Low temperature power generation (LTPG)

Can it be part of our clean energy future?

Boaz Habib
Heavy Engineering Research Association (HERA)
Background - Global and NZ clean energy drivers

- Population growth
- Alternative to carbon fuel
- Climate change
  - NZ GHG reduction target 11% below 1990 levels by 2030
- Low temperature sources = clean energy
  - Geothermal
  - Waste heat
Background - Low temperature heat source

- Geothermal wellheads
- Hot springs
- Back end of geothermal plants
- Geothermal bores

85°C to 150°C
### Background - Geothermal energy spectrum

<table>
<thead>
<tr>
<th>Low temperature</th>
<th>Metric</th>
<th>High temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low – medium</td>
<td>Industry application international</td>
<td>Medium – high</td>
</tr>
<tr>
<td>None</td>
<td>Industry application NZ</td>
<td>High</td>
</tr>
<tr>
<td>50-1000kW</td>
<td>Scale of application</td>
<td>10-100MW</td>
</tr>
<tr>
<td>High</td>
<td>Research international</td>
<td>N/A</td>
</tr>
<tr>
<td>Low</td>
<td>Research NZ</td>
<td>N/A</td>
</tr>
<tr>
<td>Organic fluid</td>
<td>Heat transfer medium</td>
<td>Steam</td>
</tr>
</tbody>
</table>

**85-150°C**

**400°C**

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Background – Organic Rankine Cycle process

![Diagram of Organic Rankine Cycle process](image)

- **Geothermal heat source**
- **Evaporation**
- **Expansion**
- **Condensation**
- **Cooling water**
- **Pump**


**Legend:**
- Fluid
- Subcritical ORC process
- Supercritical ORC process

**Diagram:**
- Temperature vs. Entropy graph showing the cycle's temperature and entropy levels for different processes.
Background - International ORC manufacturers

<table>
<thead>
<tr>
<th>Suppliers</th>
<th>Power range (kW)</th>
<th>Heat source temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ormat, US</td>
<td>1000-140000</td>
<td>95-300</td>
</tr>
<tr>
<td>Turboden, Italy</td>
<td>1000-16500</td>
<td>100-300</td>
</tr>
<tr>
<td>Cryostar, France</td>
<td>500-15000</td>
<td>100-400</td>
</tr>
<tr>
<td>AQYLON, France</td>
<td>1000-10000</td>
<td>85-330</td>
</tr>
<tr>
<td>GMK, Germany</td>
<td>35-3700</td>
<td>85-300</td>
</tr>
<tr>
<td>Enertime, France</td>
<td>100-5000</td>
<td>90-200</td>
</tr>
<tr>
<td>ElectraTherm, US</td>
<td>35-110</td>
<td>77-122</td>
</tr>
<tr>
<td>Zero Emission, UK</td>
<td>39-130</td>
<td>100-300</td>
</tr>
<tr>
<td>Enogia, France</td>
<td>5-100</td>
<td>80-500</td>
</tr>
<tr>
<td>Exergy, Italy</td>
<td>1000-25000</td>
<td>90-350</td>
</tr>
<tr>
<td>Atlas Copco, Sweden</td>
<td>2000-45000</td>
<td>120-650</td>
</tr>
</tbody>
</table>
Background - Where does NZ sit?

Pioneer

Fast follower

Late follower (me too)

Late follower (Niche supplier)
Forming the vision - Needs analysis

LTPG technology status
- Inefficient
- Expensive
- Follow not lead
- Prefer off-the-shelf

Research vision
- Improve efficiency
- Reduce costs
- Lead not follow
- Buy NZ made
Forming the vision – HERA connection

- HERA wood strategy
- Biomass heat and ORC
- AGGAT programme
Forming the vision – What’s the value proposition

Technology platform for R&D in above ground technology

Manufacturability that lifts NZ Heavy Engineering industry

Export streams for growth of NZ economy

Filling a gap in above ground technology in NZ

Job opportunities created through new technology

Improved perception for NZ in renewable energy globally
Knowledge base development - Trade delegations and conferences

Trade delegation USA 2012
Pure cycle plant at RMOTC

ORC conference 2015
E-Rational ORC 165kW plant
Knowledge base development - Our own workshops and conferences

Top left: NZGW 2016; Above and left: AGGAT Conference 2015
Research agenda

Above Ground Geothermal and Allied Technologies

Technology concepts
- Turbines
- Heat Exchangers
- Materials and fluids
- Control systems

Knowledge base

Low enthalpy systems
Research agenda

Above Ground Geothermal and Allied Technologies

IS1
Knowledge base

IS1-1 Expert Design Tool
IS1-2 Materials Knowledge Base
IS1-3 Scaling Mechanisms
IS1-4 Heat Transfer Data
IS1-5 Expander Research
IS1-6 Control Research

IS2
Advanced low enthalpy conversion system

IS2-1 Systems and Modules
IS2-2 Heat Exchanger Concepts
IS2-3 Turbo Machinery Development
IS2-4 Control Systems Development

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Research agenda – Summary of objectives

- **Expert design tool** to better inform our members
- **Two ORC pilot plants** close to testing phase
- **Turbine design concept** specifically for AGGAT
- **Heat exchanger** design concepts
- **Control systems** modelling packages
- **Materials test rig** for geothermal scaling research
Research outcomes – Technology concepts EDT

Simple ORC

Please select the heat source:

- Condenser gas

- Inlet temperature of the heat source, °C

- 100.0

- Flow rate of the heat source, kg/s

- 3.0

- Pressure of the heat source, Bar

- 1.0

Please select the cooling medium:

- Air

- Inlet temperatures of cooling medium, °C

- 35.0

- Pressure of cooling medium, Bar

- 1.0

Please select a working fluid:

- R-134a

Summary

- Residence time: 7.2
- Mass flow rate: 0.18 kg/s

Process Flow Diagram

Key Financial Data

- Objective power (kW): 20
- Collector area (m²): 120
- Energy input (kg/kW): 200

Preliminary Equipment Design

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Research outcomes – Technology concepts
NZ manufactured ORC plant
Research outcomes – Heat exchanger ORC fluid

- R245fa
  - Not flammable, dry fluid
  - Reduced equipment costs
  - Average thermodynamic properties
  - GWP ~ 930-1030
  - Phasing out

Quolin et al., 2013
Research outcomes – Heat exchanger ORC fluid

- R245fa research
  - Temperature limits
  - Thermodynamic performance in expander vs. turbine

- New fluids research
  - HFO-1234ze
  - HDR-14

Zyhoswki & Brown, Honeywell
Research outcomes – AGGAT Heat Exchanger Test Rig
Research outcomes – NZ turbo-generator technology

- 100kW radial inflow turbine
- NZ based manufacturing
- Overseas magnetic bearing generator technology
- Potential to scale up dependent on success
Research outcomes - Materials test rig
Now what?

- Research partnerships
- NZ manufacturing and research capability
- Realities of SME environment
Where to from here?

Monitor global trends

Leverage support mechanisms for industry partners

Inform policy environments

Sustain today, lead tomorrow

Your part in this?
What’s in it for the NZ geothermal sector?

The opportunity
The ‘NZ Story’

Claim an international profile
Be a leader in low temperature power generation
Respond to the energy trilemma
Let’s do this man!