Solar-Powered Landfill Piston-Pumping
Seven Years of Success and Learnings

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Environmental Show of the South - May 15, 2019
Why Solar?

- No power near wellhead
- Power can be located directly with well or sump
- Low operating costs
- No cost of power once installed
- Durable
- Low maintenance
Solar Power + Piston Pumping

- Solar power & piston pumps work well together
- Pistons allow efficient use of solar power
- Simple & compact mechanical actuator design
- Pumps can be located where needed
Why Piston Pumps? Positive Displacement

Pistons:

• Pump anything flowable
• Pump at constant flow rate
• Pump to bottom of well or sump
• Unaffected by + or - changes in pressure
• Pump dry without harm
Why Piston Pumps?

• No electric or air power enters well
• Easy service - Low maintenance
• Can pump 90° vertical to horizontal axis
• Pump rate can be tuned to yield of well
Problems of Over-Pumping

Inadequate recharge rates disturb balance of formation

- Cone of depression forms
- Velocity gradients increase
- Formation can shift or collapse
- Pumping viability compromised
Downhole Pump: Positive Displacement

- Simple, two-valve downhole
  - Standing valve & traveling valve
- Traveling-valve reciprocation cleans barrel w/each stroke
Piston Pump: Top-head drive

- **Mechanical actuator & motor**
  - On top of well casing or sump
  - Above grade - mechanical operation

- **Solar, electric or pneumatic power**
A Working Piston Pump

Diagram showing the components of a piston pump system including:
- Tank
- Solar panel
- Above-ground drive motor
- Well seal
- Well casing
- Driver rod
- Riser pipe
- Pump barrel
- Drive piston
- Foot valve
- Pump intake

Click to see Drive Motor
Click to see Downhole
How Solar Piston Pumps Work

- Linear-rod driver
- Pump discharge tee
- Well seal
- Well casing
- Driver rod
- Riser pipe
- Pump barrel
- Drive piston
- Foot valve
- Pump intake

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Solar Piston Pumping Environments

- Remote locations
- Sites not served by power
- Closed landfill sites
  - Leachate removal
  - Gas-well dewatering
  - Side-slope riser wells
  - Condensate sump
- Controlled flow
CASE STUDY

Agency installs gas system in Class D landfill -- 2010

- Production disappoints
- Leachate migration threat
- High costs of expansion & power

Agency engages engineers to define issues, offer solutions, implement program
Test Plan - 2011

4-month in-well test using low-flow piston pumps
   -- Landfill site #2, NE of city
   -- 3 wells, deeper than 50 ft.
   -- 30-acre closed cell

3 pump-power options
   -- Electric grid: GW-01
   -- Solar with batteries: GW-02
   -- Solar panel only: GW-05

Clockwise from upper left: Wells GW-01, GW-02, GW-05
# Wells Nearly Identical

<table>
<thead>
<tr>
<th>Gas Well</th>
<th>Initial Liquid Elevation (ft amsl)</th>
<th>Pump Intake (ft amsl)</th>
<th>Top of Screen (ft amsl)</th>
<th>Bottom of Screen (ft amsl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GW-01</td>
<td>865.55</td>
<td>~850</td>
<td>886.35</td>
<td>840.35</td>
</tr>
<tr>
<td>GW-02</td>
<td>868.56</td>
<td>~849</td>
<td>888.21</td>
<td>843.21</td>
</tr>
<tr>
<td>GW-05</td>
<td>871.67&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>~849</td>
<td>890.07</td>
<td>838.07</td>
</tr>
</tbody>
</table>


G. Nauman and B. Harthun, Foth Infrastructure & Environment, LLC, Client memorandum, 2012
3 piston pumps installed

- Identical 3/8 HP 24v DC motors
- Linear-actuated driver
- Low flow max to 1.3 gpm (4.9 lpm)
- Intakes at 1-3 feet above bottom
- Test begins Dec. 2011, winter

1 power source for each pump

- Electric 220v AC to 24v DC (GW-01)
- Solar panel with 12v batteries (GW-02)
- Solar panel direct to motor (GW-05)
Measurements

- Liquid levels Dec. 2011 thru March 2012
- Transducers installed 3/6/12; report every 15 minutes
- Methane & O₂ noted before & during operations
- 42° North latitude (= Toronto)
  - 65-76% cloudy days
  - 10-11 hrs./day sunlight
Results: All options viable

- All 3 sources, including solar, dewater wells -- reduce liquid to intake
- Ave. 24-hr. liquid levels satisfactorily lowered and maintained
- Exposes gas-screen slots, increasing gas recovery
- Addresses migration issue
Finding #2 - Solar-Only Works

Solar maintains low liquid levels over each 24-hour span

- On-off matches day/night
- 3-4 feet leachate recharge at night - pump off . . .
- . . . Morning pumping lowers leachate to bottom of pump intake
- Consistent day to day
- No maintenance

Site installed simple insulation below driver
Results

- Solar Only

At 42º North latitude/winter

- Maintains liquid levels over 24 hours
- On-off matches day/night
- 3-4 feet liquid accumulate at night
- Day pumping lowers liquid to intake
- Operation consistent day to day
- No periods of pump-in

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Graph 6 - Liquid Elevations in GW-05 (During Pumping)
Graph 9 - Gas Concentrations at GW-05

- Methane
- Oxygen
- Pump On

Concentration (%)

Date & Time

8/23/2011 12:00
9/21/2011 12:00
10/21/2011 12:00
11/21/2011 12:00
12/21/2011 12:00
1/21/2012 12:00
2/21/2012 12:00
3/21/2012 12:00
4/21/2012 12:00

Finding #3 - More Methane

More screen = More gas

- All power sources dewatered 75-90%+ screen (15-18+ ft.) in each well
- Methane production increased 15%+ in electric & solar-battery wells . . .
- . . . And 20%+ in solar-only

Positive correlation: More screen exposure = higher gas flow
## Screen Exposure to Gas Flow

<table>
<thead>
<tr>
<th>Gas Well</th>
<th>Average Liquid Elevation During Pumping (ft amsl)</th>
<th>Initial Length of Screen Exposed (feet)</th>
<th>Length of Screen Exposed During Pumping (feet)</th>
<th>Percent Of Additional Screen Exposed During Pumping</th>
<th>Percent Increase In Gas Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>GW-01</td>
<td>850.96</td>
<td>20.80</td>
<td>36.42</td>
<td>75.0</td>
<td>15.9</td>
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<tr>
<td>GW-02</td>
<td>850.15</td>
<td>19.65</td>
<td>38.06</td>
<td>93.6</td>
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<tr>
<td>GW-05</td>
<td>853.65</td>
<td>18.40</td>
<td>35.39</td>
<td>92.3</td>
<td>20.2</td>
</tr>
</tbody>
</table>
• Several more solar pumps installed
• Operating at levels consistent with early 2012
• Minimal maintenance; low incidence of repair
• Motor brushes need replacement once a year
• Starting eighth year, site engineer pleased
CASE STUDY

**Issue:** Cost-efficient management of migrating leachate at closed, city-owned landfill

**Background**
- Site closed in mid-1980s
- No power on site
- Leachate removal by waste-haul trucks
- High-cost program suspended
- Leachate migrates to perimeter
Urbana - Solar-Pump Solution

**Application plan**
- Attach solar piston pump to existing 4” well
- Pump leachate to removal line

**Action**
- Operate daylight hours
- Wettest June in area’s weather history
  - 9.16 in. vs average 4.34 in. -- More than double
Urbana - Results

**Results**
- By Aug. 27, liquid down 1.33 ft
- 92,000 gallons pumped
- Summer average 550 gpd

**Brad Bennett, asst. city engineer:**
- Significant cost savings
- Low maintenance
- “Happy with performance, meeting expectations”
Monroe Tsp. NJ - Ex-Superfund

Liquid management, odor issues, 25 yr. after close

- Migration at site border
- Area-resident complaints
- Closed site - no power

Goals:
- Reduce odor
- Dewater, remove condensate
- Power gas-to-energy system
- Avoid trenching-in elec power
- Quiet operation - next to residential

Action:
- 3 solar pumps installed Dec. 2014
- Single panel for each

Results:
- Runs day/idle at night - sawtooth
- “Very pleased . . . Optimal performance”
  --Site manager

25-ft gas-extraction wells
6-in diameter HDPE casing
Compatible w/QED gas wellhead
Flooding Balefill Wells - Florida

Goals:
- Control leachate movement
- Significantly improve LFG collection
- Avoid expensive power in new phase

Action:
- 6 vert LFG wells early 2015
- 4 solar pumps; no batteries

Results:
- Continuous successful operation
- Controlling liquid levels & side-slope leachate breakouts
- “Pumps have operated flawlessly . . . very effective . . . They just keep pumping!”

--Consulting engineer
Operational necessities

- **Lubricate drive rod/seal-plate**
  - Continuous lubrication protects stuffing-box seals

- **Lubricate driver rails monthly with light, air-line oil**

- **Monitor motor brushes; replace when wear observed**

- **Grid power can be used**
  - AC or DC brushless motor
  - 6-amp breaker
Learnings -- Discharge

Liquid **must** be expelled at pumping rate -- or back pressure will reduce effectiveness of pump system.

**Six causes of discharge blockages -- Pipe is:**

1. Closed by mistake
2. Damaged during install
3. Too small for # of pumps attached
4. Obstructed by calcium/magnesium carbonate
5. Obstructed by bio-fouling
6. Restricted by oxygen air bubbles in pipe
Restricted Discharge

**AIR LOCKS**

Pneumatic air/O$_2$ is a danger in pressurized discharge lines

1. Lighter than leachate, air bubbles gravitate to system high points & become trapped

2. If air/oxygen continues to leak, pockets form that may restrict liquid flow and promote corrosion

   -- As the pockets grow, restriction increases, creating destructive back pressure

3. Air locks eventually break away, creating damaging surges
Thank You

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