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Geothermal Power Generation From Oil & Gas Wells

PureCycle®

An Overview of the PureCycle® Power System

Disclaimer

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United Technologies Corporation

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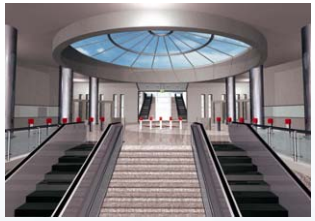
Fortune 50 corporation
$58.7B in 2008 sales
62% revenues outside US



Otis

Carrier

Pratt & Whitney

UTC Fire & Security

Sikorsky

Hamilton Sundstrand

Research Center

UTC Power

180 countries
225,000 employees

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POWER SYSTEMS

- **Large Engines**

- **Small Engines**

- **After market**

- **Marine**

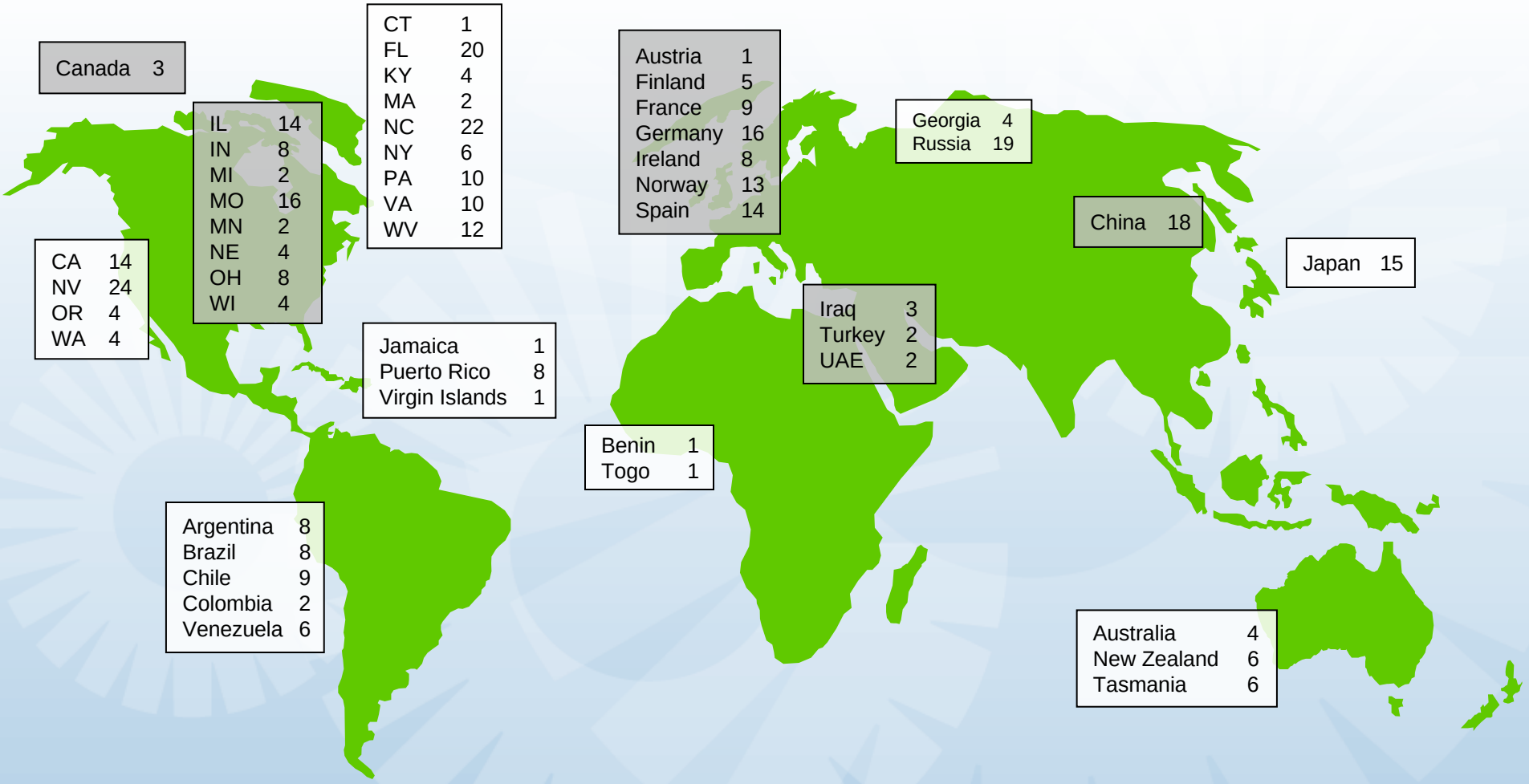
- **Mobile Power**

- **Heat to Electricity**

Turnkey Power Plants Capabilities
Global Sales & Service

PWPS Global footprint

FT8 Fleet Summary



Over 2000 Gas Turbines Installed in 40 Countries

Turboden Acquisition

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clean energy ahead
TURBODEN

Turboden Headquarters – Brescia, Italy

600KW ORC by Turboden Shown

100 ORC's Operating, 400KW – 2.2MW, High Efficiency, Proven Reliability

The PureCycle® Power System

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Heat to Electricity Power Generation

PureCycle®

- Zero fuel input costs - Hot Fluid
- Non Flammable Working Fluid
- 280KW of Renewable energy
- Modular and scalable for larger plants
- Off-the-shelf production; rapid deployment
- Low to moderate temps 195°F – 300°F
- Full remote monitoring and control
- Full service capabilities
- High power plant availability

The PureCycle® Power System

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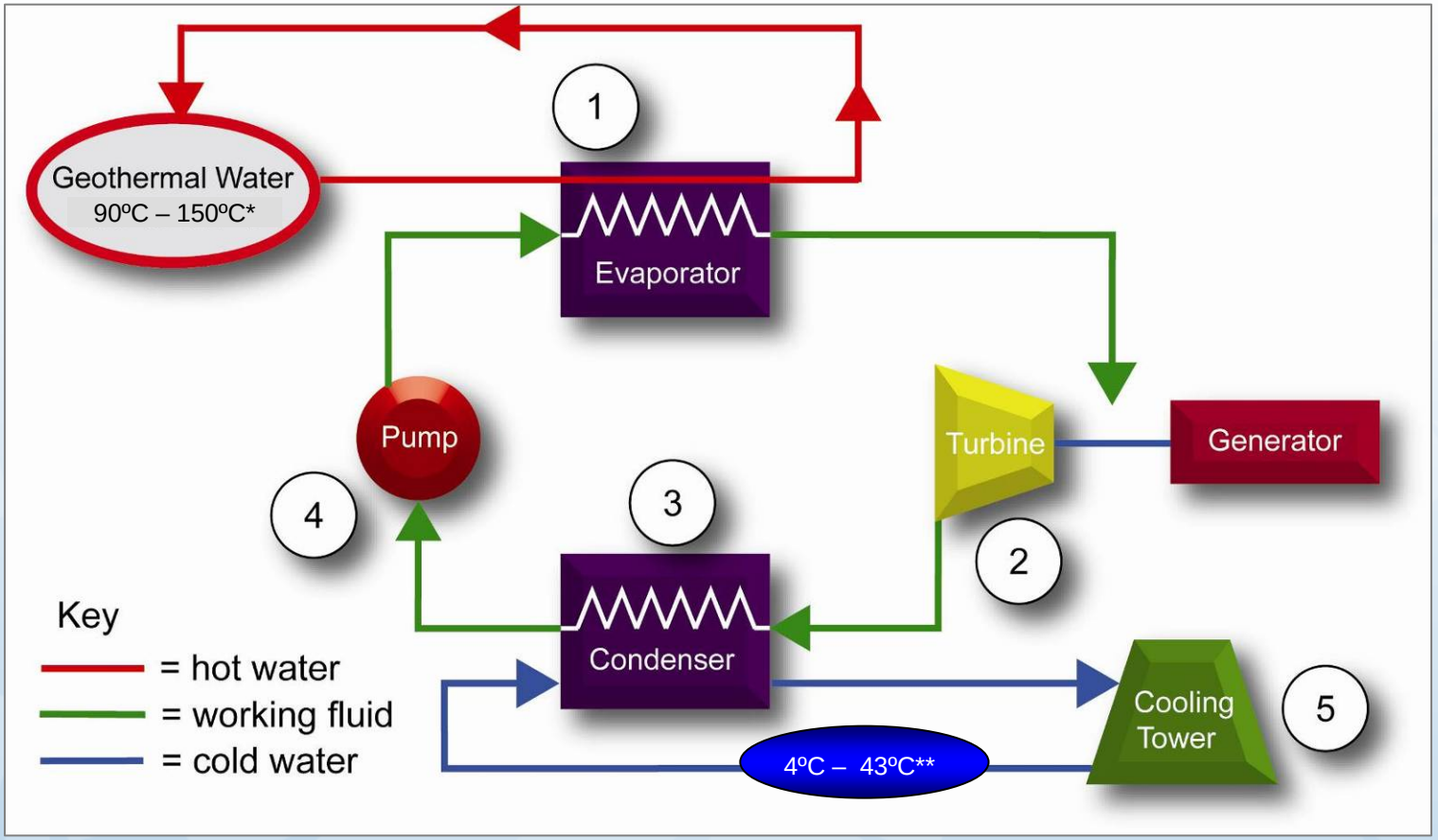
Based on the Organic Rankine Cycle



Heat In – Power Out

* 195ºF – 300ºF

** 40ºF – 110ºF

Based on Commercial Equipment

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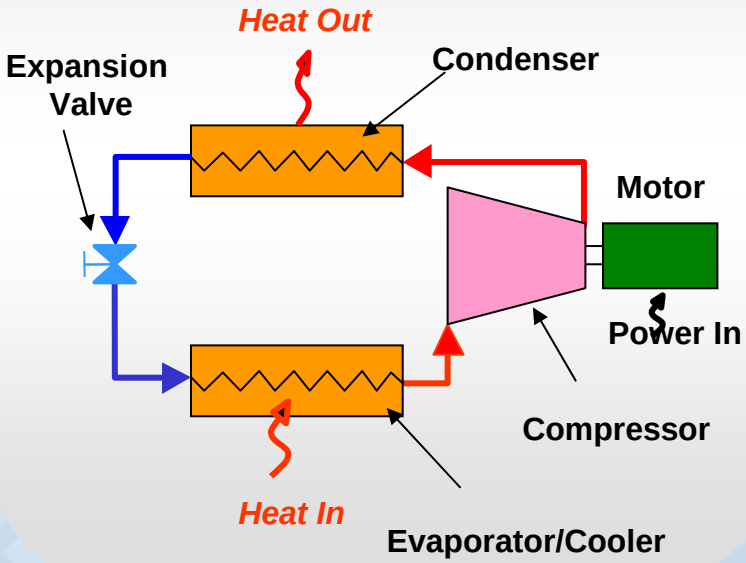
HVAC Component Synergy

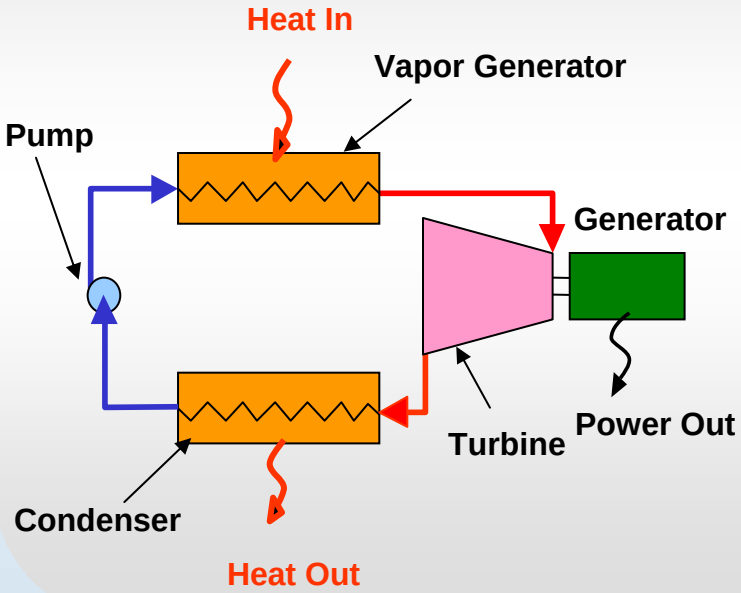
Carrier's commercially available centrifugal compressor



Vapor Compression Cycle (VCC)

Minor Modifications

Pratt & Whitney Power System's radial expansion turbine



Run in reverse

Organic Rankine Cycle (ORC)

Top Level Assembly

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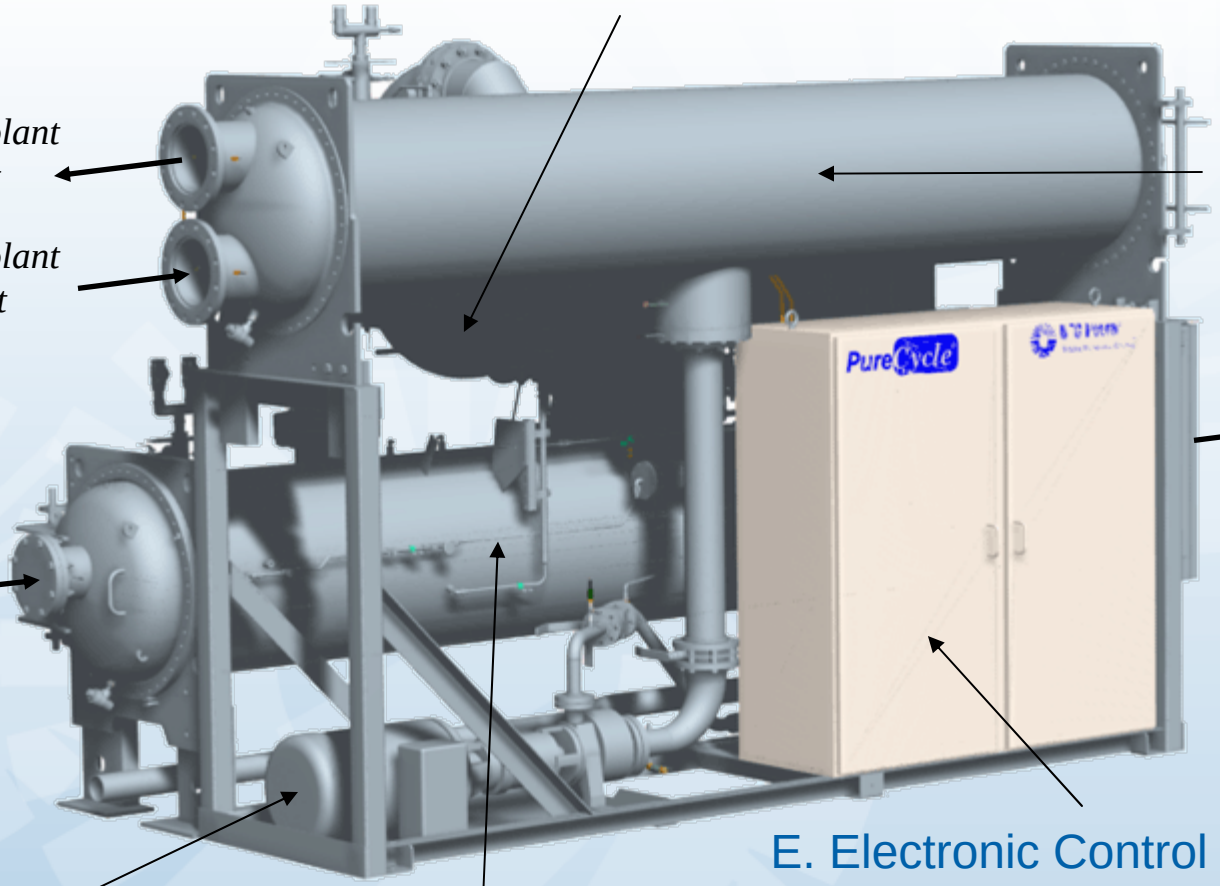
5 Major Components



B. Turbine-Generator

Customer coolant water exit

Customer coolant water inlet

C. Condenser

Thermal source exit

Thermal source inlet

D. Refrigerant Pump

A. Evaporator

E. Electronic Control System (ECS)

Markets

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Current Market

Geothermal

Recips

Developing Market

Oil & Gas

Industrial Waste Heat

Biomass

Key Global Geographies

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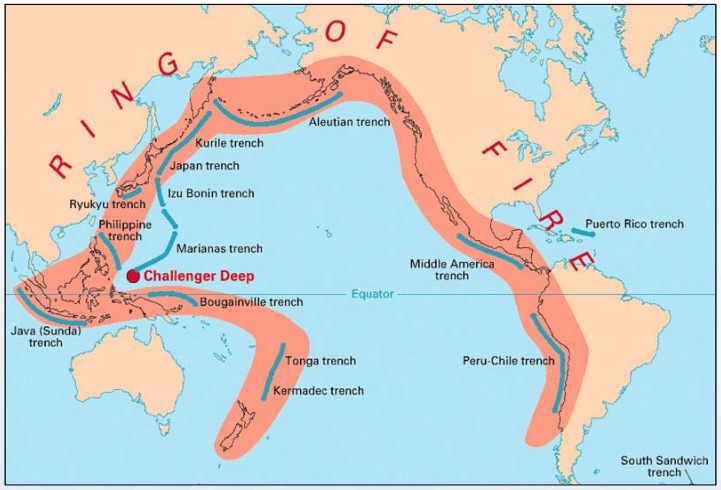
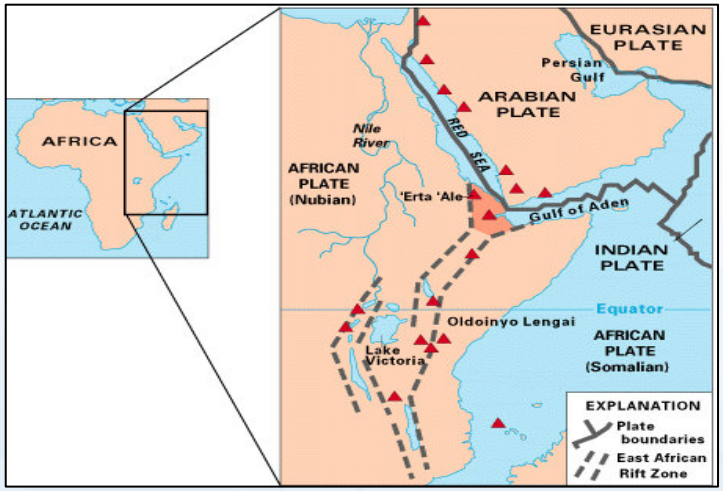
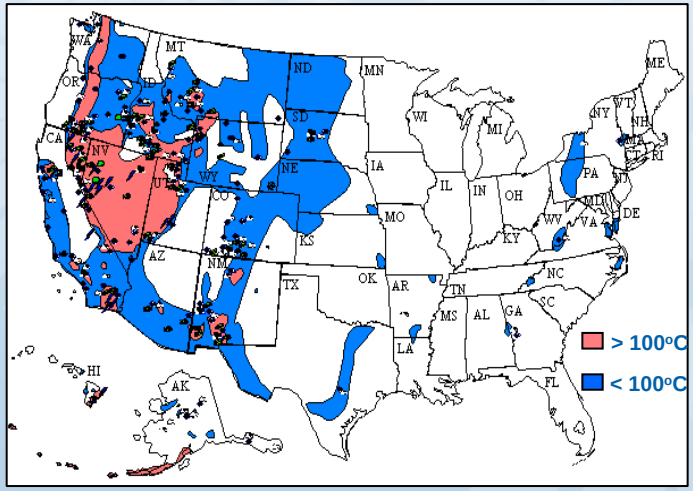
Pacific Ring of Fire



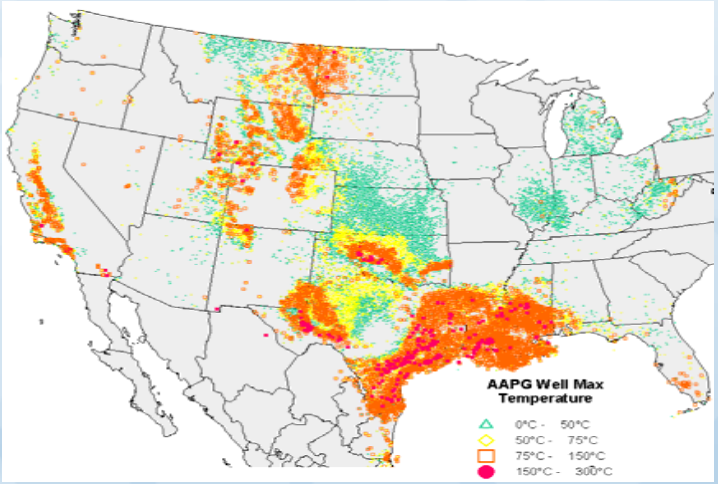
East Africa



United States



US Oil & Gas potential



Commercial Validation

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Chena Hot Springs in Alaska

- 1st unit commissioned July 2006
- 2nd unit December 2006
- 165ºF hot water resource
- 40°F cooling water available
- > 98% availability to date

- Drivers:
  - Cost savings
  - Off-Grid operation
  - Baseload application
  - Sustainable power

Commercial Application

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Greenhouse in New Mexico

- Commissioned July 2008
- Utilizes 225°F resource
- Exceeding 500 kW Net Power
- Supplies all power and heating for greenhouse
- 98% Availability

First Recip Application

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Industrial application in Guatemala

- Commissioned December 2008
- Operating on jacket water of 8MW reciprocating engine ~ 200kW net
- Displaces expensive fuel costs
- Supports green initiative of customer

LATEST INSTALLATION

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Oregon

- First geothermal power plant in Oregon commissioned in Aug 2009
- Supplies 20% of the electricity for the campus
- ~ 195°F water at 320 GPM
- Unit will produce ~ 180 kW (summer) and ~ 200 kW (winter)

Utility Geothermal Application

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10 MW+ Net Renewable Power Sold to California Utility

- UTC teamed with Raser Technologies
- Modular, scaled approach for rapid power plant
- Power will be sold to under 15–20 yr PPA's*
- Full time UTC service technicians on-site
- Developing multiple projects in Western US over the next several years

A July 2008 arial view of the site shows two drilling rigs, the concrete foundation for the cooling towers, and foundation preparation for the generator array.

Fifty Units work in tandem to create a 10MW+ net power plant.

* Power Purchase Agreement

First Oil and Gas Application

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- Funded by DOE, UTC, Quantum & Chena
- Utilizing 120,000 barrels of oil & gas fluid
- Low temperature Resource (170°F)
- Consume power onsite
- Demonstrate economic viability in oil/gas

"Separator Tank" used to capture and store solids from process stream entering the Oil Plant. PureCycle® system will be located in front of the "Separator Tank" as close to the highest temperature point in the stream as practically possible.

Production Facility

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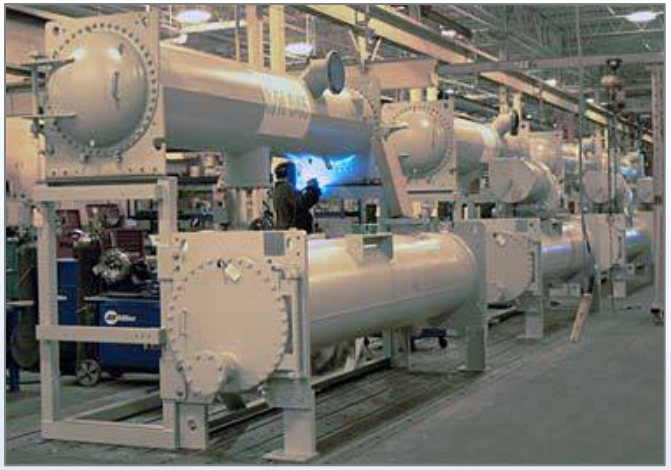
Factory Assembled and Field Tested

- High-Volume, lean flow lines with demand flexibility
- Standardized assembly processes
- Leveraging UTC's high quality supply base and manufacturing technologies
- Delivered fully integrated and tested
- Shipped on standard trucking
- 16 week lead time



Delivered fully assembled

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Environmental Benefits

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Example – California

	CO_2	NO_x
Average annual reductions†		
PureCycle® Model 280	**871 metric tons*** **200 acres**	**1.5 metric tons*** **88 cars**

† Based on a Nevada installation assuming 250 kW net power/unit

* Calculated using guidance from EPA's Combined Heat & Power office

Services

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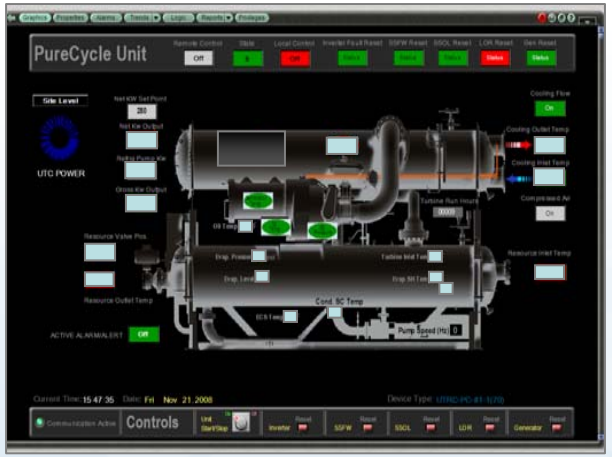
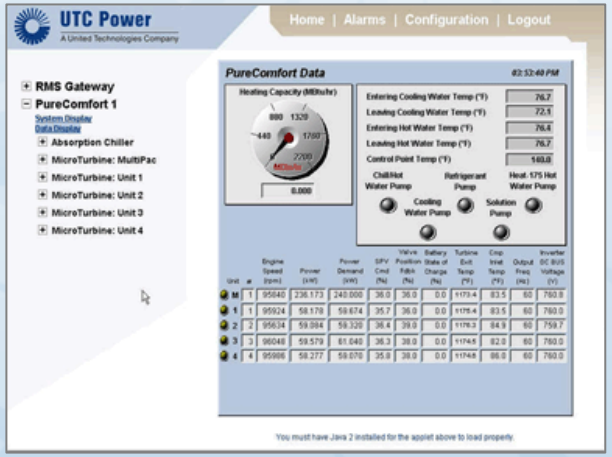
Full Range of Services

- Comprehensive maintenance, extended warranty, and 24/7/365 remote monitoring services
- Key system metrics captured and standard reports / alarm history reports can be generated
- Local, trained service technicians





Oil & Gas Integration

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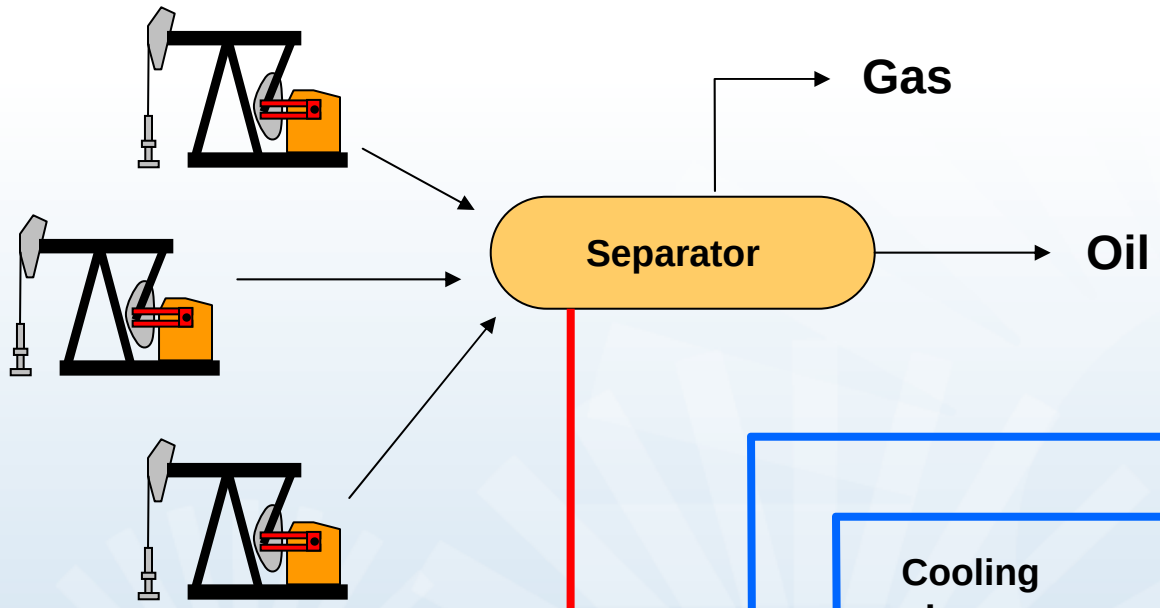

Challenges

- Considerable Flows Required
- High Summer Temps & Humidity
- Availability of Cooling Make Up Water

Cooling Tower

Make up Water
480 BPD

Cooling Loop
24,000 BPD min

Produced Water
300°F – 3,000 BPD
195°F – 11,000 BPD
Min Power (100KW)

300°F – 5,000 BPD
195°F – 37,000 BPD
Max Power (260KW)

260 KW Net Output

Disposal 165°F

Texas Severance Tax Exemption

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- Severance Tax Exemption for Oil & Gas incidentally produced during Geothermal Energy Generation (Texas HB 4433 amended tax code Sections 201.060 and 202.063)

- Exempted tax:
  - 7.5% of the market value of natural gas produced
  - 4.6% of the market value of oil produced

- Effective September 1, 2009

- Currently no cap on amount of oil & gas incidentally produced

- Incentivizes oil & gas producers to utilize geothermal heated liquid to generate electric power.

Estimated Project Economics

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- Two Savings Opportunities
  1. Electricity Cost Savings 2. Severance Tax Exemption Savings

- Assumptions
  - 1 PureCycle® unit; 280KW Gross, 210KW Net Power
  - Net Power includes fluid pump & cooling tower parasitic loads
  - 8.5¢/KWhr Electricity Cost Avoidance
  - 1.5¢/KWhr O&M Cost
  - 98% Availability

Estimated Installed Cost*	$800K (conservative)
Electricity Cost Savings	$125K/yr
Tax Savings** (gas well)	$150K/yr
Simple Payback	~3.0 Yrs

* Includes cooling tower, pumps & piping, controls, electrical, civil works, engineering & construction.
** Based on 1000MCF/Day at $5/MCF w/7.5% Gas Severance Tax Exemption

Additional Potential Benefits

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- 2.1¢/KWhr Production Tax Credit (PTC) or
- 30% Investment Tax Credit
- Monetize Renewable Energy Credits (REC's), Carbon Credits
- Extend the economic life of wells
- Leverage exploration & production expertise to become geothermal power producers
- Create/Maintain Skilled Jobs

Summary

- The PureCycle® system delivers:
  - ❑ Energy Cost Savings
  - ❑ Reliable Power
  - ❑ Zero fuel costs
  - ❑ Easy Integration, Unmanned Operation
  - ❑ Less than 16 Week Lead Time
- Energy solutions for geothermal / oil and gas and industrial waste heat to power
- 24/7/365 coverage through our service network

THANK YOU !

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