Groundwater Remediation and Alternate Energy at White Sands Test Facility

September 2008

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Facility Operations

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Hypergolic Fluids Materials and Systems Testing

NASA-STD 6081 Test

Evaporation Tank

Ignition Test

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300 Propulsion Testing

Night firing of Shuttle Forward RCS primary and vernier thrusters

Night firing of Shuttle Aft RCS primary and 24 lb thrust vernier engines
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400 Propulsion Testing

- Static firing of DC-X with 4 LOX/Hydrogen RL10-A5 engines
- Cassini - Saturn orbit insertion engine glows during 3 hr. 20 min. continuous firing

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Flight Hardware Processing
Restoration Program

• Historic operations and practices beginning in the 1960’s (through the early 1980’s) resulted in contamination of WSTF’s groundwater.
  – Propulsion system testing programs:
    • N-Nitrosodimethylamine (NDMA)
    • Dimethylnitramine (DMN)
  – Component Servicing and Cleaning Operations:
    • Trichloroethene (TCE)
    • Tetrachloroethene (PCE)
    • Freons: (11, 21, and 113)
• WSTF contaminated ground water is NASA HQ’s greatest liability (estimated at $350M).

Restoration Program

• Priority: Protect the public’s health and the health of our workforce.
  – Containment
    • Stop the migration of contaminated groundwater
    • Greatest health-risk liability pursued initially
      – Plume Front
      – Mid Plume
      – Source Areas
  – Restoration
    • Clean-up the environment to preexisting conditions
Public and Employee Assessment

- There is no impact to any drinking water well
  - Includes public wells and the NASA supply well.
- There is no public exposure
  - Groundwater is several hundred feet below ground.
  - No air or surface water exposure.
  - Plume is moving very slowly to the west.
    - Plume Front Treatment system will stop this westward movement.
- NASA performs on-going monitoring
  - More than 200 wells and zones are routinely sampled.
  - ~850 samples are obtained monthly and analyzed for over 300 different hazardous chemicals.

Containment and Restoration

- A Staged Approach over ~60 years:
  - Attack the greatest risk to public health first
    - Stabilize the plume front (in progress)
  - Stop migration of contaminant into the plume front
    - Extraction and treatment at the Mid Plume Constriction Area (~2009)
      - 60% Review completed, 90% Review Oct 08
    - Stop migration into the Mid Plume Constriction Area
      - Clean up the source areas (~2012-2015)
Contaminated water containing nitrosamines and VOCs

- Extraction Wells
  - 1
  - 2
  - 3
  - 4A
  - 5
  - 7

- Air Strippers

- Water Filters
  - #1
  - #2

- UV Tower
  - UV-Photolysis of Nitrosamines
  - Particulate filtration

- Injection Wells
  - 1
  - 2
  - 3
  - 4

Treated water injected back into aquifer

Plume Front Treatment System
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Calgon Rayon® Tower UV Reactor in Bldg. 650

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Alternate Energy

Wind Energy
Alternate Energy

- Wind Energy:
  - Monitored Quartzite Mountain Range since about 2005 – 4 to 5 class wind site
  - Initial EA performed by WSTF Environmental
    - Bat study (Fall 2007/Spring 2009)
    - Radar issues with WSMR (formed working group with WSMR test ops)
    - Cost for road to access planned wind farm area about $5 – 6 M
  - Developers interested in constructing wind and solar
  - EPEC interested in future wind project

Alternate Energy

PV Parking Shade Structure
Photovoltaic System

- Task order has been issued
- PV will provide peak shaving during daylight hours
- Charge storage batteries
- Batteries will provide peak shaving
- System will provide shading for vehicles in parking lot.
- Provide Plug-in for POVs
- Could be used for PV test bed
  - Installation of separate modules (different technologies)

Efficiency of PV modules

- Commercial modules: 10-22%

Irradiance = 1000 Watt/m²

100 - 220 Watts
Electrical power

PV/BATTERY HYBRID SYSTEM

- The test bed renewable system will charge batteries throughout the day during off peak load demand and discharge batteries during peak load demand.
  - Will determine the benefits of utilizing the Zinc-bromine batteries for utility peak shaving application.
  
  - Includes evaluating the economic benefits of the system and monitoring the operation and performance of the PV and Batteries.
  
  - Data will be collected to evaluate the overall system performance overtime and to verify the storage system operates when necessary and provide the necessary power required by end user.
Energy Storage Unit

- Two 50kWh battery modules connected electrically in parallel.
- A control system (Power Conversion System (PCS, inverter)
- A pair of electrolyte storage tanks.
- Electrolyte circulation equipment.

Advantages

- Uses electrodes that do not take part in the reactions consequently there is no material deterioration that would cause long term loss performance.
- Rapid recharge (two to four hours).
- Deep discharge capability (100%).
- Built in thermal management system.
- Can be used for large scale application.

PV/Battery Hybrid System for Energy Storage Use

PV Subarray 10kW
PV Subarray 10kW
PV Subarray 10kW
PV Subarray 10kW

PV Array DC Disconnect

Bi-Directional

PCF Converter DC/DC

Integrated Inverter

AC Disconnect

50kW Inverter

PV Energy

WSTF Utility Grid

AC Load Panel

80kW 50VAC 60HZ

Battery Energy

50kWh Capacity

50kWh Capacity

100kW/50kW Battery Bank
Zinc-Bromine
Shaded PV Structure Plan View

23,293 sq m Area Available

PV Power Coincides with Peak Demand Load

Building 107 Daily Peak Demand vs Daily PV System Power Production
April 23, 2008

Battery discharges (100%) during customer peak usage, reducing the customer load

Battery capacity of 100kWh will be discharged in 1 hr, twice a day

Daily Avg PV System Energy Production = 313 kWh

Daily Demand Load = 511 kWh

Day April 23, 2008
System’s Energy Production

Monthly PV System Energy production kWh

Annual Energy = 94,426 kWh/yr

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Alternate Energy

Utility Size Solar Peak
Shaving
Peak Shaving Solar Plant

- NASA owns land at White Sands and could be available for a solar power generation plant
  - Approximately 400 acres
  - Existing injection and monitoring wells that NASA will need full access to (including drilling rigs)
- Plant will be built and operated by the developer.
- Developer is responsible for ALL financing of design, construction and operation.

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Peak Shaving Solar Plant

- Current Electrical Power to WSTF
  - 69kV Transmission line to Apollo Substation from El Paso Electric Company
  - 24kV distribution line down to NASA land area
  - Substation rated for 15MW
- NASA desires power to support site
  - Currently NASA has a ~5.5MW peak load
  - DOD Installation on-site is also interested in renewable energy
Peak Shaving Solar Plant

- Preliminary Environmental Assessment (EA) has been completed, but a complete EA is required prior to construction start
- NASA facility-type support is available, but a cost will be associated with this support

Peak Shaving Solar Plant

- RFI on GovBiz (14 responses)
  - Number: 2008LUA
  - Posted Date: May 14, 2008
  - Response Date: May 27, 2008
  - 14 responses received
- Industry day on Aug 12, 2008
  - MMA Renewable Ventures, LLC
  - Abenc/Abengoa
  - Acciona
  - International Power America
  - EverGuard Roofing, LLC
  - Greenlight Sunstream Holdings, LLC (dba Helios Energy)
  - Consolidated Solar Technologies
  - North Wind Inc
  - Juwi Solar
Peak Shaving Solar Plant

- New website for vendors has been generated. We are in the process of posting project information and Q&A
- Working with NREL and NMSU on the RFP (late October)
- Options going forward:
  - Provide land to EPEC for 92 MW CSP plant (E-Solar)
  - Sell power to PNM or other NM utilities
  - Sell power out of state
  - Use power only behind the meter
    (NASA, WSMR, HAFB, Fort Bliss)
Backup Slides

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[Image of a construction site with a blue framework and two individuals working on it]
Component Description

- **PV Solar Modules:** 189 total, 265Wp each. Will provide shade for 1,200 m² (~13000 ft²).
- **Balance of Systems**
  - 2 Power Conditioning Unit for battery voltage control to manage power delivery bi-directional. Manage the charge and discharge rates of battery and ensure compliance with utility harmonics standards.
- **Inverter:** Utility Interactive 50kW rating
  - Zinc Bromine Battery package has integrated utility inverter built in.
- **Batteries (Zinc Bromine):** 2-50kW battery bank for Total of 100kWh storage capacity.
  - Batteries will be programmed to discharge during customer peak (weekday) usage, thereby reducing customer demand charges.
- **Data Acquisition System**
  - The DAS system will monitor real-time PV production, customer load, battery State of Charge, Charging and Discharging voltages and currents.
  - Campbell Scientific datalogger

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Energy Production Summary

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<tr>
<th>Quantity</th>
<th>Value</th>
<th>Units</th>
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<tr>
<td>PV Production</td>
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<tr>
<td>Rated Capacity</td>
<td>50</td>
<td>kW</td>
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<tr>
<td>Output</td>
<td>294 kWh/day</td>
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<tr>
<td>Capacity Factor</td>
<td>24.5</td>
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<td>Total Production</td>
<td>94426 kWh/year</td>
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<td>Rated Capacity</td>
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<td>kW</td>
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<td>Usable Storage Capacity</td>
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<td>Round Trip Efficiency</td>
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<td>Battery losses</td>
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<td>%</td>
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<table>
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<th>Units</th>
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<tr>
<td>Carbon Dioxide</td>
<td>36,557</td>
<td>Kg/yr</td>
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<tr>
<td>Carbon Monoxide</td>
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<td>Sulfur dioxide</td>
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<td>Kg/yr</td>
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<tr>
<td>Nitrogen Oxide</td>
<td>77.5</td>
<td>Kg/yr</td>
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System Performance Monitoring

Data Acquisition System Parameters - One line diagram

- PV Array
- 189 modules
- Power Center
- Inverter
- 277V/480V AC
- Inverter
- AC kWh
- Battery Bank
- AC KWh
- WSTF
- Utility Grid
- Campbell Scientific Datalogger
- Charging/Discharging
- Batter Temp
- Batter
- V batt
- I batt
- I dc
- Inv
- I dc
- Inv
- I ac inv
- I ac inv
- Solar Irradiance
- Ambient Temperature
- Other Sensors

System Component Cost Break Down

Total System Cost (loaded) = $766,261
(True total cost is posted on last slide)

Note: Costs displayed for each component is NOT loaded
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National Aeronautics and Space Administration
White Sands Test Facility

Summary

System Architecture

| Total Area | 1,200 m² (~13,000 ft²) |
| PV Array Rating | 50 kW (approx. 189 PV modules of 265Wp) |
| Battery Bank | 100 kWh Capacity (2 - 50kW modules) |

Cost Break Down

| PV Array Module | $240K |
| Inverter | $35K |
| Batteries Zinc Bromine | $120K |
| Balance of System | $25K (2 power conditioning units) |
| Shade Parking Structure | $75K ($20K to $30K per 18kW array) |
| Installation | $100K |
| Data Acquisition System | $18K (hardware only) |
| Cost Per Watt Installed | $12.46/Watt (PV/Battery application--$8/Watt PV only) |
| Total Loaded Cost of System | $766,261 |

Annual Energy Production

| AC Energy Production | 94,426 kWH (output of PV/Battery System) |
| Capacity Factor | 24.0% |
| Levelized Cost of Energy | $0.25 kW/H (cost to produce energy kWh) |

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New Technologies

• Implement Renewable Initiatives by combining the best technologies to arrive at most efficient system(s):
  – Solar power PV system
  – Geothermal heat pump systems
  – Wind generated power
  – Solar powered thermal system
  – Hydrogen
  – Fuel cells
  – Hybrid systems
5 Year Long Term Goals

- Develop a Solar Powered PV farm for providing electrical power to WSTF and sell surplus power to utility companies.
- Develop 3MW of wind generated power with wind farm on top of Quartzite Mt.
- Utilize geothermal heat pump systems for WSTF facilities heating and cooling to greatly reduce utility costs.
- Provide renewable energy test beds for supporting future Orion energy requirements.
Facility’s Peak Demand and PV System Production

Day - April 23, 2008
PV Power Vs WSTF Peak Demand Load

WSTF Demand

Day-April 23, 2008