Waste Heat to Power Generation

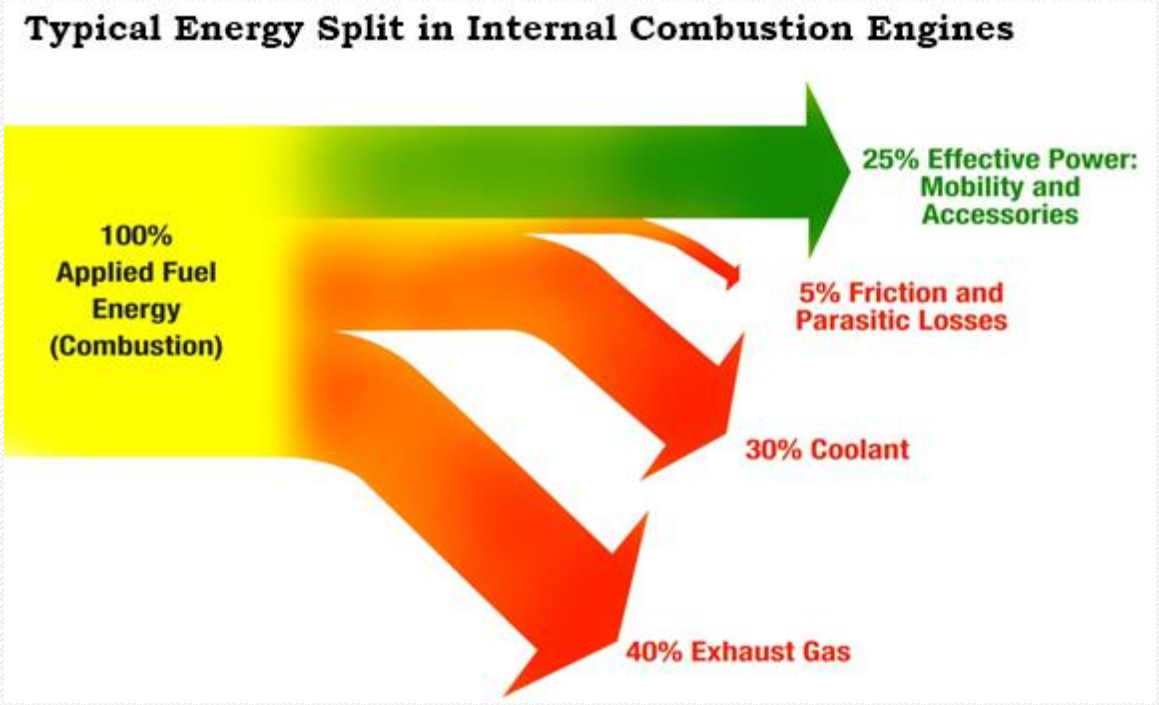
Alex Alexandrovich, P.E.



Outline

- Free Energy Potential
- The Rankine Cycle
- Barriers to The Rankine Cycle
- The Organic Rankin Cycle (ORC)
- Applications
- Packaged System Approach

Heat Energy Utilization

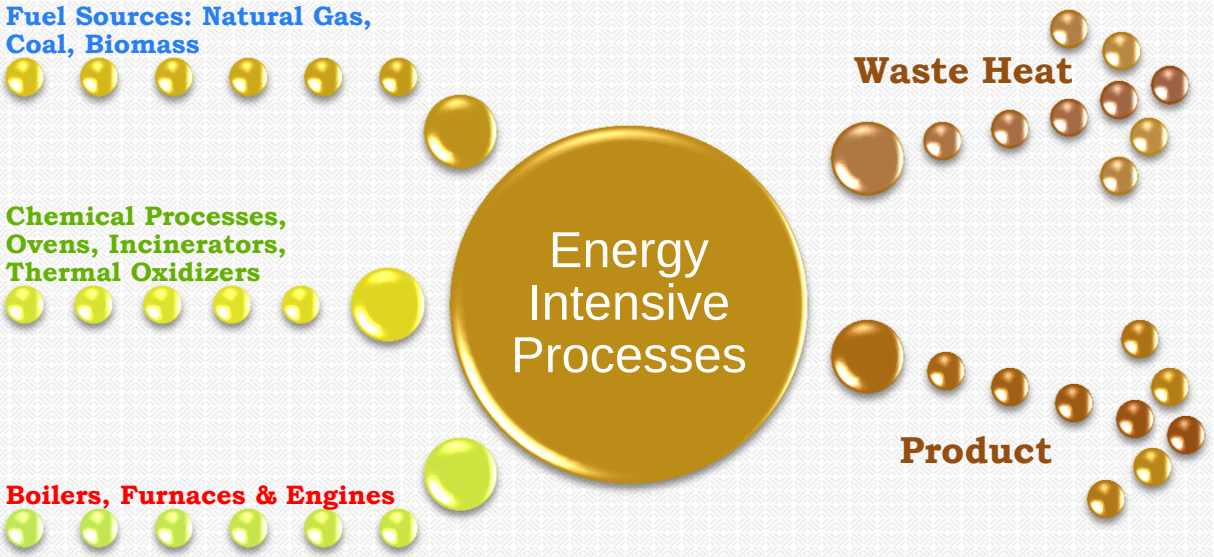


The majority of the heat resulting from the burning fuel in an internal combustion engine is lost in the coolant and exhaust, each of which represents an opportunity for heat recovery.

Waste Heat Sources

Most industrial processes produce significant waste heat.

Boilers, engines, furnaces, chemical reactions, gas compression, are just a few examples.



Potential For Free Electricity

EPA estimates that the waste heat produced by American industry could generate 10 gigawatts of emission-free electricity annually.

EPA estimates that energy produced from harnessing emission free waste heat could power 10 million homes, save the industry 3 billion annually, and produce 160,000 new jobs.

But how can we use free waste heat effectively?

Rankine Cycle

- **The Rankine cycle is a thermodynamic cycle which converts heat into work. The work can then be used to generate electricity.**

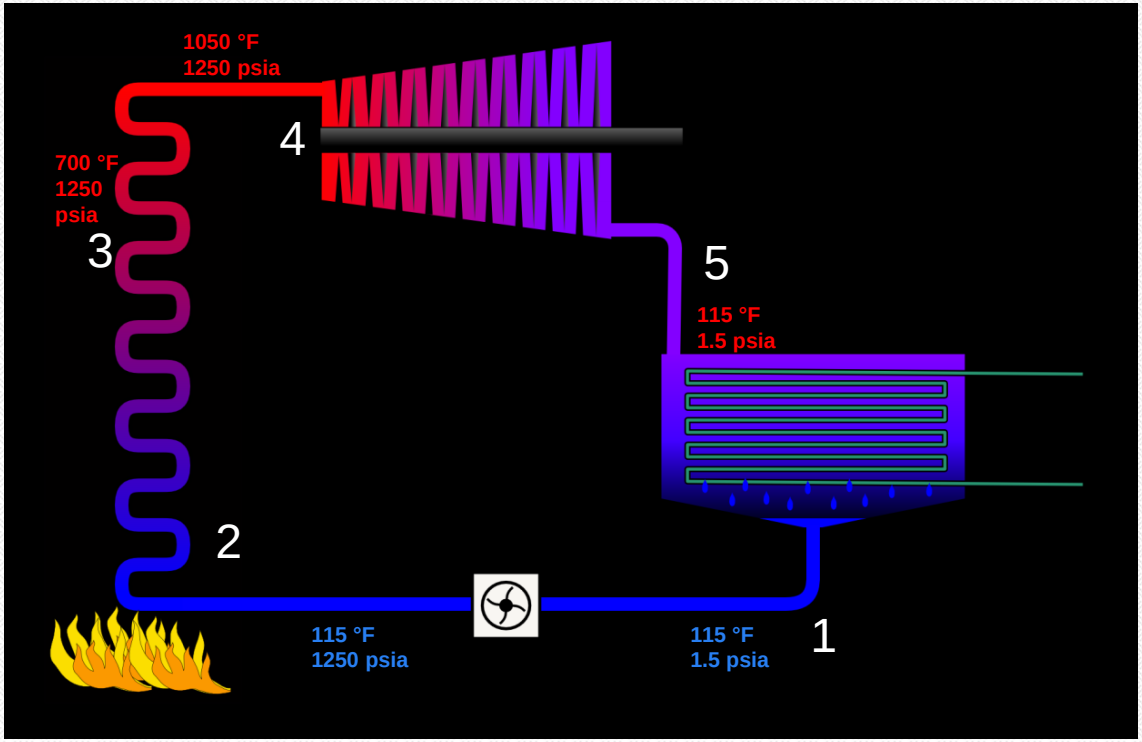
- **The efficiency of a Rankine Cycle process is limited by input temperature of the working fluid. The higher the temperature, the higher the potential efficiency.**

- **The Rankine Cycle is about 35% efficient.**

Process 1-2: The working fluid is pumped from low to high pressure. As the fluid is a liquid at this stage the pump requires little input energy.

Process 2-3: The high pressure liquid enters a boiler where it is heated at constant pressure by an external heat source to become a dry saturated vapor.

Process 3-4: The dry saturated vapor is superheated.



Process 4-5: The superheated vapor expands through a turbine, generating power. This decreases the temperature and pressure of the vapor, and some condensation may occur.

Process 5-1: The wet vapor then enters a condenser where it is condensed at a constant pressure to become a saturated liquid.

Heat Recovery Barriers

- **Conventional Rankine Cycle requires high temperatures.**
- **Though many heat sources exist, most are too spread out to be utilized effectively by common large scale heat-recovery equipment.**
- **Lack of experienced operational personnel at heat sources.**

How ORC Overcome Simple Rankine Barriers

Conventional Rankine Cycle requires high temperatures.

ORC operates with low temperatures.

Most heat sources are too spread out to be utilized effectively by common heat engines.

ORC solutions can be small scale (20-110kW).

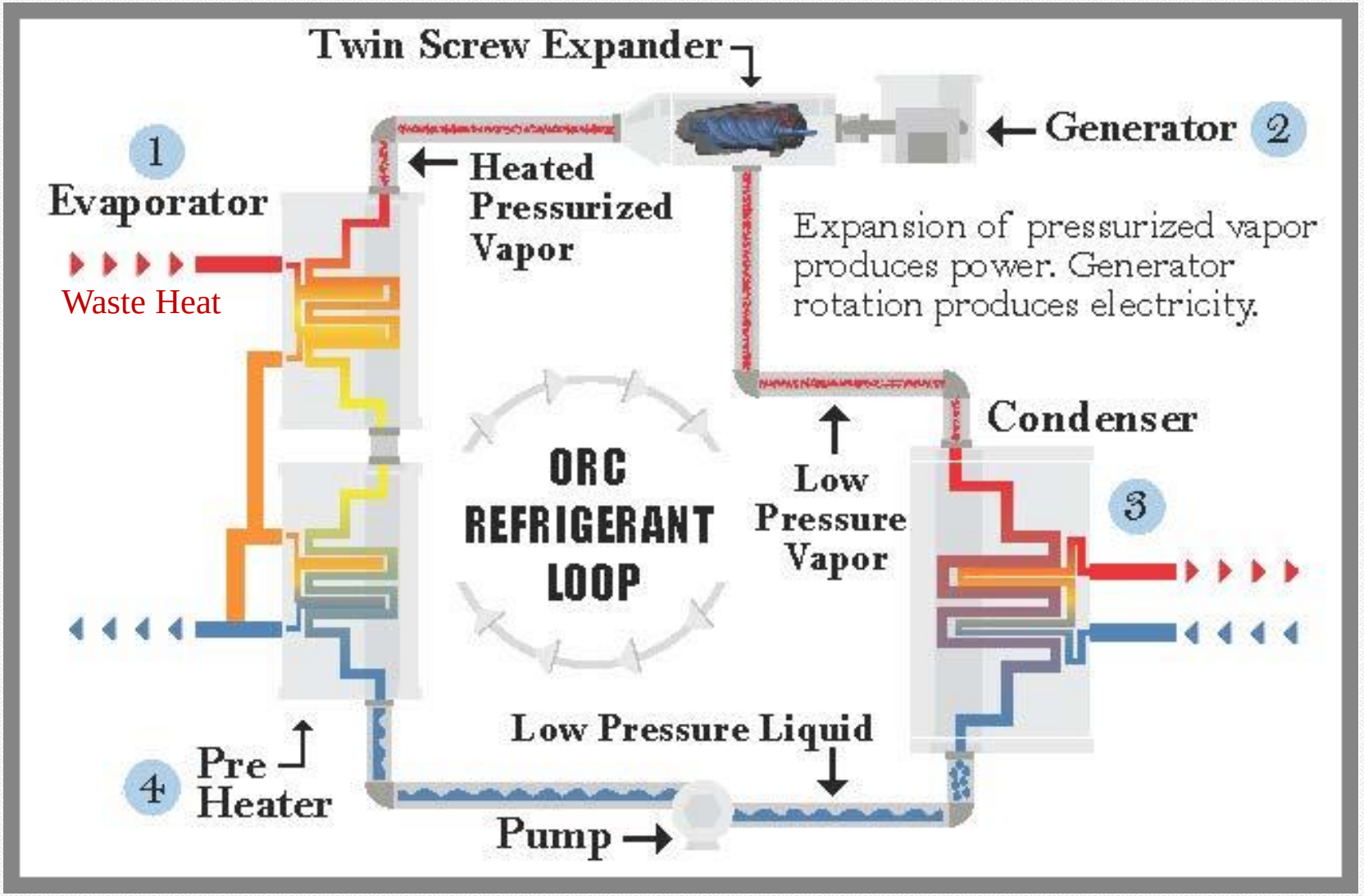
Lack of experienced operational personnel at heat sources.

ORC technology has fully automated controls and remote support.

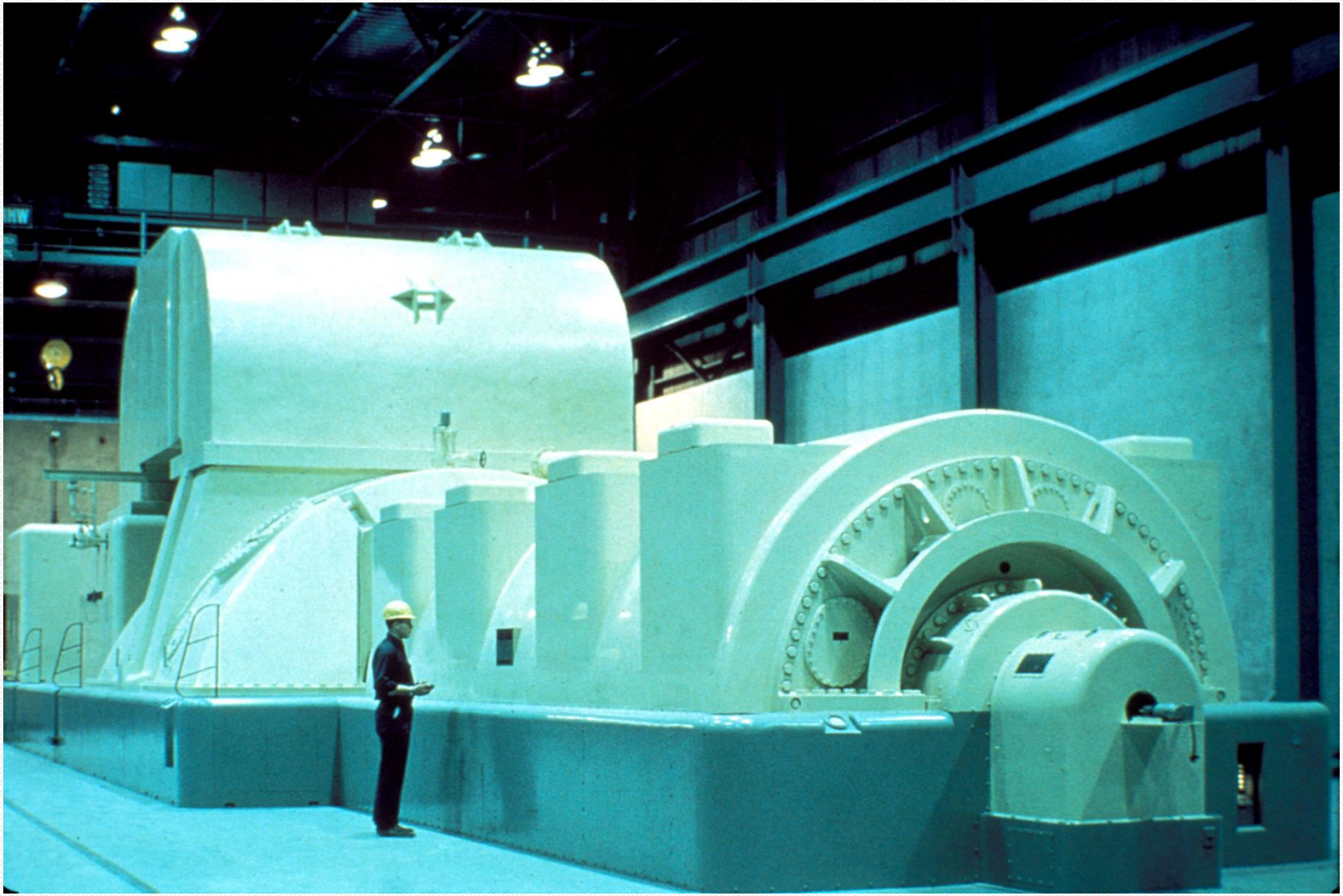
Waste Heat Recovery Solution

- **Organic Rankine Cycle Technology utilizes low temperature heat for power generation.**
- **ORC generators are small scale. This makes them a suitable solution for relatively low waste heat applications.**
  Proven reliable and effective. Made with common equipment.
- **Utilizes waste heat from processes. No additional fuel required.**
- **Organic Rankine Cycle technologies use refrigerant (HFC-245FA) with a low boiling point (60 °F) as a media.**
- **ORCs are closed loop.**

ORC Figure


Twin Screw Expander
Generator
2
1
Evaporator
Heated
Pressurized
Vapor
Waste Heat
Expansion of pressurized vapor produces power. Generator rotation produces electricity.
Condenser
ORC
REFRIGERANT
LOOP
Low
Pressure
Vapor
3
Low Pressure Liquid
4
Pre
Heater
Pump

Steam Turbine Footprint



Packaged ORC Footprint



Application Focus

Waste Heat Sources:
Stationary or Marine Engines
Oil and Gas Process Heat
Other Process Waste Heat
Down Cycle Condensing

Renewable Heat Sources:
Biomass Boilers
Geothermal/Oil & Gas Wells
Solar Thermal







Project Values
Better fuel/power/emissions output ratios = ↑ Efficiency
Distributed Power Generation
CHP potential

Geothermal In USA

Site: Nevada, USA
Installation December 2012







Internal Combustion Engine, USA

Site: East Texas, USA
Gross Power Output Avg: 28kW
Total Run Time: 5,075 Hours
Thermal Heat Input: 235 - 450kWt
Hot Water Input Range: 82 - 88°C
Hot Water Flow: 12.6 l/s
Direct Condenser: Ambient air temp from -1-38°C; avg is 21°C





"Natural gas compressor stations powered by internal combustion engines are located all over North America, and these waste heat streams can be captured to generate additional power and cool the engine at the same time,"

- Loy Sneary, President, Gulf Coast Green Energy

Solar Thermal, USA

Site: Kona, Hawaii
Gross Power Output Avg: 100kW
Total Runtime: 3,022 Hours
Thermal Heat Input: 325-650kWt
Hot Water Input Range: 71 - 118°C
Hot Water Flow: 7.26 l/s
Cold Water Input: 9°C
Cold Water Flow: 7.26 l/s





"The delivery and performance of the Green Machines has allowed us to fully utilize our solar field and we've extended renewable solar generation via the storage capacity, and ORC technology."

- Darren T. Kimura, Founder of Keahole Solar Power

Biogas in Germany

Site: Trechwitz, Germany
Gross Power Output Avg: 30-35kWe
Current Runtime: 19,120 Hours
Thermal Heat Input: 375 - 450kWt
Hot Water Input Range: 90-95°C
Hot Water Flow: 39 m3/hour
Ambient Temperature: 0-15°C







Potential Applications in New England

- Potential or existing CHP projects
- Thermal Oxidizers & Afterburners
- Biogas Flares
- Residual heat from melting, casting, and sintering
- Chemical Processes
- Exhaust heat from combustion processes
- Heat from steam condensate that is not utilized

mass save
Savings through energy efficiency

On October 11, 2012 the statewide Massachusetts Technology Assessment Committee (MTAC) approved the eligibility of equipment utilizing the ORC technology for power generation for participation in the Custom efficiency programs.

Under the MassSave Custom energy efficiency project path, each site specific project will have to have a detailed technical assistance study performed to fully document the estimated energy savings and installed equipment costs.

In Summary,

Organic Rankine Cycle Systems Deliver:

- **Distributed, renewable power production**
- **Ease of installation, operation and maintenance**
- **Low operational costs with strong ROI**
- **Robust, reliable, off-the-shelf components**
- **A modular solution that can scale to the heat source**
- **Digital controls with remote monitoring & standard interface**

ElectraTherm Inc. – The Green Machine



- **Founded in 2005**
- **Approx. 50 Employees**
- **Patented & Patent-Pending Technology**
- **44 Operational Machines**
- **Headquarters - Reno, Nevada**
- **EU Sales and Service - Munich, Germany**

NCET | Nevada's Center for Entrepreneurship and Technology

NCET
2009 Green Company of the Year

THE WALL STREET JOURNAL 2009 TECHNOLOGY INNOVATION AWARDS

THE WALL STREET JOURNAL
International Innovation Award
Energy 2009

POPULAR SCIENCE THE FUTURE NOW BEST OF WHAT'S NEW 08
"Best Green Tech" Award 2008

Popular Science Best of 2008
Green Technology

Best of Show 2007 Geothermal Energy Association
GRC Best Scientific Paper Award 2007 Geothermal Resources Council Annual Meeting

Geothermal Energy Association Best of Show; Best Scientific Paper 2007

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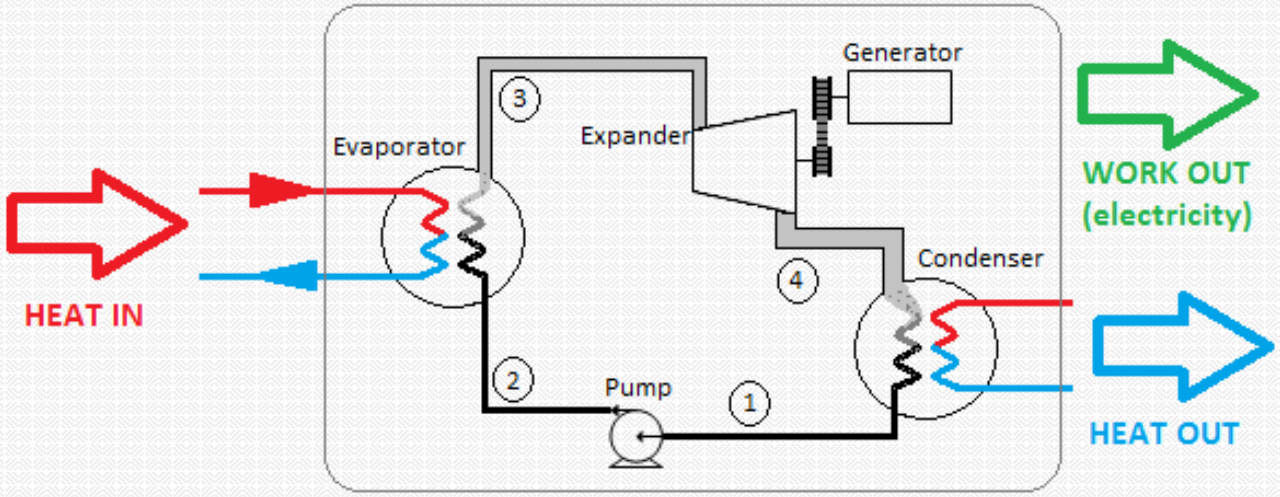




ElectraTherm's Heat-to-Power Generator

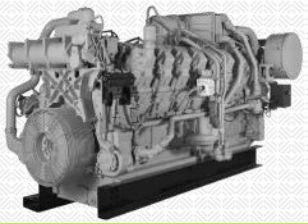
- Exploits low grade waste heat
- Produces up to nominal 110 kWe at 480V, 3phase, 50 or 60Hz power
- Modular and Commercially Mobile:
  - 6,600-7,200 lbs. (3,000-3,200 kg)
  - 6.5 ft. wide 8 ft. long x 7.25 ft tall
- Patented technologies enable:
  - Low maintenance
  - No oil pump, no oil changes, no gearbox
  - Off the shelf components & simple design

How It Works



1. Low pressure liquid
2. High pressure liquid
3. Heated, pressurized vapor
4. Low Pressure Vapor

Example on a stationary engine:



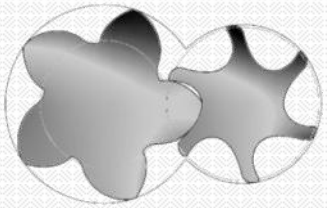
Hot Water In

Cooler Water Out



kW Output

ElectraTherm Advantages and Working Parameters



Patented ORC Technology

Owned and licensed patents issued and pending worldwide for core technology and innovative applications



Robust, Proven Hardware

Patented Expander Rotor Profile:

- Works with "wet" vapor, two phase flow
- Low Speed, <5000 rpm
- Variable output range

Accepts a range of input parameters…

- 55-350gpm @ 170-240°F hot water in
- 220-350gpm @ 40-100°F for cooling water input
- -Air Cooled Condensing Green Machine is available.

…to produce a range of output

Up to 110kW Currently



ElectraTherm Has Commercialized Product Ready To Ship

- 44 operational machines
- New machines starting every month.
- Achieved 290,000+ hrs runtime
- Monitoring fleet performance + R&D testing
- Optimized design turn complete
- Building production backlog through distributor network



ElectraTherm's 4-bay test cell.

Thank You!

Alex Alexandrovich, P.E.

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SOURCES

http://en.wikipedia.org/wiki/Rankine_cycle