rate ($)
January	2.75	36,966	$1,194	$3,212
February	3.62	43,144	$1,394	$3,749
March	4.66	59,446	$1,920	$5,166
April	5.45	64,771	$2,092	$5,629
May	5.95	71,018	$2,294	$6,171
June	6.36	71,742	$2,317	$6,234
July	6.12	70,810	$2,287	$6,153
August	5.81	67,323	$2,175	$5,850
September	5.11	58,414	$1,887	$5,076
October	4.47	54,358	$1,756	$4,724
November	2.97	36,228	$1,170	$3,148
December	2.54	33,425	$1,080	$2,905
Annual	**4.65**	**667,645**	**$21,565**	**$58,018**

Table 6 shows the theoretical performance results for a 1.1 MW, 20-degree fixed tilt PV system at the Lee’s Lane Landfill site as calculated by PVWatts assuming both the wholesale and commercial electric rates.

Table 6. Lee's Lane Landfill Site PVWatts Results for the 1.1 MW PV System

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value Assuming the Wholesale Electricity Rate ($)	Energy Value Assuming the Commercial Electricity Rate ($)
January	2.75	81,325	$2,627	$7,067
February	3.62	94,917	$3,066	$8,248
March	4.66	130,782	$4,224	$11,365
April	5.45	142,496	$4,603	$12,383
May	5.95	156,239	$5,047	$13,577
June	6.36	157,833	$5,098	$13,716
July	6.12	155,783	$5,032	$13,538
August	5.81	148,110	$4,784	$12,871
September	5.11	128,511	$4,151	$11,168
October	4.47	119,589	$3,863	$10,392
November	2.97	79,701	$2,574	$6,926
December	2.54	73,535	$2,375	$6,390
Annual	**4.65**	**1,468,821**	**$47,443**	**$127,641**

Table 7 shows the theoretical performance results for a 12.2 MW, 20-degree fixed tilt PV system at the Lee's Lane Landfill site as calculated by PVWatts assuming both the wholesale and commercial electric rates.

Table 7. Lee's Lane Landfill Site PVWatts Results for the 12.2 MW PV System

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value Assuming the Wholesale Electricity Rate ($)	Energy Value Assuming the Commercial Electricity Rate ($)
January	2.75	901,964	$29,133	$78,381
February	3.62	1,052,716	$34,003	$91,481
March	4.66	1,450,493	$46,851	$126,048
April	5.45	1,580,415	$51,047	$137,338
May	5.95	1,732,827	$55,970	$150,583
June	6.36	1,750,510	$56,541	$152,119
July	6.12	1,727,773	$55,807	$150,143
August	5.81	1,642,671	$53,058	$142,748
September	5.11	1,425,302	$46,037	$123,859
October	4.47	1,326,347	$42,841	$115,260
November	2.97	883,952	$28,552	$76,815
December	2.54	815,565	$26,343	$70,873
Annual	**4.65**	**16,290,535**	**$526,183**	**$1,415,647**

Cautions for Interpreting the Results - Weather Variability

The monthly and yearly energy production are modeled using the photovoltaic system selected parameters and weather data that are typical or representative of long-term averages. Typical Meteorological Year (TMY) weather data is used in the PVWatts analysis which is based on 30 years of weather data. Because weather patterns vary from year to year, using TMY data in the PV simulations is a better indicator of long-term performance.

Photovoltaic system performance is largely proportional to the amount of solar radiation received, which may vary from the long-term average by ±30% for monthly values and ±10% for annual values.

V. **Forecasted Economics and Performance**

The PV system includes the solar modules, inverter, and other system parts known as the solar balance-of-system components, which include:

- Mounting racks and hardware for the panels; and,
- Wiring for electrical connections.

The forecasted economics for the solar PV system include the PV array and the balance of system (BOS) components (including the inverter and electrical equipment) costs, as well as the installation cost. The system costs also include estimated federal incentives and a national-average labor rate, but do not include land cost.

In general, the economics of a grid-tied PV system will also depend on available financial incentives, the cost of electricity, the solar resource, and panel tilt and orientation. The cost of a PV system will also depend on the system size and other factors such as geographic location, mounting structure, type of PV module, etc. For this analysis, the installed cost of the fixed- tilt ballasted system is assumed to be $2.15/Wdc for commercial-scale PV systems (i.e., 500 kW PV system); $2.58/Wdc for commercial-scale PV systems built on capped landfills, which assumes a 20% premium on the overall installed cost of a PV system for building on landfills (i.e., 1.1 MW PV system); and $1.77/Wdc for utility-scale PV systems (i.e., 12.2 MW PV system), which are based on the costs stated in the *U.S. Photovoltaic Prices and Cost Breakdowns: Q1 2015*[5].

Table 8 provides a summary of the economic comparisons from PVWatts outlining the average cost of electricity generation serving the area, the initial system costs $/Wdc, and the projected costs of electricity generated by the proposed solar PV systems. The installed PV system cost includes the installation of the PV panels and the balance of system (e.g., racks, inverters, wiring, hardware, etc.). This cost does not include additional costs that could be incurred preparing or redeveloping the site for PV (e.g., grading, removing structures, addressing contaminations issues, etc.). The PVWatts results show the cost for solar PV electricity generation is lower than the average electrical utility generation but higher than the electricity buyback rate.

Table 8. PV System Installed Costs and Electric Rates

Simulation Inputs	Fixed-Tilt System
Installed Cost for the Commercial-Scale 500 kW PV System	$2.15/Wdc
Installed Cost for the Commercial-Scale 1.1 MW PV System	$2.58/Wdc
Installed Cost for the Utility-Scale 12.2 MW PV System	$1.77/Wdc
Wholesale Electric Rate LG&E and KU	3.23 ¢/kWh
Commercial Electric Rate LG&E and KU	8.69 ¢/kWh

An estimate for the proposed PV systems based on the usable site area for solar generation, the system size, and the initial system costs assuming the Federal Investment Tax Credit (ITC) is obtained is outlined in Table 9.

[5] http://www.nrel.gov/docs/fy15osti/64746.pdf

Table 9. Estimated PV System Sizes and Costs

PV System Type	Estimated Acres/MW	Estimated System Size	Estimated System Cost with ITC	Estimated System Cost without ITC
Fixed-Tilt Sample Size 3 Acres	6.0 acres/MW	500 kW	$752,500	$1,075,000
Fixed-Tilt Capped Landfill 6.5 Acres	6.0 acres/MW	1.1 MW	$1,986,600	$2,838,000
Fixed-Tilt Entire Site Excluding Capped Landfill 73.4 Acres	6.0 acres/MW	12.2 MW	$15,157,100	$21,653,000

VI. Incentives

The economics of grid-tied PV depends on financial incentives, available federal tax credit, the regional cost of electricity, the solar resource, panel tilt, and orientation. Table 10 provides possible financial incentives to assist with financing a proposed solar PV system.

Table 10. Summary of Applicable Incentives

1. Federal and State Investment Tax Credit*	System owners may qualify up to 30% federal tax credits. Must be a taxable entity to qualify for these, or partner with a taxable entity.
2. Modified Accelerated Cost Recovery System (MACRS)	MACRS depreciation is also considered another important financial incentive. The MACRS is a method of depreciation in which a business' investments in certain tangible property are recovered, for tax purposes, over a specified time period through annual deductions. Qualifying solar energy equipment is eligible for a cost recovery period of five years. More information about MARCS is available here: http://www.seia.org/policy/finance-tax/depreciation-solar-energy-property-macrs
3. Sales Tax Incentive	Up to 100% of the sales and use tax for a maximum of 50% of the capital investment.
4. Corporate Tax Credit	100% of the corporate income tax. 100% of the limited liability entity tax.
5. Other Incentives	For other applicable incentives, go to the following website: www.dsireusa.org

*Note: The Federal Tax Credit is currently available through December 31, 2019.

The Commonwealth of Kentucky offers incentives through the Incentives for Energy Independence Act. A renewable energy facility that meets the minimum electrical output requirement of at least one megawatt of power for: wind, hydro, biomass, landfill methane; or generation of 50 kilowatts for solar and a minimum capital investment is $1,000,000 are eligible for sales and use tax refunds up to 100 percent of tax paid on tangible property, tax credits up to 100% of corporate income or Limited Liability Entity Tax liability arising from the project, and wage assessment incentives up to 4% of gross wages of each employee. The RE facilities must be able to generate electricity for sale through alternative methods such as solar power, wind power, biomass resources, landfill methane gas, hydropower, or other renewable resources.

Net metering is allowed in Kentucky but it is limited to RE systems up to 30 kW in size. In a conventional net metering situation, a customer-sited RE system is connected to the utility grid through a customer's utility meter. This is known as "behind-the-meter generation." At any given moment, if the site is using more electricity than the system is producing, all the electricity produced by the system is used on-site and the site's electricity needs are supplemented from the grid. If the site is using less electricity than the system is producing, the excess electricity is exported to the grid and the customer receives a Kwh credit. This is typically recorded as negative use and is commonly referred to as the "meter spinning backwards." At the end of the billing cycle, the grid-supplied electricity and the credits for any exported electricity are reconciled, and any surplus credits can be carried forward to the next billing cycle. The specifics of net metering are dependent on the customer's service classification.

Because of the relatively low net-metering limit of 30 kW for PV systems, net-metering will not come into play for the larger PV systems discussed in this report.

Kentucky's regulated utilities do offer small power production and co-generation tariffs for generation projects greater than 30 kW per the Public Utility Regulatory Policies Act (PURPA) requirements for purchase of electricity from qualifying facilities. Criteria for qualification of small power production facilities and cogeneration facilities constructed on or after November 9, 1978, are the same as those adopted by the Federal Energy Regulatory Commission including 18 C.F.R. Parts 292.203, 292.204, 292.205, and 292.206 as published in the Federal Register March 20, 1980 (45 F.R. 17959). Each regulated electric utility in Kentucky is required to purchase any energy and capacity which is made available from a qualifying facility except in a few specific instances. Qualifying facilities have the option to supply their own power requirements and sell their surplus to the utility; or simultaneously sell their entire output to the utility while purchasing their own requirements from that utility.

In addition, Kentucky has access to Regional Transmission Organizations (RTOs) and specifically both markets of the Midcontinent Independent System Operators and the Pennsylvania, Jersey, Maryland (PJM) Power Pool. For example PJM offers markets for demand response, energy, and capacity that generation units can bid into and be compensated for based on performance. Kentucky does have requirements for merchant electric generating facilities that are capable of operating capacity of 10 MW or more and sell the electricity they produce in the wholesale market, at rates and charges, not regulated by the Public Service Commission. A merchant electric generation facility must obtain a construction certificate from the Kentucky State Board on Electric Generation and Transmission Siting.

In addition, in 2015, the Kentucky Public Service Commission issued a staff opinion regarding special contracts between utilities and energy users in the Commonwealth. This staff opinion reinforces the ability of utility to procure renewable energy facilities for those customers who are interested in renewable energy. Theoretically, a solar array built on Lee's Lane Landfill could be procured by a utility through a special contract for a customer interested in acquiring renewable energy. As quoted from the staff opinion:

"Considering the authority for utilities to enter into special contracts, Commission Staff believes that a request by an energy intensive customer to purchase renewable energy is a "reasonable consideration" within the scope of KRS 278.030(3) to justify the use of a special contract for that customer. Upon the filing of a special contract with the Commission, a review is conducted to ensure that the rates are fair, just and reasonable under KRS 278.030(1), that there is no undue discriminatory in violation of KRS 278.170(1), and that there are reasonable considerations to justify the use of a special contract as a unique classification as required by KRS 278.030(3)."

VII. Conclusions

An analysis of solar photovoltaics was performed for the Lee's Lane Landfill in Louisville, Kentucky. The Lee's Lane Landfill site appears to have somewhat favorable site conditions to support solar PV generation and economic viable reuse, transmission lines, accessible roads, open area, and minimal shading issues once the site is cleared.

The annual energy output, annual energy value, and various economic results are listed in the two tables below along with the annual emissions reductions. Table 11 lists the results assuming the 30% Federal ITC is not captured and Table 12 lists the results assuming the 30% Federal ITC is captured. Results are also presented for assuming both the wholesale electric rate of $0.0323/kWh and the commercial electric rate of $0.0869/kWh. As shown, capturing the Federal ITC heavily influences the financial viability of a PV project coupled with the corresponding buyback electricity rate of a PV project. The economics are most favorable for the utility-scale PV system (i.e., 12.2 MW) due to the reduced installed cost of this system. The economics are least favorable for the PV system on the capped landfill due to the increased installed cost related to building on a capped landfill. It is important to note that the economics for building on the capped landfill could be more favorable when compared to the larger site when the cost of tree clearing and site preparation is accounted for (note, assessing the cost of tree clearing and site preparation is beyond on the scope of this project). A system of approximately 500 kW could be implemented on the site, offering a positive redevelopment option that could power the equivalent of approximately 60 homes.

Table 11. Lee's Lane Landfill Site PV System Simulation Results without Federal ITC

PV System	Potential Area for PV (Acres)	PV System Size (MW)	Current Electricity Rate (¢/kWh)	Annual Energy Output (kWh/year)	Annual Energy Value ($/year)	Estimated Initial Cost without 30% ITC ($)	Simple Payback without ITC (years)	Annual CO_2e Emissions Reductions (metric tons/year)
3-Acre Sample Size	3.0	0.5	Wholesale 3.23	667,645	$21,565	$1,075,000	49.8	407
6.5-Acre Capped Landfill	6.5	1.1		1,468,821	$47,443	$2,838,000	59.8	895
73.4-Acre Site	73.4	12.2		16,290,535	$526,184	$21,653,000	41.2	9,931
Entire Site (79.9 Acres)	79.9	13.3		17,759,356	$573,627	$24,491,000	42.7	10,826
3-Acre Sample Size	3.0	0.5	Commercial 8.69	667,645	$58,018	$1,075,000	18.5	407
6.5-Acre Capped Landfill	6.5	1.1		1,468,821	$127,641	$2,838,000	22.2	895
73.4-Acre Site	73.4	12.2		16,290,535	$1,415,647	$21,653,000	15.3	9,931
Entire Site (79.9 Acres)	79.9	13.3		17,759,356	$1,543,288	$24,491,000	15.9	10,826

Table 12. Lee's Lane Landfill Site PV System Simulation Results with Federal ITC

PV System	Potential Area for PV (Acres)	PV System Size (MW)	Current Electricity Rate (¢/kWh)	Annual Energy Output (kWh/year)	Annual Energy Value ($/year)	Estimated Initial Cost with 30% ITC ($)	Simple Payback with ITC (years)	Annual CO_2e Emissions Reductions (metric tons/year)
3-Acre Sample Size	3.0	0.5	Wholesale 3.23	667,645	$21,565	$752,500	34.9	407
6.5-Acre Capped Landfill	6.5	1.1		1,468,821	$47,443	$1,986,600	41.9	895
73.4-Acre Site	73.4	12.2		16,290,535	$526,184	$15,157,100	28.8	9,931
Entire Site (79.9 Acres)	79.9	13.3		17,759,356	$573,627	$17,143,700	29.9	10,826
3-Acre Sample Size	3.0	0.5	Commercial 8.69	667,645	$58,018	$752,500	13.0	407
6.5-Acre Capped Landfill	6.5	1.1		1,468,821	$127,641	$1,986,600	15.6	895
73.4-Acre Site	73.4	12.2		16,290,535	$1,415,647	$15,157,100	10.7	9,931
Entire Site (79.9 Acres)	79.9	13.3		17,759,356	$1,543,288	$17,143,700	11.1	10,826

EPA supports the potential solar PV generation at the Lee's Lane Landfill site. Other possible benefits from solar generation at the site include, revenues via land lease payments from a solar developer, potential increase in biodiversity and habitat restoration, and reduced operation and maintenance responsibilities and costs.

The Lee's Lane Landfill site was chosen as a favorable site because:

- The available are for PV is relatively large (79.9 acres);
- RE development is one of the highest uses for this space;
- The project has already gotten a lot of public attention and fits with the sustainability goals of both the city and some of the local businesses;
- Possible off-taker scenarios have been identified and would fit into a utility's shared or custom build solar program; and,
- The site is easily maintained as protective.

By choosing an implementation mechanism, this could become a showcase for the state and the country of a creative reuse of an underutilized parcel.

VIII. Recommended Next Steps

This solar screening study provides the PV system sizes based on the proposed usable area. However, the actual system installation will need to factor the availability of funds and the amount of power that can be sold. There are a number of ways the parcel could be developed with renewables.

- The utility could utilize a special contract at the site for a specific corporate off-taker whereby it could procur the renewable energy resource via a power purchase agreement with a third party.
- The utility could develop a renewable energy facility to support its long tern resource and distribution planning. In exchange for access to a site through a lease arrangement, the utility can finance, develop, own, and operate the solar projects utilizing their own expertise and sources of financing.
- A third party merchant developer could develop the renewable energy facility, license portions of the array to the community, but sell the electricity into the wholesale markets. The developer would not be "selling" electricity.
- The site could be leased or sold for redevelopment to a developer that is interested in incorporating RE into their development.
- The city could develop the site using bonds and work on an arrangement with the utility to supply the city with its renewable energy needs. The City of Louisville in its STAR certification received no credit for demonstrating that the community receives a portion of its overall energy supply from renewable energy sources. This is an area for improvement.

Public private partnerships are favorable ways to structure site development, due to the ability of private partners to take advantage of the tax benefits that cannot be captured by municipalities (or other entities that do not pay corporate income taxes). Once the system is installed, the third-party developer can sell the electricity to the local utility via a PPA – a contract to sell electricity at negotiated rate for a fixed period of time. The term of the PPA typically varies from 20 to 25 years. Utilities have little incentive in Kentucky to enter into a PPA unless specifically to support the goals of a commercial or industrial customer.

The following steps should be taken in order to develop a project on this site:

- Compile all information available on the site and assemble a master repository for the information, including Phase 1 ESAs, ownership documents, historical uses, etc. A list of pre-construction activities that are generally completed is listed in Appendix A.
- Refine notion of land available for a potential PV installation (for example, impacts of state specific incentives and limitations; more detailed shading analysis, etc.)
- Identify the off-taker for the power. This could be the site, adjacent businesses, members of the community, the tenants of a potential redevelopment, or the utility.
- Finalize the project implementation pathway, and assemble the stakeholders.
- Engage the utility and offer full transparency into project plans, technology sizes, and partner organizations.
- Identify a developer who will build the project and/or finance the system.

By following these steps, in this order, many of the pitfalls and project roadblocks may be avoided. The actual mechanics of a development, as well as the amount of money changing hands may be much different than the scenarios investigated here, but the underlying economics of building a system appear to be workable.

Additional evaluations will need to be conducted to fully characterize the feasibility and economics of the Lee's Lane Landfill site for PV installation. Third party solar developers and local utility companies may have technical and financial interests to pursue potential solar renewable energy projects and perform additional solar assessments to determine if projects are economically viable.

This study does not assess the environmental conditions at the site.

Appendix A: Pre-Construction Development Activities

Lee's Lane Landfill Site – Pre-Construction Activities

The activities discussed below are critical to making decisions concerning the feasibility of redeveloping the land into a solar power generating (SPG) station, including technical and financial aspects of a project.

Environmental Due Diligence – Completion of environmental due diligence to support property assemblage, ownership transfer, financing, constructability, and operations, including any associated potential liability issues, is important to ensure successful completion of a SPG project. Conducting due diligence taking into account its operational history and regulatory status, will provide a broad, comprehensive understanding of actual site conditions and will be needed to inform subsequent decisions regarding the development of a SPG station. The following recommended tasks should be undertaken on an area-by-area basis.

Requisite components of environmental due diligence include (with order of magnitude pricing estimates):

1. Phase I Environmental Site Assessment (ESA) – Estimated Price Range: $10,000 – 20,000, depending upon actual parcels selected for project. A Phase I Environmental Site Assessment (ESA) determines the likelihood that environmental contamination is present at the site. The assessment includes a visual site assessment; interviews with past and present owners and occupants; a search for any environmental liens; a review of historical documents; and a search of federal, state, and local databases regarding contamination at or near the site, and should be conducted for all parcels being considered for assemblage to support this project. A preliminary feasibility study (e.g., quickly determining which parcels are not suitable for solar or likely have a high cost associated with redevelopment) of the individual parcels prior to the Phase I ESA could assist in eliminating parcels that are unlikely to be usable by the development, which will assist with focusing the Phase I ESA and subsequent activities and controlling costs. In accordance with ASTM standards, a Phase I ESA report should be no older than 6 months at the time of transfer of ownership and/or beginning of operations at the site, whichever comes first. Phase I ESAs that are between six and 12 months in age may be updated.
2. Phase II ESA – Estimated Price Range: $50,000 – $100,000. A Phase II Environmental Site Assessment (ESA) provides a more thorough evaluation of site conditions that includes physical sampling to determine the extent and severity of possible contamination. Phase II assessments typically include soil and groundwater sampling and analysis. While not always necessary, a Phase II ESA is typically appropriate at a landfill such as the Lee's Lane landfill. A Phase II ESA would be the basis for preparing a Baseline Environmental Assessment. Efforts should be made to evaluate this data in advance of conducting any field activities to assist with cost control and efficient use of funding.

Geotechnical Analysis – in addition to environmental due diligence, it will be necessary to evaluate the subsurface geotechnical conditions within appropriate sections of the target parcels to address constructability issues prior to making final decisions regarding the parcels to be assembled for project use. Grubbing and clearing of vegetation (e.g., removing trees to remove or reduce shading effects) should also be considered as part of a geotechnical analysis.

Based on currently known and assumed geotechnical and environmental conditions, for purposes of this summary it is assumed that the SPG will use a ballasted ground mount panel racking approach.

3. Geotechnical engineering evaluation – Estimated Price Range: $25,000 – $50,000. A geotechnical engineering evaluation of construction soil stability needs to determine best and most cost-effective path forward to managing building debris, subgrade voids, and other subsurface debris challenges. This analysis should be conducted on a parcel-by-parcel basis to determine subsurface conditions, evaluate existing information and determine what additional geotechnical data is needed for design of solar racking foundations and installation methods.
4. Geotechnical investigation – Estimated Price Range: $50,000 – $100,000. Based on above evaluation findings, the SPG developer will likely need to conduct a site-specific, parcel-by-parcel, geotechnical investigation to determine the actual soil constructability conditions. This investigation would include collection of soil samples for specific laboratory testing of soil characteristics. This information will be used to design solar racking system foundations.

Public engagement – engaging with the site, adjacent and surrounding property owners, as well as other public entities, will be an important part of successful development of the project. Gaining public support is key to a smooth and efficient permitting process, as well as the long term good will of the project. An open and transparent process in which the community participates is also key to meeting some of the metrics involved with Environmental Justice concerns for this area.

5. Public Outreach Program – Estimated Price Range: $25,000 – 50,000, depending upon number of meetings and venues selected. Design and host open house meetings within the neighborhood to present proposed redevelopment plans. Includes preparation of site drawings, venue and refreshments.

As previously indicated, the above price ranges are only preliminary order of magnitude estimates based on current information and past experience on similar projects. As this project proceeds, the estimates for these tasks should be refined to provide better understanding of Capital Expenditure needs, as well as an examination of on-going Operations & Maintenance (O&M).

It is strongly recommended that the environmental due diligence and geotechnical activities for all potential parcels for this project be completed prior to the assemblage/transfer of parcels and final planning and permitting of the project. Conducting these activities will provide significant data necessary to make decisions concerning the actual parcels that are adequately positioned for inclusion in the SPG station at a reasonable price for pre-construction and construction activities.

Additional Considerations

In addition to the above due diligence and planning work tasks, it is recommended that the following items and activities be explored to provide additional insight into the technical and financial challenges to developing solar power at the site.

- Environmental justice implications – evaluate impacts/opportunities on the surrounding community associated with land use as a SPG facility.
- Electrical interconnect study – an electrical interconnection study with the local utility (i.e., GA Power) will be required.
- Electrical line corridor - determine the necessary permitting and engineering activities to install the electrical interconnection line from the SPG facility to the approved substation, such as right of way permits for utility easement and pole mount or subsurface installation of line.
- Identify land zoning requirements - special land use permits or rezoning may be required to redevelop the selected parcels as a SPG facility.
- Stormwater management – evaluate the integrity of the adjacent municipal stormwater infrastructure to verify adequacy to manage run off from the proposed SPG facility.
- Explore availability of incentives for environmental and/or geotechnical Brownfield activities – identify the brownfield redevelopment authority (BRA) with jurisdiction, verify site is in a Core Community, explore the potential availability of brownfield assessment funding, and evaluate the support.

Appendix B: Re-Powering America's Land – Background and Resources

Through the Re-Powering America's Lands Initiative, the U.S. EPA promotes the reuse of potentially contaminated properties, landfills, and mining sites for RE generation. This initiative identifies the RE potential of these sites and provides useful resources for communities, developers, industry, state and local governments or anyone interested in reusing these sites for RE development. The various Re-Powering America Initiative resources are summarized below and can be found at http://www.epa.gov/oswercpa.

- Mapping and Screening Tools - Under the Mapping and Screening tools, EPA's Re-Powering America's Land team screened more than 80,000 potentially contaminated sites and MSW landfills covering nearly 43 million acres across the United States for suitability to site RE generation facilities, including utility-scale solar. Maps depicting the locations of these EPA tracked sites and their potential for supporting RE generation can be found at www.epa.gov/oswercpa/mapping_tool.htm. These maps enable users to view screening results for various RE technologies at each site.
- Technical Assistance and Support - As part of the Re-Powering America's Land Initiative, the EPA and the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) are evaluating the feasibility of developing RE production on Superfund, brownfields, and former landfills or mining sites. This project pairs EPA's expertise on contaminated sites with the RE expertise of NREL.
- A list of feasibility studies for RE production for various technologies including solar can be found at www.epa.gov/oswercpa/rd_tech_assist.htm.
- Redevelopment Tools and Resources – Under the Redevelopment Tools and
- Resources, EPA and NREL created the joint publication, "*Best Practices for Siting Solar PV on Municipal Solid Waste Landfills*" to provide assistance in addressing common technical challenges of siting PV on MSW landfills (such as impacts to landfill settlement differentials and the PV solar performance, impacts to other landfill systems, understanding landfill cap integrity/characteristics, and understanding landfill post closure requirements for solar PV design considerations) and provide other useful information for solar developers, landfill owners, and federal, state, and local government entities. Other documents for stakeholders to consider are "*EPA RE Powering Finance Fact Sheet*," "*Handbook on Siting Renewable Energy Projects while Addressing Environmental Issues"* and "*Revised Bona Fide Prospective Purchaser (BFPP) Provisions Enforcement Guidance for Tenants*"
- Fact Sheets and Success Stories - The Re-Powering Team highlighted numerous successful stories and fact sheets of RE projects implemented throughout the United States. The Re-Powering America Team also maintains a list of completed RE installations on contaminated sites and landfills. To date, the Re-Powering Initiative has identified 190 RE installations on 181 contaminated lands, landfills, and mine sites, with a cumulative installed capacity over 1,172 megawatts (MW) and consistent growth in total installations since the inception of the Re-Powering Initiative.

Appendix C: PV Systems Overview

Solar PV technology converts energy from solar radiation directly into electricity. Solar PV cells are the electricity-generating component of a solar energy system. When sunlight (photons) strikes a PV cell, an electric current is produced by stimulating electrons (negative charges) in a layer in the cell designed to give up electrons easily. The existing electric field in the solar cell pulls these electrons to another layer. By connecting the cell to an external load, this current (movement of charges) can then be used to power the load, e.g., light bulb.

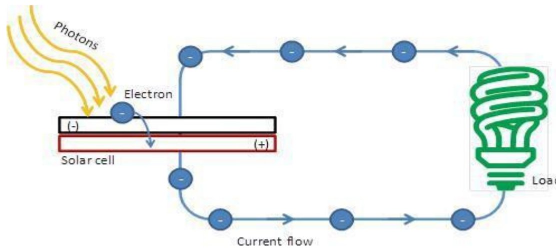

Figure 8. Generation of electricity from a PV cell
Source: NREL

PV cells are assembled into a PV panel or module. PV modules are then connected to create an array. The modules are connected in series and then in parallel as needed to reach the specific voltage and current requirements for the array. The direct current (DC) electricity generated by the array is then converted by an inverter to useable alternating current (AC) that can be consumed by adjoining buildings and facilities or exported to the electricity grid. PV system size varies from small residential (2-10 kilowatts (kW)), commercial (100-500 kW), to large utility scale (10+ megawatts (MW)). Central distribution plants are also currently being built in the 100 MW+ scale. Electricity from utility-scale systems is commonly sold back to the electricity grid.

PV Module

Module technologies are differentiated by the type of PV material used, resulting in a range of conversion efficiencies from light energy to electrical energy. The module efficiency is a measure of the percentage of solar energy converted into electricity. Two common PV technologies that have been widely used for commercial- and utility-scale projects are crystalline silicon and thin film.

Crystalline Silicon

Traditional solar cells are made from silicon. Silicon is quite abundant and nontoxic. It builds on a strong industry on both supply (silicon industry) and product side. This technology has been demonstrated for a consistent and high efficiency over 30 years in the field. The performance degradation, a reduction in power generation due to long-term exposure, is under 1% per year. Silicon modules have a lifespan in the 25-30-year range but can keep producing energy beyond this range.

Typical overall efficiency of silicon solar panels is between 12% and 18%. However, some manufacturers of mono-crystalline panels claim an overall efficiency nearing 20%. This range of efficiencies represents significant variation among the crystalline silicon technologies available. The technology is generally divided into mono- and multi-crystalline technologies, which indicates the presence of grain-boundaries (i.e., multiple crystals) in the cell materials and is controlled by raw material selection and manufacturing technique. Crystalline silicon panels are widely used based on deployments worldwide.

Thin Film

Thin-film PV cells are made from amorphous silicon (a-Si) or non-silicon materials such as cadmium telluride (CdTe). Thin-film cells use layers of semiconductor materials only a few micrometers thick. Due to the unique nature of thin films, some thin-film cells are constructed into flexible modules, enabling such applications as solar energy covers for landfills such as a geomembrane system. Other thin film modules are assembled into rigid constructions that can be used in fixed tilt or, in some cases, tracking system configurations.

The efficiency of thin-film solar cells is generally lower than for crystalline cells. Current overall efficiency of a thin-film panel is between 6% and 8% for a-Si and 11-12% for CdTe. Figure 4 shows thin-film solar panels. Industry standard warranties of both crystalline and thin film PV panels typically guarantee system performance of 80% of the rated power output for 25 years. After 25 years, they will continue producing electricity at a lower performance level.

Inverters

Inverters convert DC electricity from the PV array into AC and can connect seamlessly to the electricity grid. Inverter efficiencies can be as high as 98.5%. Inverters also sense the utility power frequency and synchronize the PV-produced power to that frequency. When utility power is not present, standard inverters will stop producing AC power to prevent putting power into the grid while utility workers are trying to fix what they assume is a de-energized distribution system. This safety feature is built into a majority of grid-connected inverters in the market. There are, however, “smart inverters” that can operate in “island mode” during a grid outage. Electricity produced from the system may be fed to a step-up transformer to increase the voltage to match the grid. There are two primary types of inverters for grid-connected systems: string and micro inverters. Each type has strengths and weakness and may be recommended for different types of installations.

String inverters are most common and typically range in size from 1.5 kW to 1,000 kW. These inverters tend to be cheaper on a capacity basis, as well as have high efficiency and lower O&M costs. String inverters offer various sizes and capacities to handle a large range of voltage output. For larger systems, string inverters are combined in parallel to produce a single point of interconnection with the grid. Warranties typically run between 5 and 10 years with 10 years being the current industry standard. On larger units, extended warranties up to 20 years are possible. Given that the expected life of the PV panels is 25-30 years, an operator can expect to replace a string inverter at least one time during the life of the PV system.

Micro-inverters are dedicated to the conversion of a single PV module's power output. The AC output from each module is connected in parallel to create the array. This technology is relatively new to the market and in limited use in larger systems due to potential increase in O&M associated with significantly increasing the number of inverters in a given array.

Current micro-inverters range in size between 175 W and 380 W. These inverters can be the most expensive option per watt of capacity. Warranties range from 10 to 20 years. Small projects with irregular modules and shading issues typically benefit from micro inverters.

With string inverters, small amounts of shading on a solar panel will significantly affect the entire array production. Instead, it impacts only that shaded panel if micro-inverters are used. Figure 5 shows a string inverter.

Figure 9. String inverter
Source: NREL PIX 07985

Mounting Systems

The array has to be secured and oriented optimally to maximize system output. The structure holding the modules is referred to as the mounting system.

Wiring for Electrical Connections:

Electrical connections, including wiring, disconnect switches, fuses, and breakers are required to meet electrical code (e.g., NEC Article 690) for both safety and equipment protection.

In most traditional applications, wiring from (i) the arrays to inverters and (ii) inverters to point of interconnection is generally run as direct burial through trenches. In contaminated site applications, this wiring may be required to run through above-ground conduits due to restrictions with cap penetration or other concerns. Therefore, developers should consider noting any such restrictions, if applicable, in requests for proposals in order to improve overall bid accuracy. Similarly, it is recommended that PV system vendors reflect these costs in the quote when costing out the overall system.

PV System Monitoring

Monitoring PV systems can be essential for reliable functioning and maximum yield of a system. It can be as simple as reading values such as produced AC power, daily kilowatt- hours, and cumulative kilowatt-hours locally on an LCD display on the inverter. For more sophisticated monitoring and control purposes, environmental data such as module temperature, ambient temperature, solar radiation, and wind speed can be collected.

Appendix D: Glossary of Terms

Glossary of Terms	
PV	Photovoltaic Energy
AC	Alternating Current – which can be transmitted over power lines
DC	Direct Current - which cannot be transmitted over power lines
Ballast	A footing on which a Solar Panel can be placed which will not penetrate the soil cap
Inverter	A machine which takes in Direct Current and converts it to Alternating Current which can then be transmitted to an electrical sub for transmission to a utility company
Energy Density	The number of solar arrays which can be placed in a specific area and is the packing factor – Fixed Axis Panels take up less space, Single Axis Panels take up more space.
kW or kWh	Kilowatt or Kilowatt Hours
MW or MWh	Mega Watt or Mega Watt Hours
ITC	Investment tax credits
O&M	Operations and Maintenance
Payback Period	Number of years until the project is paid for
PPA	Power Purchase Agreement - legal contract between an electricity provider and a purchaser that defines all commercial terms for the sale of electricity
RE	Renewable Energy
SPG	Solar Power Generation

Appendix E: Vegetation at Lees Lane Landfill

The vegetation at Lees Lane Landfill is typical for the urban environment. The shrub understory is dominated by the invasive introduced bush honeysuckle which is the most conspicuous of the plant species. The canopy is composed of mostly native species, although a Callery pear was observed at the site, an extremely noxious introduced species. Cottonwoods are located closer to the river and hackberries are farther back on the site. Sycamores and silver maples are also present. Oaks were young and coming in along the edges. As for vines, passion flower are located along the edge. Other natives include greenbrier, poison ivy, and grape. Nonnatives include Japanese honeysuckle and creeping euonymous. Herbaceous layer had the typical nonnatives such as ground ivy and purple violet, but also a decent showing of the native wingstem, goldenrod, and avens. There are also significan stands of brambles, *Rubus* sp.