Potential for Geothermal Technologies in Heat Recovery

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Typical Waste Heat Sources

- Utility Industries
- Heavy Industries: Steel, Aluminum, Copper, Cement, Pulp & Paper, and Glass
- Refinery and Petrochemical Plants
- Incinerators/Gasification/Combustors
- Gas Compression/Pipelines
Unit Ops Generating Waste Heat

- Boilers, heaters and furnaces (gas, diesel, coal, nuclear, refuse, petroleum, and coke)
- Gas turbine exhaust
- Steam turbine exhaust
- IC engine exhaust
Potential (GW)
Potential by Industry

- Inceneration
- Pulp and Paper
- Cement
- Refinery
- Foundary
- Petrochemical
Typical Steam System Heat Flow

MAKE UP

BOILER

STEAM DISTRIBUTION SYSTEM

CLIENT

Deaerator Vent

Hot Flue Gas

Radiant & Convective Heat From Boiler

Radiant & Convective Heat From Steam Distribution System

Heat to Client

Natural Gas

Combustion Air

Boiler Feed Water

Boiler Blowdown

Condensate From Client Heater

Distribution System Drip Condensate
Geothermal Combined Cycle Flow Diagram
using Organic Rankine Cycle Technology
ORC Heat Recovery Flow Diagram
## Cost Comparison ($/kW)

<table>
<thead>
<tr>
<th></th>
<th>Conv Geo</th>
<th>ORC Heat Rec</th>
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</thead>
<tbody>
<tr>
<td>Resource assessment (1)</td>
<td>$400</td>
<td>$200</td>
</tr>
<tr>
<td>Well field development</td>
<td>1000</td>
<td>-0-</td>
</tr>
<tr>
<td>Power plant &amp; transmission</td>
<td>2000</td>
<td>2000</td>
</tr>
<tr>
<td>Other costs(2)</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4000</td>
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<tr>
<td><strong>TOTAL COST FOR 10 MW PROJECT</strong></td>
<td><strong>$40 MM</strong></td>
<td><strong>$28 MM</strong></td>
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(1) Includes exploration costs
(2) commitment, consulting, development, contingency, legal & accounting fees, interest during construction, and operating reserve
Annualized Capital Costs (CC) for Organic Rankine Heat Recovery Projects

Capital Costs $2800/kW
@ 0.2 Annual Factor, CC = 71 $/mWh
@ 0.15 Annual Factor, CC = 53 $/mWh
@ 0.10 Annual Factor, CC = 36 $/mWh

O&M costs ~ 15 $/mWh  Fuel Cost = 0
Typical Utility Costs of Doing Business

Novec

- Wholesale Power
- T&D
- Admin
- Depreciation
- Customer Service
- Interest
In Summary

Waste heat recovery applications using geothermal technologies are available with less risk, because the heat sources can be easily quantified and accessed without drilling.

The major barrier to widespread deployment is the lack of awareness of the technology and its economic and environmental benefits.