BroadRock Renewables LLC

32 MW Combined Cycle Turbine Plant at the Olinda - Alpha Landfill

Unique Technical Challenges

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OC Waste&Recycling

Introducing Your Panelists

BroadRock Renewables LLC

- Stephen Galowitz
  - Chief Development Officer, Broadrock Renewables
- Donald Ries
  - Renewable Energy Program Manager OC Waste & Recycling
- D. Chris Lyons
  - Manager, Power Generation Solar Turbines Incorporated
- Paul Ryan
  - Executive Vice President, DCO Energy LLC

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Project is 2nd largest in U.S.

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- Utilizes waste heat recovery and beneficial water reuse
- Commenced in 2006 and cost over $120MM
- One of the most efficient LFG-to-electricity plants
  - Establishes new BACT standard
  - Received $10MM DOE stimulus grant and Treasury §1603 grant

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OCWR’s Mission

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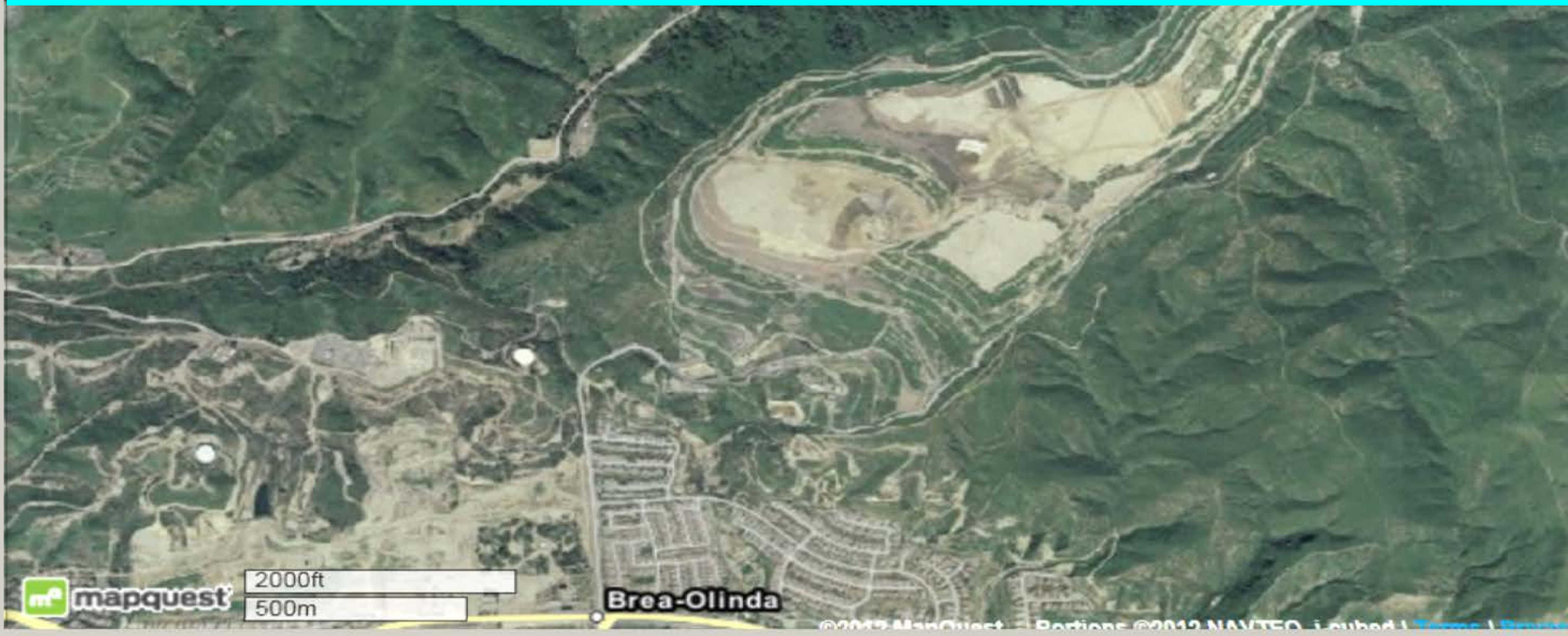
The mission of OC Waste & Recycling is to provide waste management services, protect the environment and promote recycling in order to ensure a safe and healthy community for current and future generations



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Defining the Challenge

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The challenge was integrating the construction and operation of a new power plant into the site infrastructure; both administratively and physically.

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Renegotiating the Gas Rights

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- For the County
  - ✓ Stressed compliance and teamwork.
  - ✓ More clearly outlined Operations & Maintenance duties & responsibilities.
  - ✓ Included an escalating guaranteed minimum royalty amount.
- For Broadrock
  - ✓ Flexible term start tied to Commercial Operations Date
    - ✓ Includes drop dead timelines and financial requirements
    - ✓ Allowed for a phased construction
- Mutual benefit
  - ✓ Potable water, recycled water and sewer

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Wildfire Throws Us a Curveball

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A Demanding Regulatory Environment

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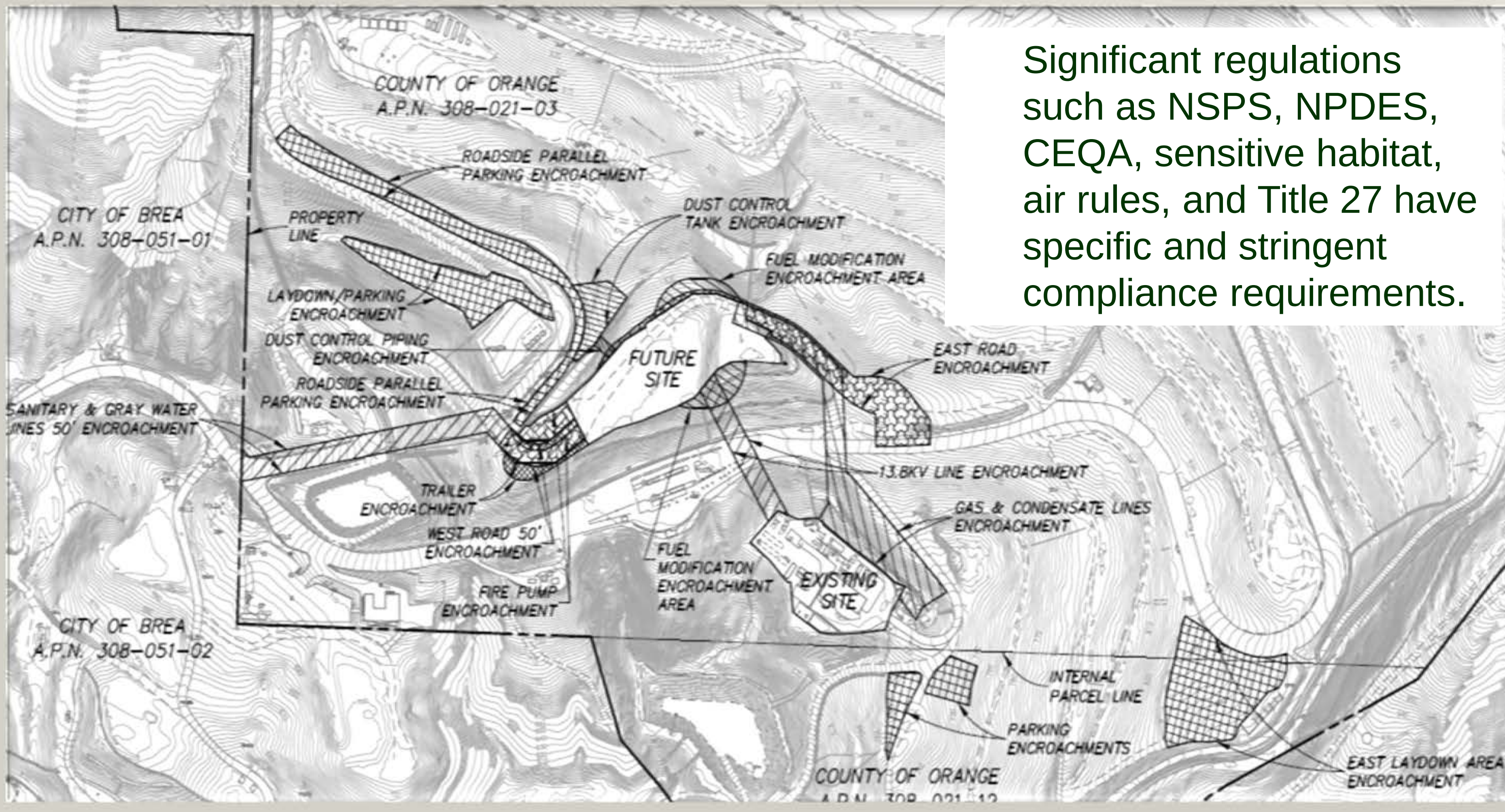

Significant regulations such as NSPS, NPDES, CEQA, sensitive habitat, air rules, and Title 27 have specific and stringent compliance requirements.

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Coordination and Teamwork

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Communication and teamwork with all of the parties through monthly, weekly and sometimes daily meetings ensured that the compliance and operational needs of the landfill were continuously addressed while minimizing any impact to the construction and testing activities.

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Takeaways

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- Communication, communication, communication
- Spend the time you need upfront and create an agreement strong enough to keep things moving and flexible enough to change quickly with the unforeseen.
- If you're going to do business in CA, hire a local consultant to educate you on the unique laws.
- Build a relationship with the adjacent property owners and local jurisdictions early on in the project.
- Establish the point of contact for public inquiries, such as a Public Info Officer.

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What are siloxanes and why all the fuss?

- Silicone-based polymers found in consumer products such as shampoos, cosmetics, and deodorants.
- Siloxanes volatize and become part of the gas stream in several forms and composition.
- Typical siloxane levels in raw landfill gas – 35 to 180 mg/m3 Si (Silica)
- Untreated raw gas combusted at high Temp & Press leaves hardened silica deposits on metal surfaces.

Siloxanes on turbine blades

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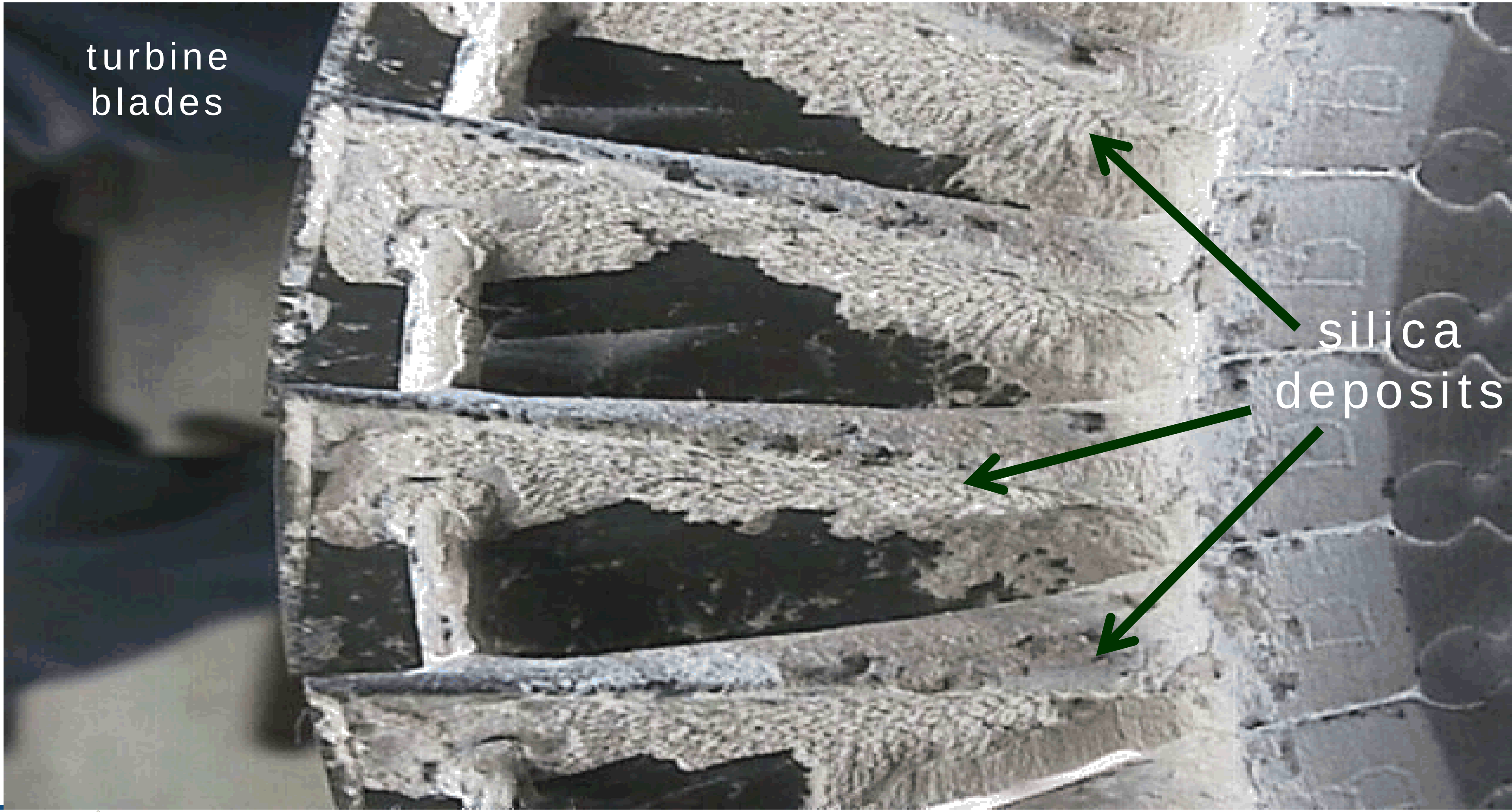

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Siloxanes on engine cylinders

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Siloxanes on SCR catalyst

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Olinda project – bases of design

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- Air permit limits
  - NOx – 25 ppmv
  - CO – 130 ppmv
- Solar T-60 guarantee
  - NOx – 42 ppmv
  - CO – 130 ppmv

- SCR and CO catalyst required by air permit.
- Maximum siloxane levels in pilot test – 140 mg/m3
- Volume of gas to be treated – 11,500 scfm

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Allowable siloxane levels for system components

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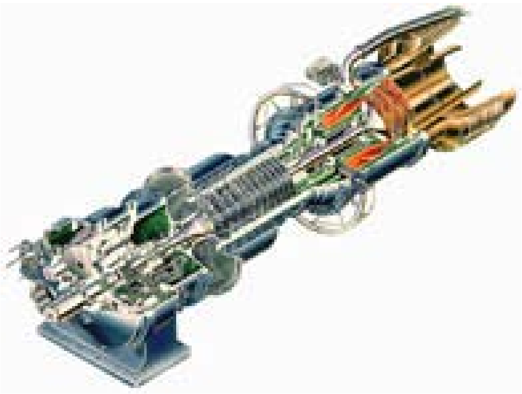
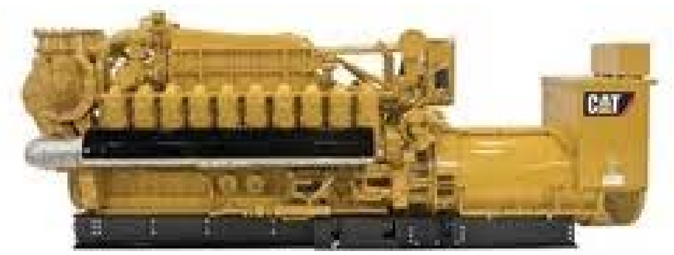


Solar turbine T-60 – 10 mg/m3

Solar turbine M-50 – 5 mg/m3



Recip engine – 5 mg/m3

Cormetech SCR – 0.38 mg/m3

Passive adsorber

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DCO Energy – BCUA project - 2006

Gas Press – 8 psi
Gas flow - 500 scfm
Raw gas Si – 85 mg/m3
Media volume – 23,400 lbs
Treated gas Si - < 5 mg/m3
Media replacement – 6 months

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Regenerative adsorber - LP

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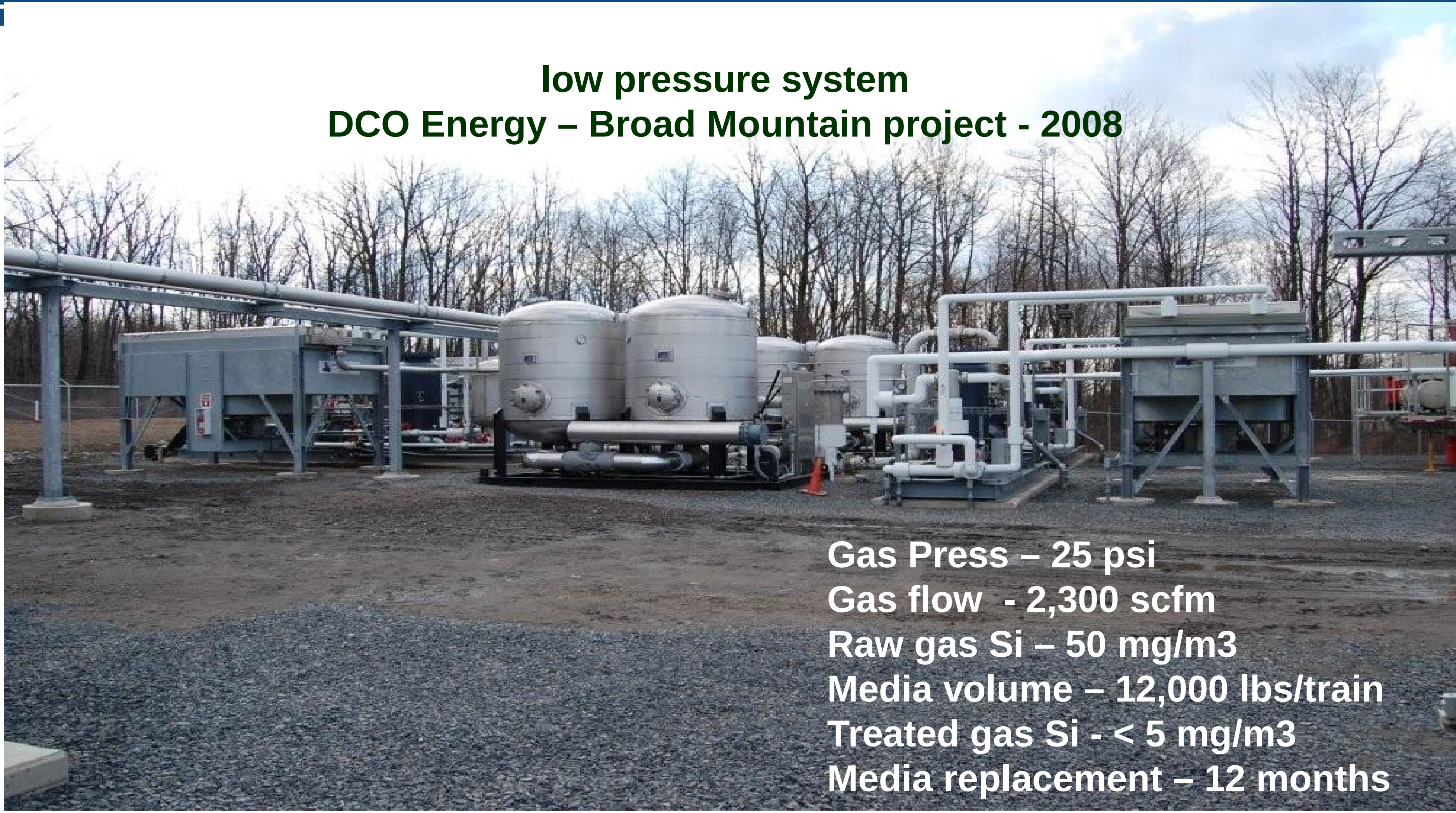
low pressure system
DCO Energy – Broad Mountain project - 2008



Gas Press – 25 psi
Gas flow - 2,300 scfm
Raw gas Si – 50 mg/m3
Media volume – 12,000 lbs/train
Treated gas Si - < 5 mg/m3
Media replacement – 12 months

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Regenerative adsorber - HP

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high pressure system
DCO Energy – Apex project - 2011

Gas Press – 80 psi
Gas flow - 4,500 scfm
Raw gas Si – 85 mg/m3
Media volume – 9,000 lbs/train
Treated gas Si – 0.38 mg/m3
Media replacement – 12 months

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Siloxane treatment system design

- NMOC's - 2500 ppmv
- H_2S - 100 ppmv
- Landfill gas volume – 11,500 scfm
- Raw gas siloxane levels – 140 mg/m3
- Treated gas siloxane levels – 0.38 mg/m3, or 75 ppbv
- Upstream chilling to remove moisture.
- 12-15 hours of regeneration time.
- Regen flare – Ultra Low Emission (ULE)

Siloxane treatment system design

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- High pressure system – 125 psig
- Two trains – 3 vessels & 28,000 lbs of media per train
- 3 layers of media – in each vessel
  - Activated Alumina
  - Silica Gel
  - Mole Sieve
- Carbon polisher
  - Passive System
  - 2 Vessels in lead – lag
  - Activated Carbon fill
  - 18,000 lbs of media

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3-D Model helped with logistics

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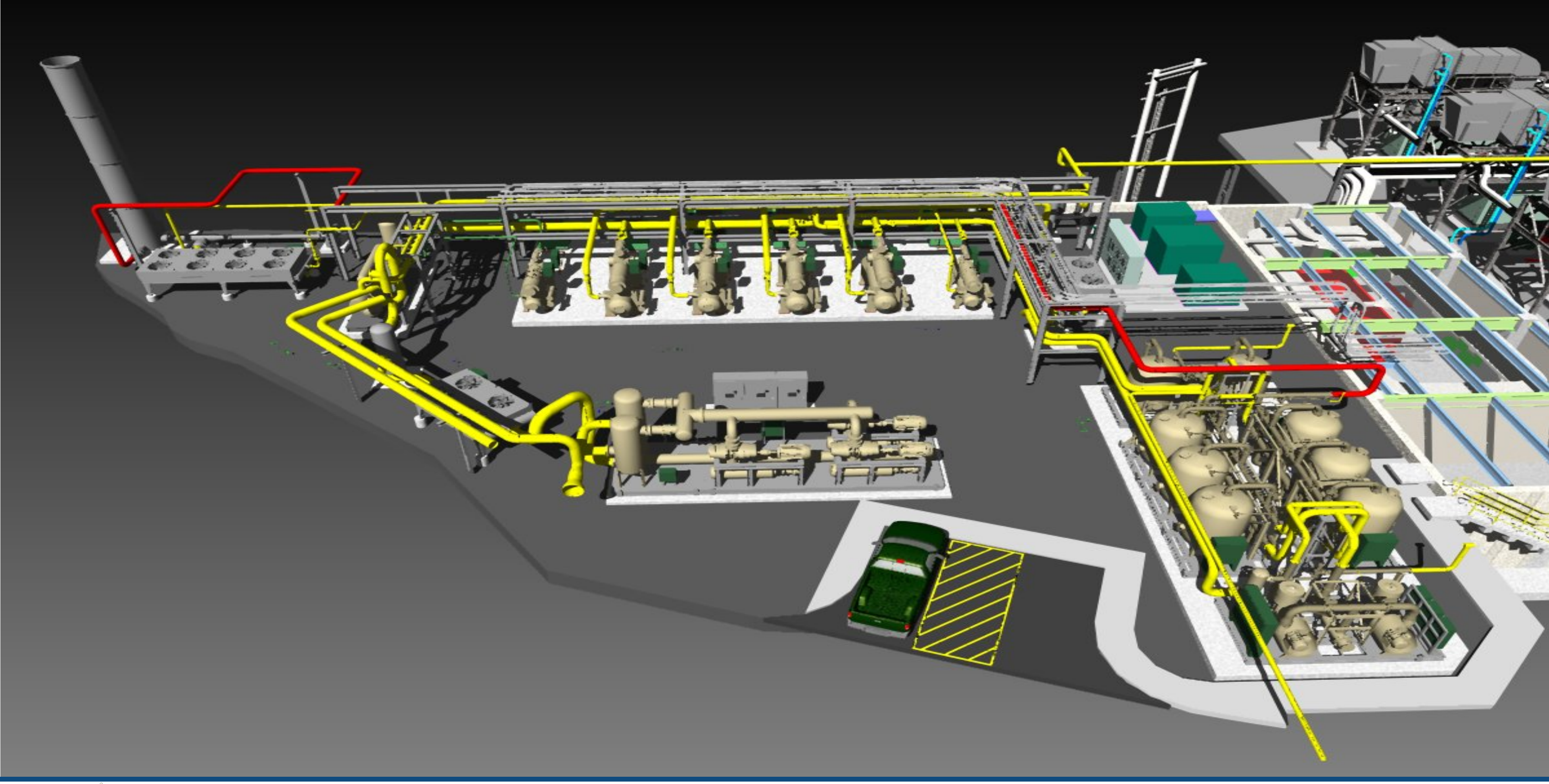
Olinda – Gas Conditioning and Compression (GCC)



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Bulk system and carbon polisher

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Risk mitigation measures

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- Carbon polisher
- Solar T-60
  - Guarantee NOx – 42 ppmv
  - Actual – 25-30 ppmv
- Cormetech SCR
  - Guarantee NOx – 25 ppmv
  - Design – 15 ppmv

- Sacrificial catalyst guard bed upstream of CO and SCR catalysts.
- Quarterly testing of SCR bed and siloxane levels in gas to turbine.

Performance assessment

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- Variable gas quality – NMOC > 2500 ppmv
  - Very high levels of certain Benzene compounds
  - Very high levels of other volatile compounds
- Temperature excursions
  - Oxidation reaction
  - Chemical adsorption

Performance assessment

- Stepped regeneration sequence
  - Start with air only
  - Stepped temperature rise
  - Soak-in time
  - Heater off
  - Cool down time
- Increase regeneration cycle time
- Life expectancy of media reduced

Several Technologies Evaluated

- Reciprocating Engines
- Solar Turbines Mercury 50 Simple Cycle
- Solar Turbines Mercury 50 Combined Cycle
- Solar Turbines Taurus 60 Simple Cycle
- Solar Turbines Taurus 60 Combined Cycle

Technology Options

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Reciprocating Engine Plant


Mercury 50 w/WHRU


Mercury 50 SC

Taurus 60 SC w/ SCR

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Technology Evaluation

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Products	Issues
• Recips	Space, emissions, maintenance
• M50 SC	New technology @time, power
• M50 CC	New technology @time, power, cost
• T60 SC	Power
• T60 CC	Winner

Bottoming Cycle was Worth the Incremental Capital Investment

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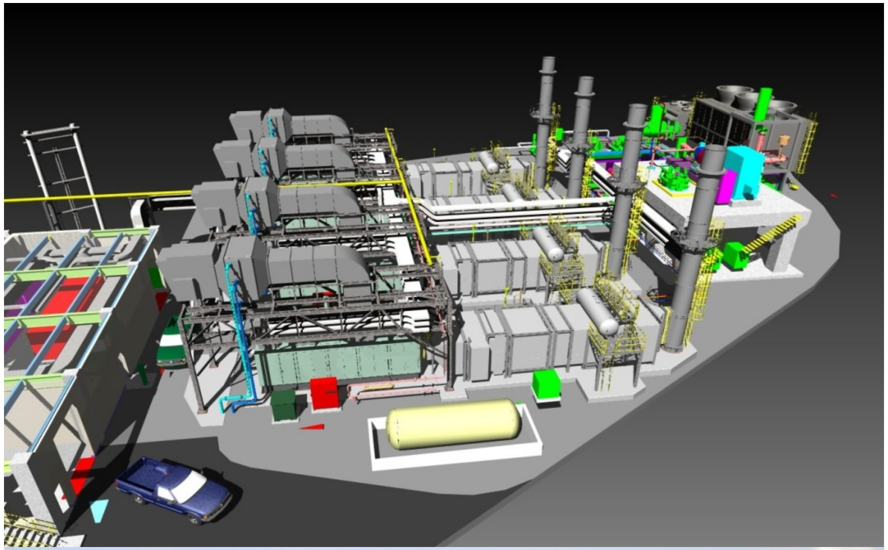

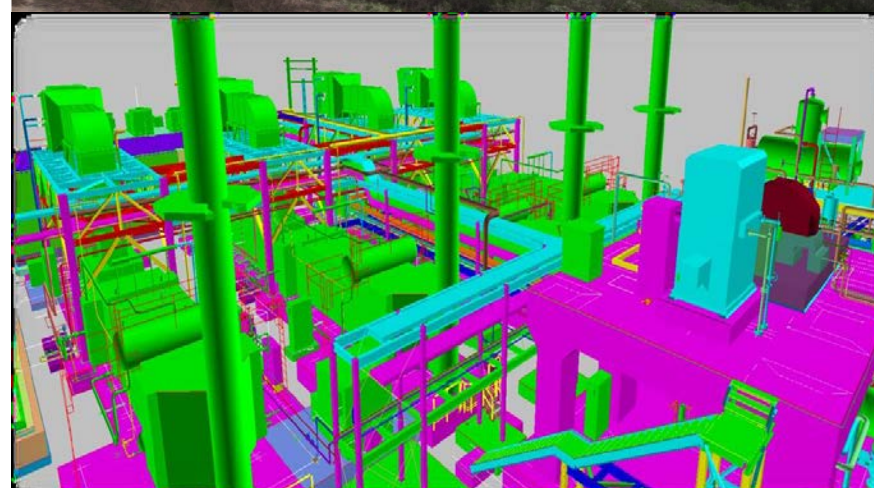

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Technology Comparisons

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Product	M50 SC	M50 CC	T60SC	T60CC
Power kw	24613	28434	19613	26392
Btu/kw	10220	8850	13000	9650
Cap.Cost	$ X*1.3	$ X*1.6	$ X	$ X*1.24
Op. Cost	$ Y*1.5	$ Y*1.8	$ Y	$ Y*1.3
Scfm	8140	8144	8251	8242

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Tariff Rates, Capital Cost & Output are Key

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Technology	NPV
Taurus 60 SC	$ Base
Mercury 50 SC	$ Plus 6%
Mercury 50 CC	$ Plus 40%
Taurus 60 CC	$ plus 105%

Combined Cycle Provides Excellent Net Plant Heat Rate

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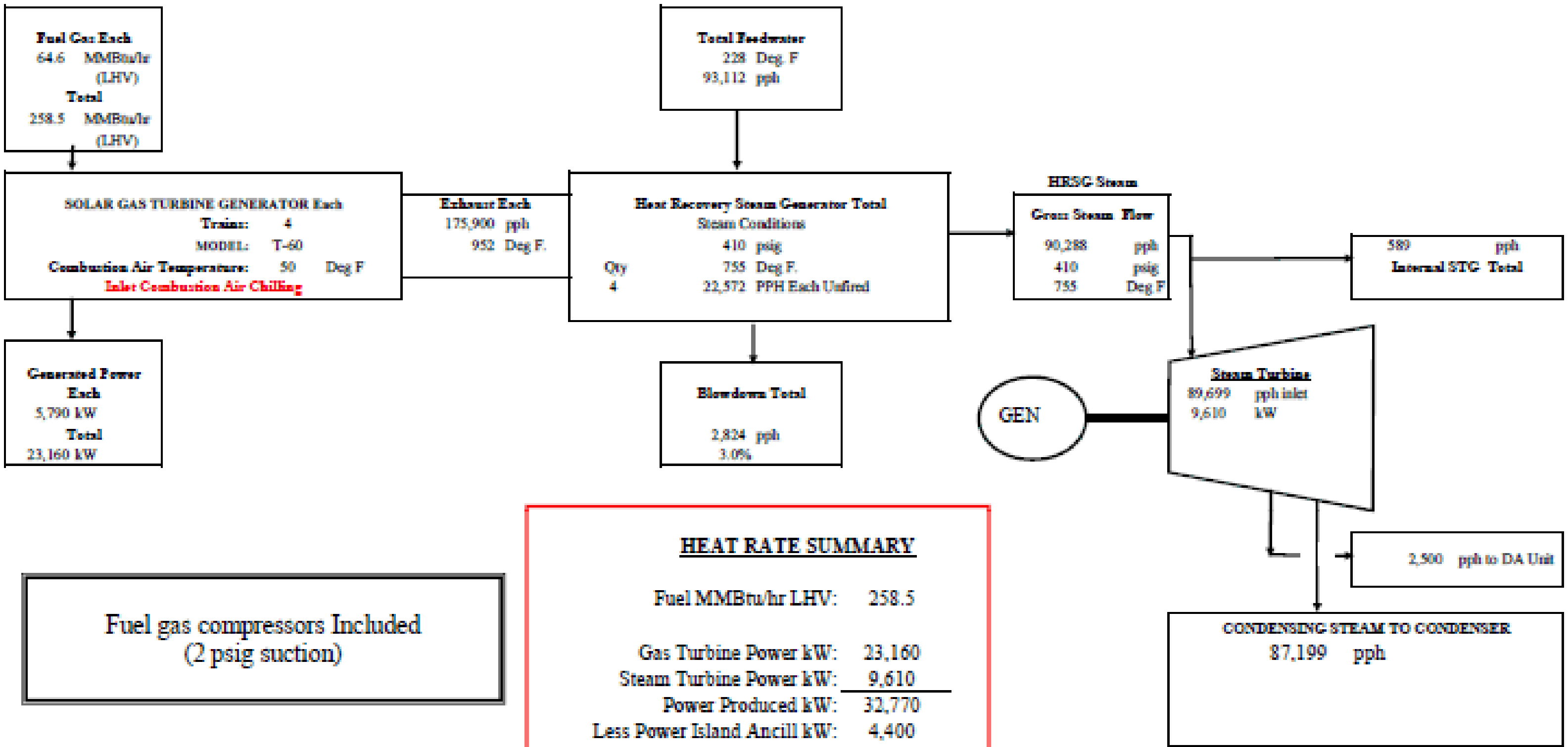

Fuel gas compressors Included
(2 psig suction)

NOTE: ALL DATA IS BASED ON EXPECTED PERFORMANCE

HEAT RATE SUMMARY

Fuel MMBtu/hr LHV:	258.5
Gas Turbine Power kW:	23,160
Steam Turbine Power kW:	9,610
Power Produced kW:	32,770
Less Power Island Ancill kW:	4,400
Less Utility Transformer Loss kW:	142
Net Power kW:	28,228
Heat Rate LHV BTU/kW:	9,157
Net Cycle Efficiency:	37.3%

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Lesson Learned w/ Selection

- Water use in Southern California
    - Secure commitment on cost of water upfront
- Small scale combined cycles are as complex as large scale plants
- A combined cycle plant entails more systems
- Capital cost is typically more than expected
    - Difficult to overestimate the complexity of piping and wiring

Contact Information

BroadRock Renewables LLC

Stephen Galowitz
Chief Development Officer
sgalowitz@broadrock.com
Broadrock Renewables
914-358-7410

Donald Ries
Renewable Energy Program Manager
Donald.Ries@ocwr.ocgov.com
OC Waste & Recycling
714-834-3703

D. Chris Lyons
Manager, Power Generation
clyons@solarturbines.com
Solar Turbines Incorporated
858-694-6586

Paul Ryan
Executive Vice President
pryan@dcoenergy.com
DCO Energy LLC
609-837-8003

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