

**Making Something From Nothing:  
“The Green Machine Turns Waste and  
Geothermal Heat Into Power”**



# Waste Heat

## Making Something From Nothing

**9 million  
megawatts**

*Assumes global average thermal efficiency of 40% X 14 terawatts total world energy consumption - Dr. Richard Smalley, Rice University, June 23 2003) Nobel prize winner*



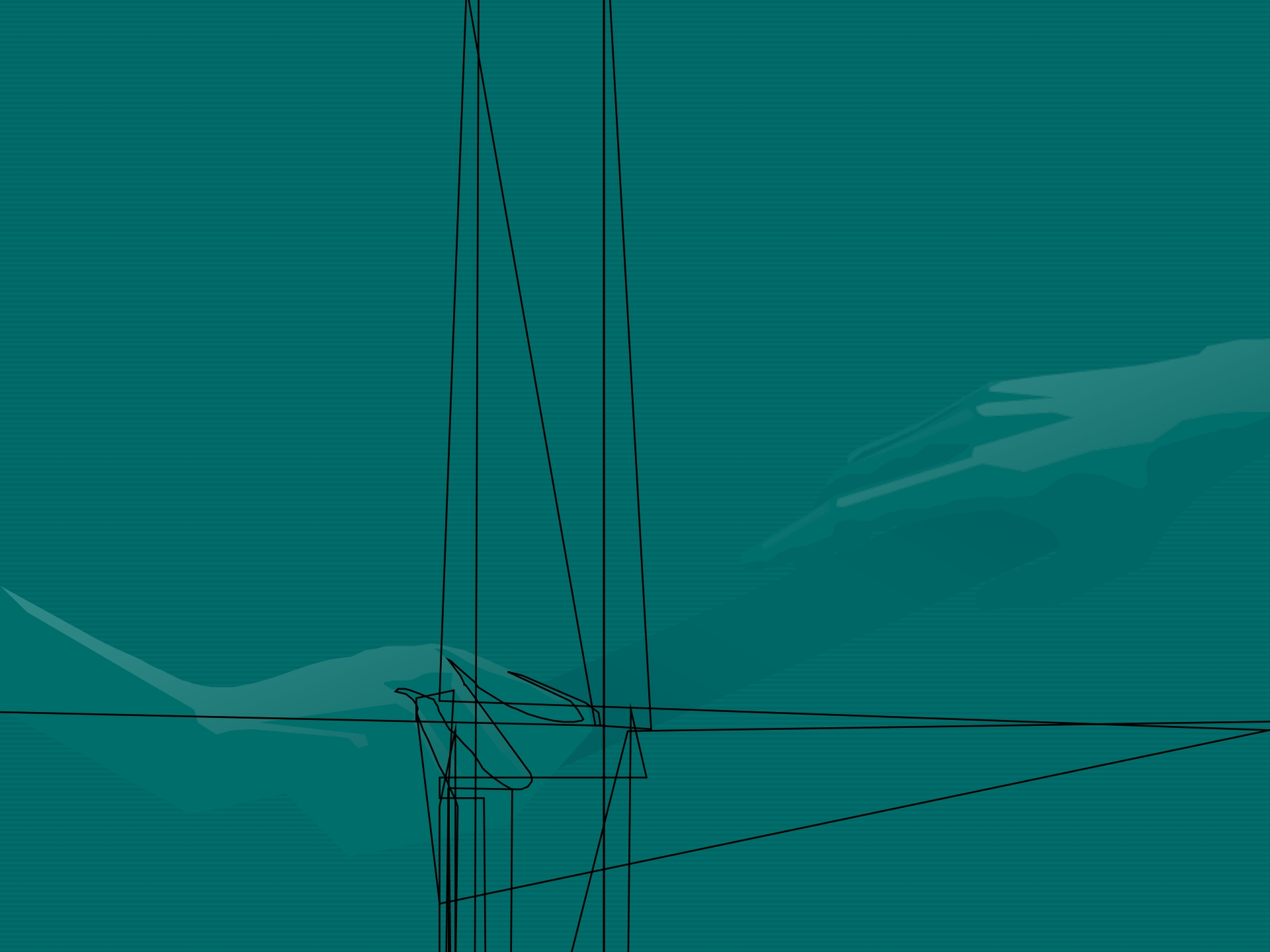
# Waste Heat is Zero-Pollution Energy

*Zero*



**Just 10% = 380,000 megawatts.  
At \$0.10 per kilowatt-hour**

















An aerial photograph of a large-scale construction project, likely a dam or reservoir. The top portion of the image is obscured by a solid green rectangular overlay. The rest of the image shows a vast, flat, light-colored area, possibly a construction site or a large reservoir, with some darker patches and structures scattered across it. The overall scene is captured from a high altitude, providing a wide perspective of the project's scale.

Denbury Resources Inc.  
Green Machine at Summerland #22

Defining Denbury

# Denbury - Summerland #22

**GCGE approached Denbury in December 2008 about participation in a study on power generation from high temperature wells.**

**Summerland well #22 was identified as a suitable candidate for the Green Machine**

**Summerland field is located in Jones County, Mississippi.**

**Well #22 produces from the Wash Fred formation at 9500 ft. under natural water drive.**

**The well produces 100 BOPD and 4000 BWPD on down hole ESP artificial lift.**

**The surface flowing temperature is 200 degrees F.**

**The well is not part of a CO2 flood.**

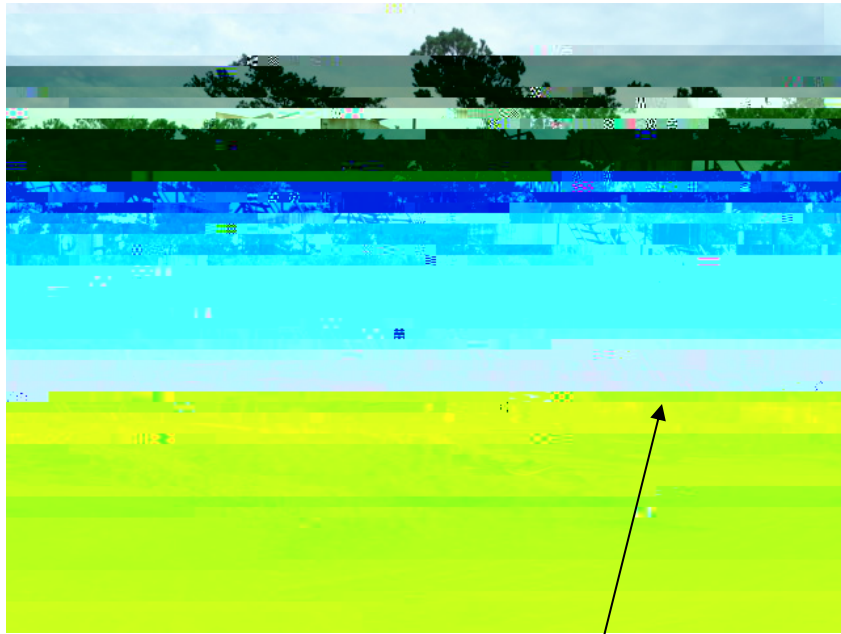
**Based on calculations from GCGE, the Green Machine can produce 30 KW or approximately 25% of the power needs of the ESP pump. About a 3 year payout.**

**Power at the site is provided by Dixie Electric, a rural power cooperative.**

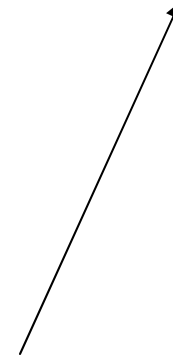
**Connection will be downstream of a primary meter. Offset \$0.098/kwh vs. selling at \$0.044/kwh.**

**Power companies are sensitive about this 2000 BTU/lb (0.5 kWh)**

# Summerland #22 Site



#22 Battery. Production Separator



Green Machine Location



# Twin Screw Rotors in a Casing

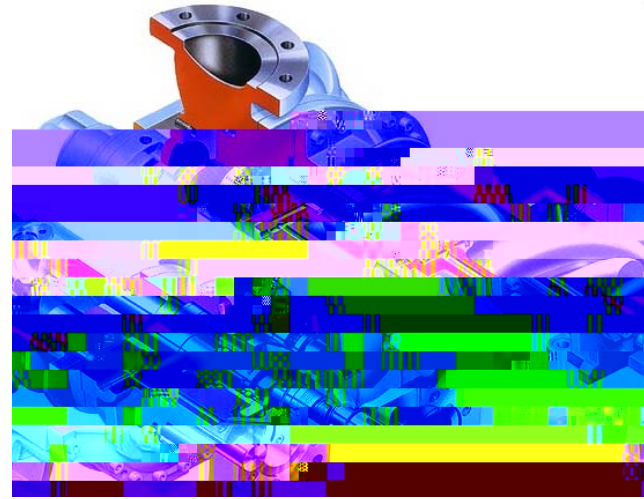






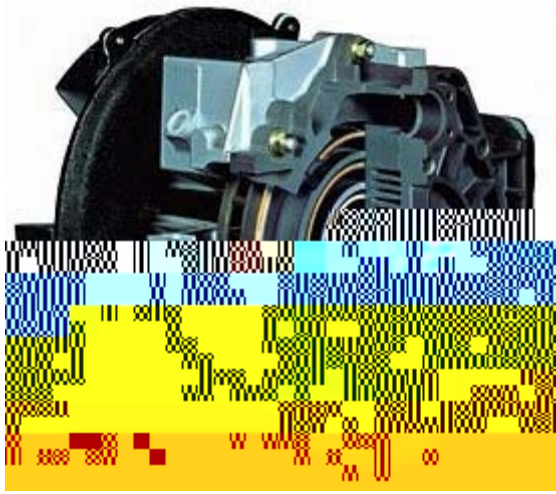


# Turbo vs. Positive



- Change of momentum imparted to the fluids
- Steady flow of fluids at high velocities

- Admitting a fixed mass of fluid into a working chamber where it is confined and then compressed or expanded and finally discharged



# Screw vs. other Displacement



- Moving parts all rotate and hence can run at much higher speeds
- Contact forces within them are low
- Sealing lines of contact which define the boundaries of each cell chamber, decrease in length as the size of the working chamber decreases and the pressure within it rises
- Rolling motion discourages seizure

# Expander advantages in small ORCs

- Wet inlet conditions are permissible
- Adiabatic efficiency can be very similar to turbines
- Improved rotor profiles mean greater efficiency
- Lower tip speeds, lower overall speed
- Mass produced
- Efficient with varying loads
- Long service life



# Expander Optimization

- Large flow cross sectional area

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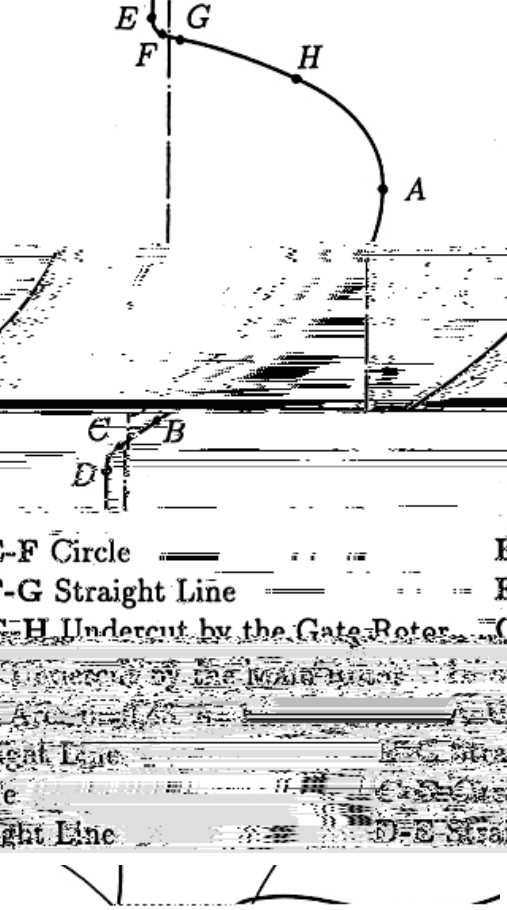
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# Main/Gate Configuration



- 3/5, dry applications, offers a high gear ratio
- 4/6, for both dry and oil-flooded
- 5 main rotor lobes are suitable for higher compressor pressure ratios
- 4/5, arrangement has emerged as the best combination for oil-flooded applications of moderate pressure ratios, permits the smallest overall dimension for the rotors
- Also, one less lobe in the gate rotor compared with the 4/6 combination can improve the efficiency of rotor manufacturing
- 6/7 for high pressure and large built-in volume ratio refrigeration applications

# N Profile and More



- Full tightness, small blow-hole area, large displacement, short sealing lines, small confined volumes, involute rotor contact and proper gate rotor torque distribution together with high rotor mechanical rigidity
- Design also involves mathematical modeling to determine the optimum rotor size and speed, shape and position of the suction and discharge ports, taking into account of the limitations imposed by bearing and seal selection.
- Goal: Maximize endurance, efficiency, and reliability!



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