Developing MW-Scale PV Solar Installations on Closed Landfills

Puerto Rico Solar Transaction Forum
University of Turabo, Caguas, Puerto Rico
March 27, 2012

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S U N L I G H T + L A N D F I L L S = P O W E R

Project Navigator, Ltd. Develops Clean, Green PV Solar Power Systems at Landfills and Brownfield Sites

- 100,000's Acres of Landfill Cap Space is Available
- No Fuel Requirements
- No Moving Parts
- Long Operational Lifetime
- Low Maintenance
- No Emissions
- No Waste Products
- Minimal Impact on Landfill Cover
- No Noise
- Simple, Fast Construction
- Continually Improving Technology
- Regulatory Incentives

Team Values

- Cost-effective execution
- Use most efficient technologies
- Operate safely
- Operate collaboratively and as a good neighbor
Large Scale Solar Facilities Face Permitting, Financing, and Interconnect Challenges. Not so for PV Developments on Urban Located Landfills.
Landfill Sites are Excellent Platforms for PV Solar Facilities. Flat Acreage, Close to Load and Interconnect, Putting Otherwise Unusable Acreage Back to Use. Projects are Technically Straightforward but Administratively Complex.

**PV Solar Power**

A photovoltaic (or PV) cell is a specially treated wafer of silicon, sandwiched between two thin contact plates. The top contact is positively charged and the back contact is negatively charged, making it a semiconductor.

- The n-type semiconductor has an abundance of electrons, giving it a negative charge, while the p-type semiconductor is positively charged.
- Electron movement at the p-n junction produces an electric field that allows only electrons to flow from the p-type layer to the n-type layer.
- When sunlight hits the solar cell, it's energy knocks electrons loose from the atoms in the semiconductor.
- When the electrons hit the electrical field, they're shunted to the top contact plate and become a usable electric current.
- PV panels are mounted in racking systems specially designed to accommodate landfill-specific requirements such as “no cap damage” and “waste settlement.”

**Landfill Gas-to-Power**

Landfill gas (LFG) migrates to waste prism extraction wells and the associated collection systems. The LFG is conveyed via a network of pipes to feed a power generation plant.

**Solar Power to the Grid**

Excess energy from the solar array is fed into the power grid. It helps provide extra electricity to the community, especially during peak daytime hours.
According to U.S. EPA, there is no shortage of Brownfields and Landfill Site acreage which could be suitable for renewable energy.

- Over 400,000 identified Brownfield sites in the United States
- 16 million acres are available for development of renewable energy
- That’s enough land to generate approximately 3,175,000 MW
- 32 Landfill Sites identified in Puerto Rico with 1,300 acres available for development which could generate over 2,000 MW

Ref: [www.epa.gov/renewableenergyland](http://www.epa.gov/renewableenergyland)
A Landfill Site is a Good PV Development Candidate if Certain Screening Criteria are Met.

- Environmentally Impacted Land (Restricted Future Use)
- Appropriate Geographic Location
- Land Control (Title or Long-Term Lease)
- Nearby Interconnection Point
- Adjacent Load (PPA Approach)
- Project Financing
  - External
  - Internal
- Green Corporate Goals
- State-Mandated Renewable Portfolio Standards

- Site Identification
- Site Control*

Early Planning, Negotiations and Project Marketing Phase
- Power Purchase Agreement (PPA) Proposal and/or Negotiations
- Power Marketing
- Interconnect Study
- Environmental Permitting Including Any EIR Work and Associated Environmental Document Revisions
- Facility Conceptual Design
- Project Economic Calculations

Civil Engineer Selection → Contract Execution → Site Plan / Layout Design
Technology Provider/EPC Contractor Selection → Contract Execution
Tariff Rate Determination → Power Purchase Agreement Execution
Permit Acquisition → Interconnection Agreement Execution

Financing → Site Upgrades → Commissioning → Operations and Maintenance
Procurement

* Can be in form of an “option agreement” between landowner and solar project developer, or a longer term land lease. Option would convert to a land lease once the scope and economics of the proposed project are better defined, such as at the execution of a PPA.
To Construct a Solar Power Facility on a Landfill, the Solar Developer Needs to Also Have a Rigorous Understanding of Landfill Closure Engineering.

PVNavigator, LLC Provides this Integrated Capability.

**Perimeter compliance goals**
- Create a subsurface ("picket-fence") gas migration barrier
- Standards: For OII, CH$_4 < 5$%; For BKK, CH$_4 < 0.1$%; VC in $10^{-4}$ to $10^{-6}$ risk range
- PNL has worked these issues at U.S. EPA regulated landfill closures in Region 2
Key Design Criteria are Minimal Settlement & The Continued Need for Cap Functionality.

Design considerations include eliminating cap penetration, continued functionality of the ET cap, storm water management, wind design and insuring protectiveness during an earthquake event.

Design of PV Array will take into consideration:

1. Settlement
   - Total
   - Differential
2. Panel placement on cap
   - Spread footings
   - Anchors
3. Continued performance of evapotranspirative (ET) cap
   - Infiltration minimization
   - Vegetative growth
4. Stormwater management
   - No standing water
   - Runoff management
5. Other
PV Navigator Prefers Prefabricated, Racked PV Systems Specifically Designed for Landfill Caps.

Features of SunPods Landfill PV Solar Unit

- 2.5 kW per array (as shown)
  - i.e. 400 arrays per MW
- Arrives prefabricated
  - Minimal onsite assembly
- 20 ft X 10 ft arrays
- Weighs 3,500 lbs, supported on a leveling support system
  - Eliminates landfill cap penetration
  - Self ballasting
- 10 Gauge steel frame
- Rated to 130 mph + wind speed
- Ready to connect
- Minimal maintenance
PVN’s Mainland Solar Development Projects.

### West Coast
1. Avon Refinery: 10 MW
2. Purity Landfill: 1 MW
3. Oil Landfill: 4 MW
4. BKK Landfill: 10 MW
5. WDI Landfill: 4 MW
6. Big Bear Landfill: 2 MW
7. Gemcor Site (Chevron Landfill): 10 MW
8. Milliken Landfill: 5 MW
9. Barstow Landfill: 10 MW

### East Coast
10. Buena Vista Landfill: 1 MW
11. Delaware City: 4 MW
12. Ocean Township: 5.86 MW
13. Lumberton Landfill: 2.4 MW
14. Owens Corning Landfill: 3.1 MW
PVN Has a Partnership with Chevron Energy Solutions, Specifically for Landfill Projects.

Renewable Energy Solutions for Landfills

Solid waste facility owners are looking for innovative ways to use their closed landfill sites. These inactive sites or “legacy landfills” carry costly, interim operations, maintenance and monitoring (OM&M) responsibilities and often have limited renewable potential due to a combination of financial, geotechnical, environmental and regulatory concerns.

Legacy landfill sites are outstanding candidates for renewable energy platforms, giving owners the capacity to improve site sustainability, demonstrate responsibility stewardship and generate renewable power for nearby buyers.

PVN has a partnership with Chevron Energy Solutions, specifically for landfill projects.

The Landfill Renewable Energy Team

Planning
The basic planning services include assessment of the power generation potential of a particular site or sites and presentations of detailed technical information. We look at site site and generation capacity, siting suitability to potential power and renewable energy technologies, costs, fuel selection and potential landfill gas capture and generation projects, fuel quality affecting landfill gas and energy usage and site regulatory status and restrictions.

Funding
We help owners identify potential funding sources, assisting with and advising on Competitively-sourced Energy Leases, Power Purchase agreements (PPA's), Third Party Ownership options, Clean Renewable Energy Bonds (CREB's) and Certificates of Public Convenience (CPC). Our teams can handle all of the details.

The Landfill Renewable Energy Team

Chevron Energy Solutions (CES) provides, finances and constructs renewable energy projects, including wind and solar power, concentrating solar power plants, biogas and landfill gas to provide customers with reliable, renewable energy while decreasing the carbon footprint. Since 2006, CES has developed hundreds of megawatt renewable energy facilities worldwide, and more than 1,000 projects.

Contact:

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Community Outreach and Project Advocacy is Conducted via Public Meetings...Where Resistance is Typically Found to be Low.

A Proposed Renewable Energy Project at the Ocean Township’s Landfill
10 MW PV SOLAR DEVELOPMENT, WARETOWN, NEW JERSEY

Who
- A development team anchored by Project Navigator, LLC, JNPL, as the project integrator.
- PEA specializes in developing small-scale distributed solar facilities on landfills.
- Design capabilities by Chevron Energy Solutions, and solar system supplier SunPower, Inc.
- Environmental and landfill post-closure document preparation by PEA, and Brotherhood Environmental Services.

What
- A 10 MW PV solar development.
- Feed-in tariff revenue and net metering.
- Direct 25 acres of landfill top each area.
- Tanks are specifically designed for landfill cap installations.
- No long-term cap damage.

When
- All permitting and design completed by end of 2012.
- System is designed and operational by end of 2012 (weather permitting and in conformance with landfill construction season).

How
- PEA, and the Township of Ocean enter into a land lease agreement which includes ability to use asbestos top caps for 30 years.
- Project will be financed via a combination of debt and equity.
- PEA has excellent track record and experience with major East and West Coast renewable energy funds.
- Options exist to sell a 60% ownership.

Summary
In summary, we propose to build a 10 MW PV solar power facility using a combination of debt and equity financing. The structure of the business arrangement with the Township involves a land lease for a term of 15 years.

The design will use projects with renewable energy industry experience to minimize the risk of future landfill settlement. The Township believes the project will support the local community’s need to ensure that energy is produced in a more productive, and sustainable manner.

Key Elements
- A 10 MW system, which will occupy the designated approximately 24 acres of the landfill.
- Full financing of the entire system.
- Non-disruptive construction of the array, as well as a long-term agreement with the Township for the revenue requirements from the facility.
- Interface with all applicable regulatory entities such as: NJDEP, Franklin Township, Ocean County, N.J. (Ocean Township is an outgrowth of Franklin Township).
- Engineering and design of the entire system including the interconnecting equipment and infrastructure systems.
- Procurement of all systems including approximately 2,100 SunPower solar panels for the system.
- Long-term operation and maintenance of the solar facility, with a complete understanding of how a solar system works and how it is maintained.
- Development of a cooperative long-term working relationship and understanding of the Township's needs or the project.

Estimated Solar Project Schedule

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Note: Actual construction time will depend on weather conditions and condition of the site.
Conceptual Plan for a 2MW PV Solar Installation on Top Deck of Capped, Closed Anguilla Landfill, St. Croix, USVI

PLAN

- Top deck development only
- PVN solar team will work with landfill closure design team (VI WMA) to formulate an integrated environmental closure/PV design
- Install 800 fixed tilt, polycrystalline solar racks on the landfill’s capped top deck
- System capacity would be approximately 2.1 MW for Anguilla
  - Total landfill generation capacity could be augmented with a LFG to power system
- Facility would operate continuously for 25-30 years
The California Energy Commission is Funding a 3 Year PVN Solar Pilot Test Program at a Closed Landfill Site. The Goal: Derive Design Criteria

**Goal:** The collection of power generation performance data as well as information on any impacts the solar racking system may have on the landfill cap’s functions regarding gas collection and infiltration minimization.

Figure shows a small scale, PV solar rack pilot system, located on a landfill cap. The purpose of the pilot unit is to measure and monitor the system's power generation operating performance on a landfill site where prior desk-top calculations have shown the installation of a 1 to 10 MW PV solar facility may be technically and economically viable.

The pilot facility would typically be operated from 1 to 2 years, thereby permitting any effects of the solar system on the cap (e.g. in the form of increased load and altered storm water management) to be evaluated.

1. WiFi/telemetric system data collection/transmission
2. Reference settlement monument
3. Landfill lateral gas collection system (which may or may not exist for the selected landfill)
4. Landfill waste
5. Engineered landfill cap/cover. This can be an ET monofill or a multilayer RCRA equivalent cap
6. Weather station
7. Wireless strain gauge monitoring system, or associated system to measure strain changes in the solar panel racking system
8. Tilt gauge
9. System orientation monitoring
10. Power generation capacity over entire annual cycle
11. Storm water run off management
12. Monitor growth of cap’s vegetative layer under array
13. Panel washing and associated water use; methods and frequency
1. Project Navigator, Ltd.’s solar company, PV Navigator, LLC, was awarded a grant from the California Energy Commission (CEC) to pilot test the performance of racked, PV solar modules, on a closed California landfill site. The business and scale-up premise is that 1,000’s of acres of closed and capped landfill space, close to urban load, make ideal siting locations for MW-scale distributed PV power installations.

Courtesy of New Cure, Inc. (NCI) and U.S. EPA, the pilot system has now been installed and is operational on the top deck of the south parcel of the Operating Industries, Inc. (OII) landfill in Monterey Park, CA.

A CEC representative visited the project site on March 7, 2012.
2. The entire pilot installation is comprised of three (3), 10 ft X 20 ft, PV racks, each weighing about 3000lbs. The racks are self-ballasting, with no need for tie down, and thereby cap penetration (which is a major consideration in any post-closure, landfill-located development.)

At OII, two (2) racks are positioned adjacent to each other (with only one having the PV modules for power generation.) The relative positioning of the racks will be monitored during the test.

The performance of the PV-module rack will be closely monitored, as described in illustration 4.
3. A third rack is located approximately 200 ft from the 2-rack system. This 3rd rack’s location has been accurately surveyed relative to the 2-rack system, with the objective of trying to evaluate the effects of any differential landfill settlement on the performance of a more extensive, larger MW-scale system.
Lessons Learned After 5 Years of PV Navigator’s Solar Project Development Efforts

- The challenges are in (1) **permitting**, and (2) finding a **power off taker** who’ll pay enough (cents/kW-hr) to make the economics work
  - Technology and construction challenges are secondary
- Have a good (probabilistic?) **economic model**
- Define and negotiate with the potential offtaker(s) early
  - Perform **power interconnect / feasibility** study early in the process
- Bid the forecasted power from the development into utility RPS RFOs
- Regarding landfill post closure use:
  - If considering a closed landfill, **evaluate the quality/quantity of existing site characterization data, esp. “geotech.”** Keep costs down by leveraging past technical info.
- Develop a project fact sheet, early, and discuss with all possible stakeholders
- **Enter into a Letter of Intent (LOI) with Municipality** to investigate the project’s technical and economic feasibility
PV Navigator, LLC At-a-Glance.
We Plan, Permit, Design and Develop MW-Scale PV Solar Power Facilities on Landfills and Brownfield Sites.

PV Solar on Landfills Focus

CA and NJ Sites in Permitting

300 MW Development Pipeline

Distributed Generation’s Growing Importance


8 MW Southern Ocean Landfill Project (NJ)

Use of Simple, Fixed Tilt, PV Systems

Caribbean Growth Initiative

The Economic Viability of PV Power is Increasing.

The Anguilla Landfill as a PV Installation Location: PVN will Formulate a Site Conceptual Model, with Associated Design Calculations, to Verify PV System Feasibility

According to U.S. EPA, There is No Shortage of Brownfield and Landfill Site Acreage Which Could be Suitable for Renewable Energy

PV Navigator, LLC Leads a Multi-talented Solar Development Team

Established Teaming Partners
PERFIL DE LA EMPRESA

Qué Hacemos

- PVN desarrolla una escala de megavatios (MW), instalaciones de energía fotovoltaica en los vertederos y zonas industriales abandonadas
- Fija la inclinación, auto-montado, instalaciones con balasto
- Aproximadamente 50 MW de capacidad del sitio en Los Terminos de Acuerdo
- Más de 300 MW en proyectos generales de PVN

Quiénes Somos

- PVN es una subsidiaria de propiedad total de Project Navigator, Ltd. (www.ProjectNavigator.com)
  - Financiación interna (hasta la fecha)
- Formados por ingenieros, expertos en desarrollo de la tierra y energía
- Cuatro años de crecimiento y esfuerzo de marca
- Relaciones con Enel, Gestamp y Chevron Energy Solutions

En Donde Trabajamos

- Proyectos principalmente en California y Nueva Jersey
- Metas de expansión en el Caribe

Cómo Lo Hacemos

- Sitios detallados y conocimiento de vertederos
- Conocimiento de las hectáreas de empresas en la lista Fortune 500
- Excelente relaciones con las agencias reguladoras
- Experiencia obteniendo permisos de fotovoltaica para los vertederos cerrados
- Aprovechar las tecnologías probadas de fotovoltaica y aplicar a los vertederos
  - (ejemplo PVN’s Beca de La Comisión de Energía de California)
- Reconocimiento de marca está creciendo

Proyectos Representativos

- Vertedero de Barstow, CA
  - 20MW

- Vertedero de Miliken, CA
  - 5MW

- Vertedero de Big Bear, CA
  - 2MW

- Vertedero de Owens Corning, NJ
  - 3MW

- Buena Vista Township, NJ
  - 1MW

- La Comisión de Energía de California
  - Beca de estudios

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