

Low temperature power generation (LTPG)

Can it be part of
our clean energy
future?

Boaz Habib
Heavy Engineering Research
Association (HERA)

NZGA Seminar

**Pulse of the New Zealand Geothermal
Industry**

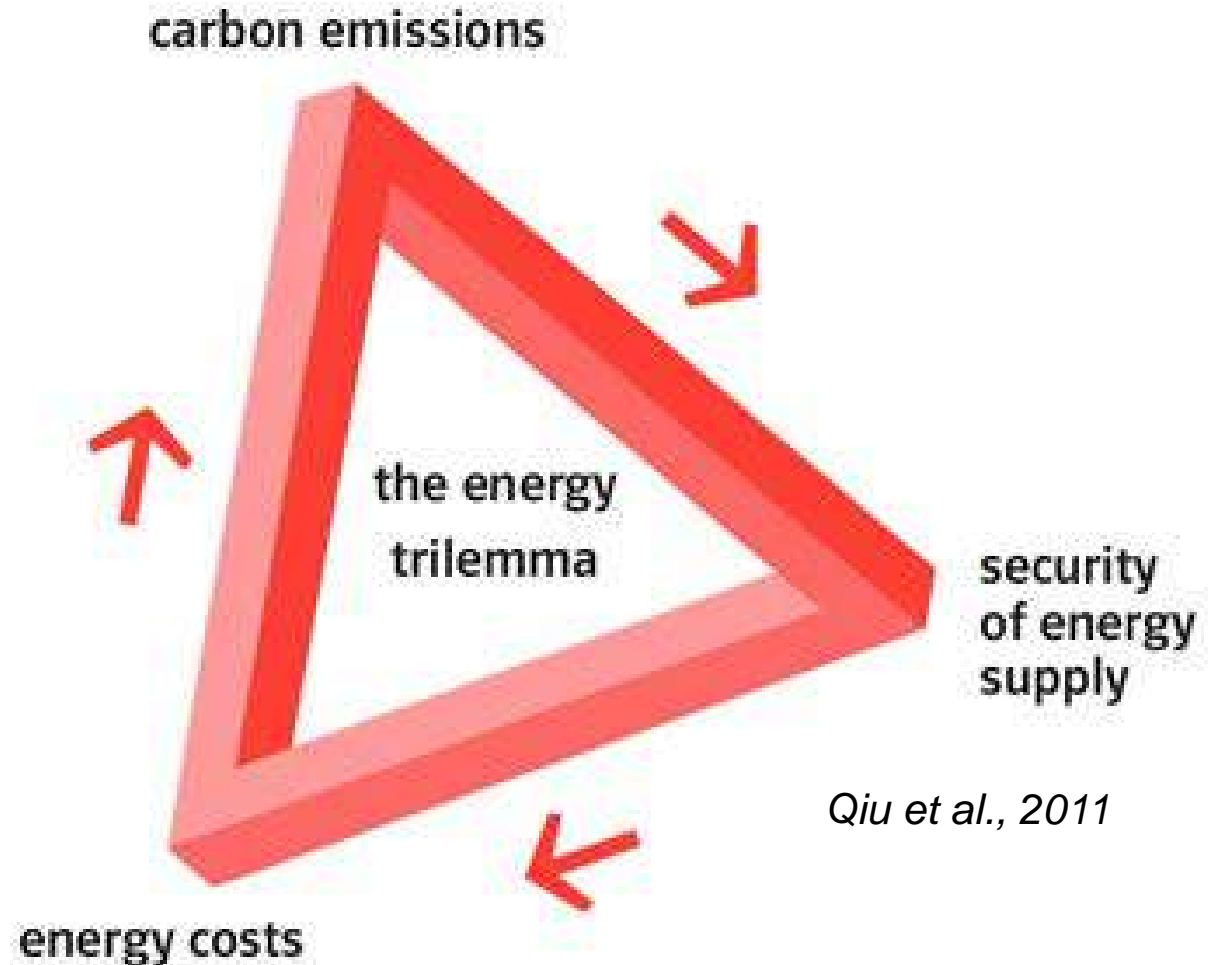
Wairakei Resort, Taupo

27th June 2017



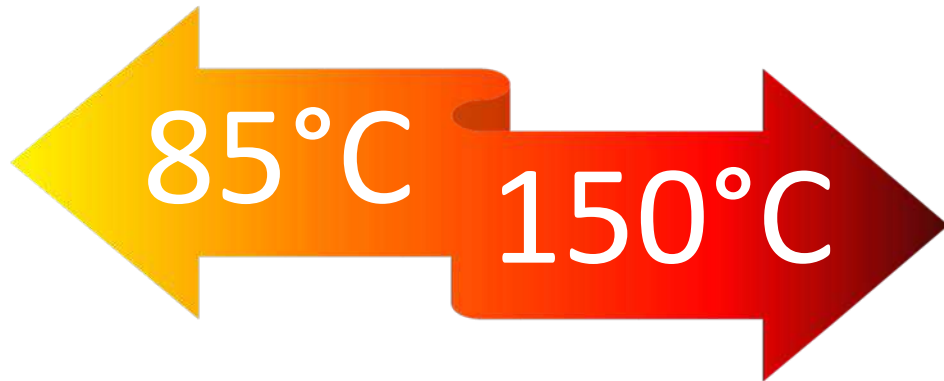
Background - Global and NZ clean energy drivers

- 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



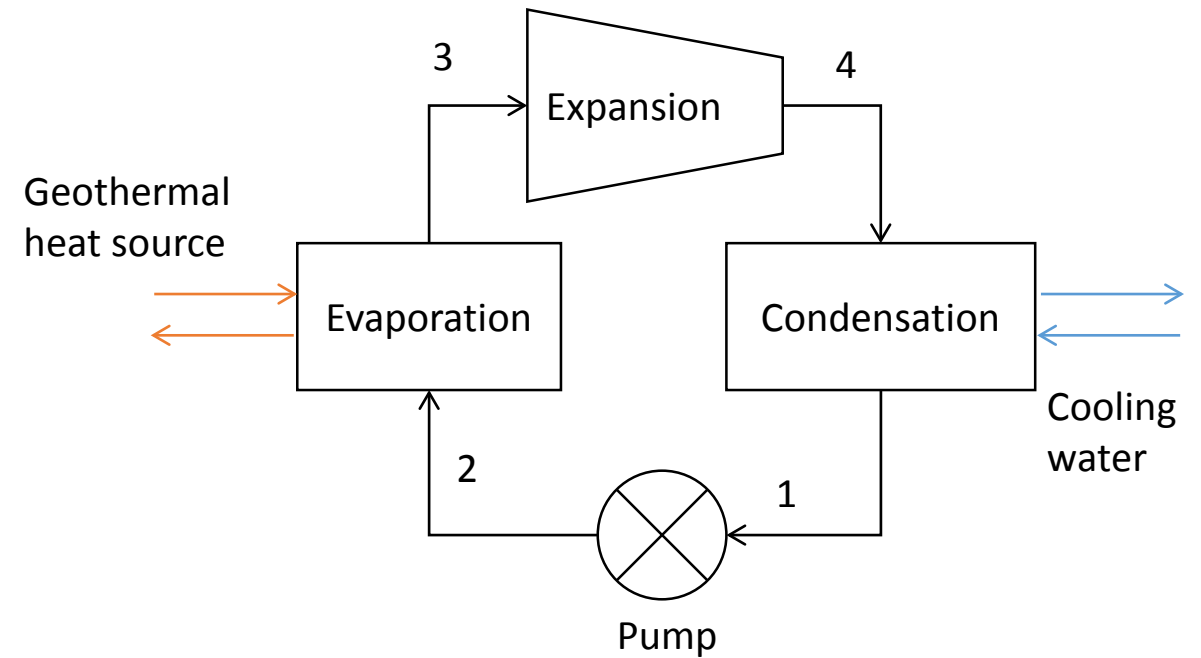
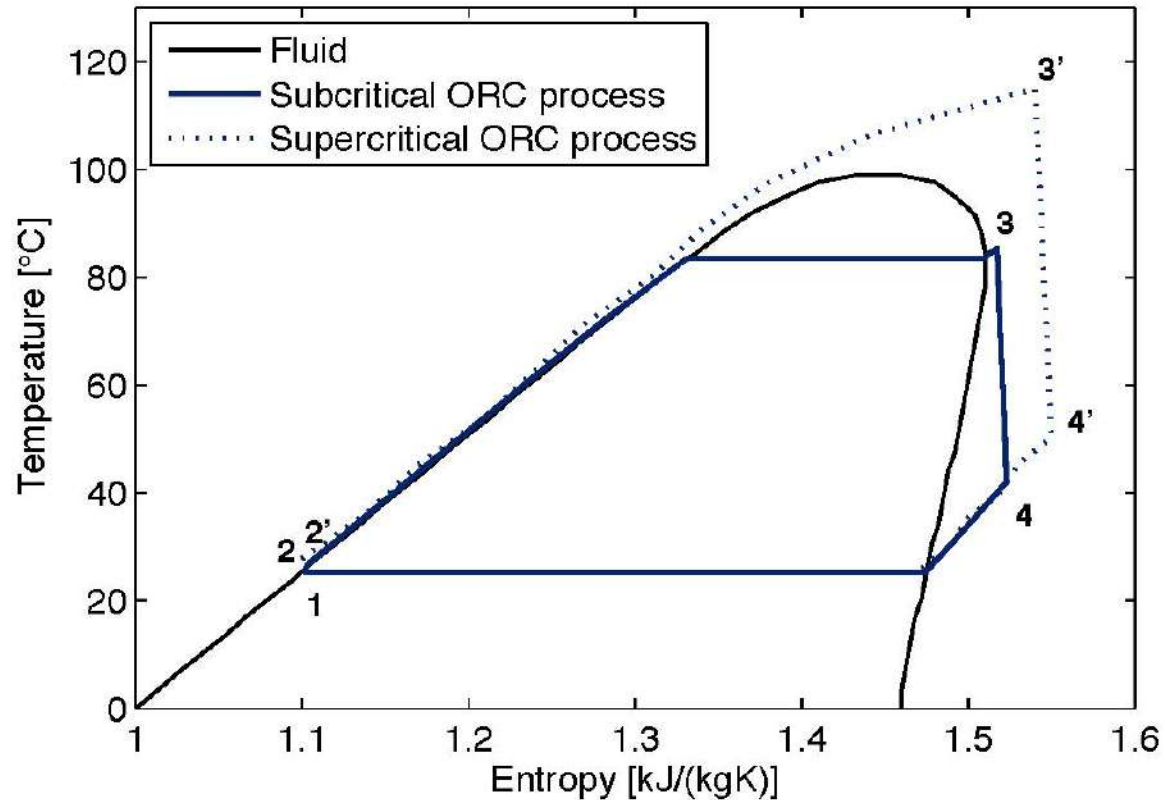
Background - Geothermal energy spectrum

85-150°C

400°C

Low temperature	Metric	High temperature
Low – medium	Industry application international	Medium – high
None	Industry application NZ	High
50-1000kW	Scale of application	10-100MW
High	Research international	N/A
Low	Research NZ	N/A
Organic fluid	Heat transfer medium	Steam

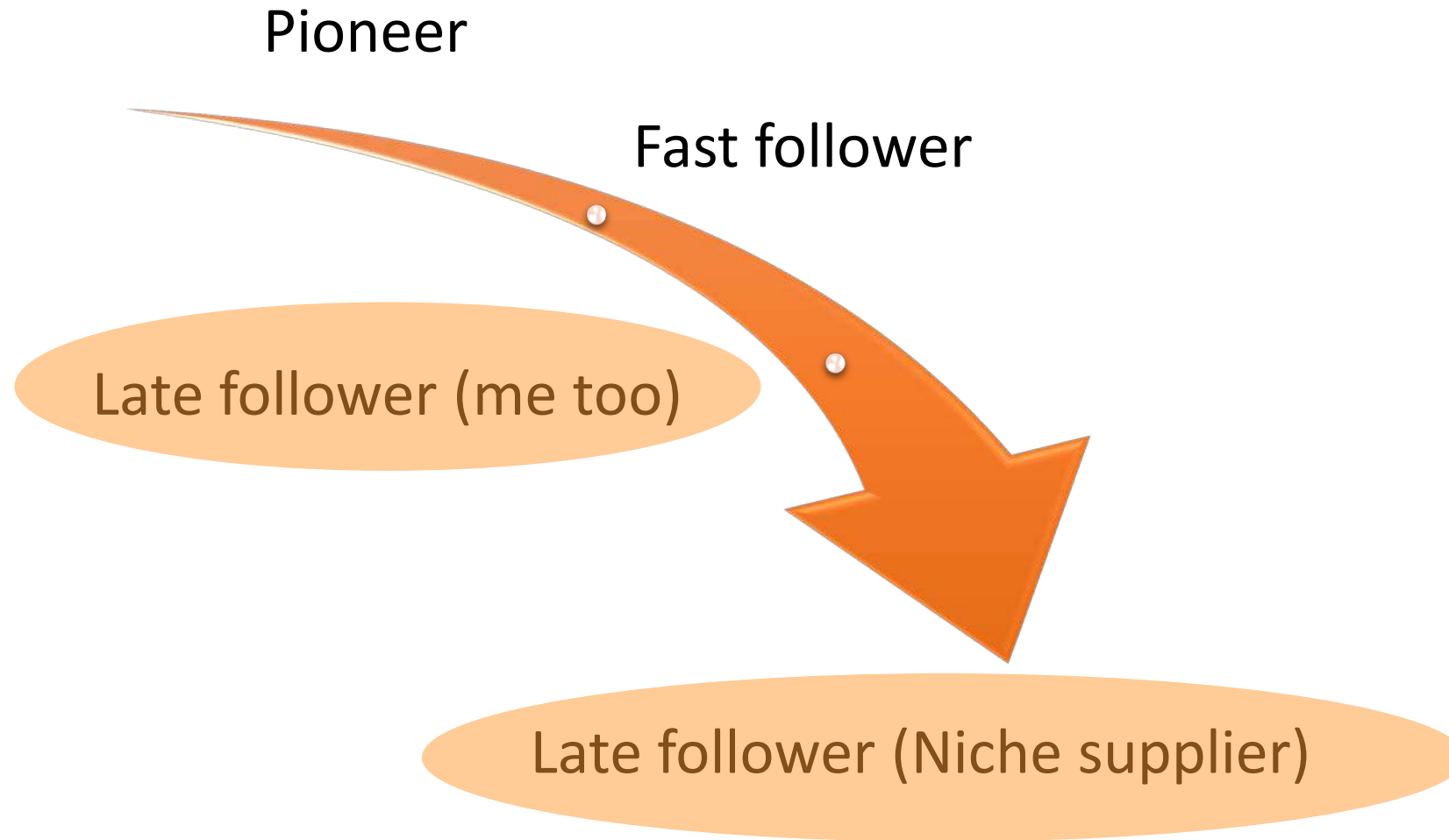
Background – Organic Rankine Cycle process



Background - International ORC manufacturers

	Suppliers	Power range (kW)	Heat source temperature (°C)
1	Ormat , US	1000-140000	95-300
2	Turboden, Italy	1000-16500	100-300
3	Cryostar, France	500-15000	100-400
4	AQYLON, France	1000-10000	85-330
5	GMK, Germany	35-3700	85-300
6	Enertime, France	100-5000	90-200
7	ElectraTherm, US	35-110	77-122
8	Zero Emission, UK	39-130	100-300
9	Enogia, France	5-100	80-500
10	Exergy, Italy	1000-25000	90-350
11	Atlas Copco, Sweden	2000-45000	120-650

Background - Where does NZ sit?



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

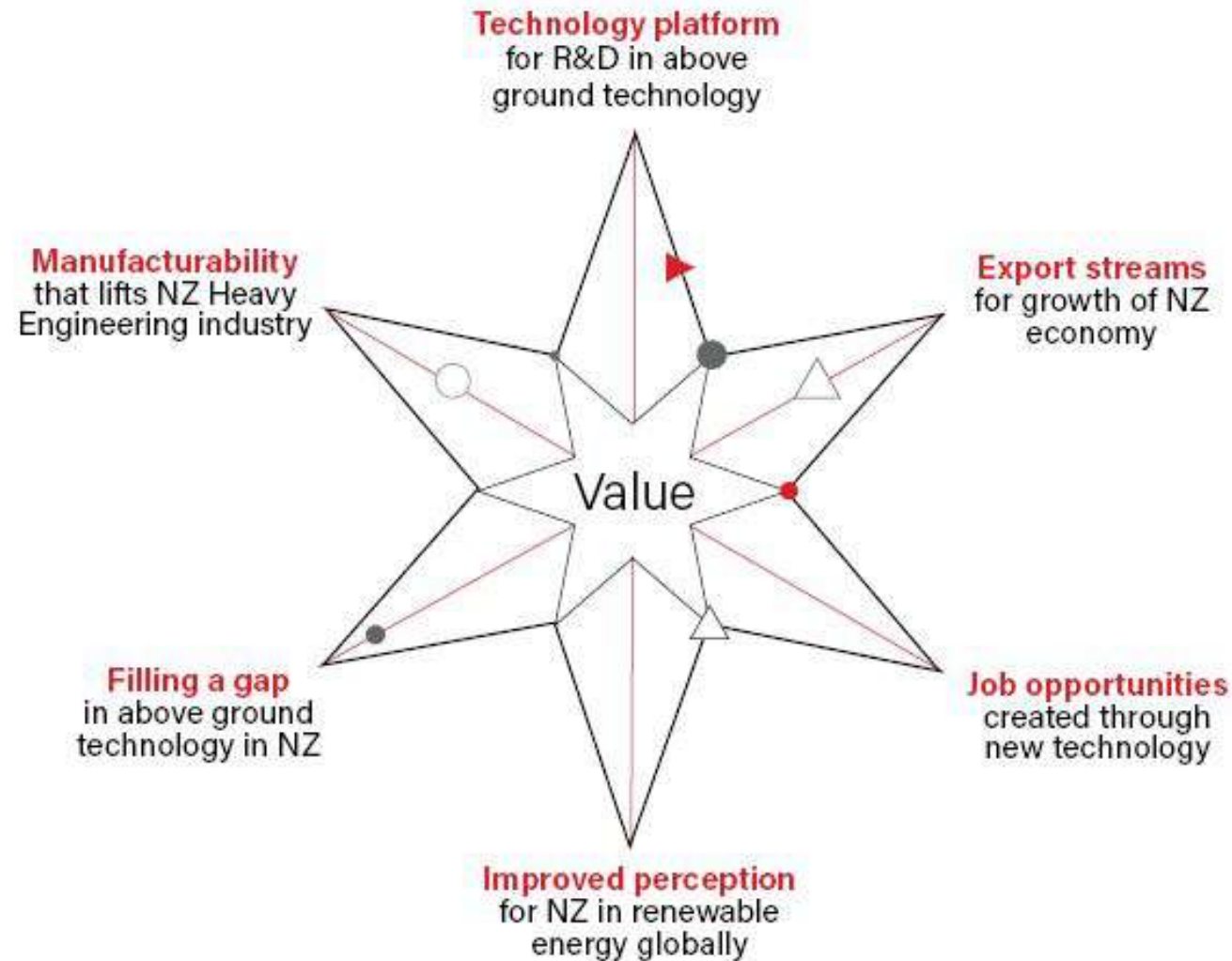
Buy NZ made

Forming the vision – HERA connection

- HERA wood strategy
- Biomass heat and ORC
- AGGAT programme



Forming the vision – What's the value proposition



Knowledge base development - Trade delegations and conferences



Trade delegation USA 2012
Pure cycle plant at RMOTC



ORC conference 2015
E-Rational ORC 165kW plant

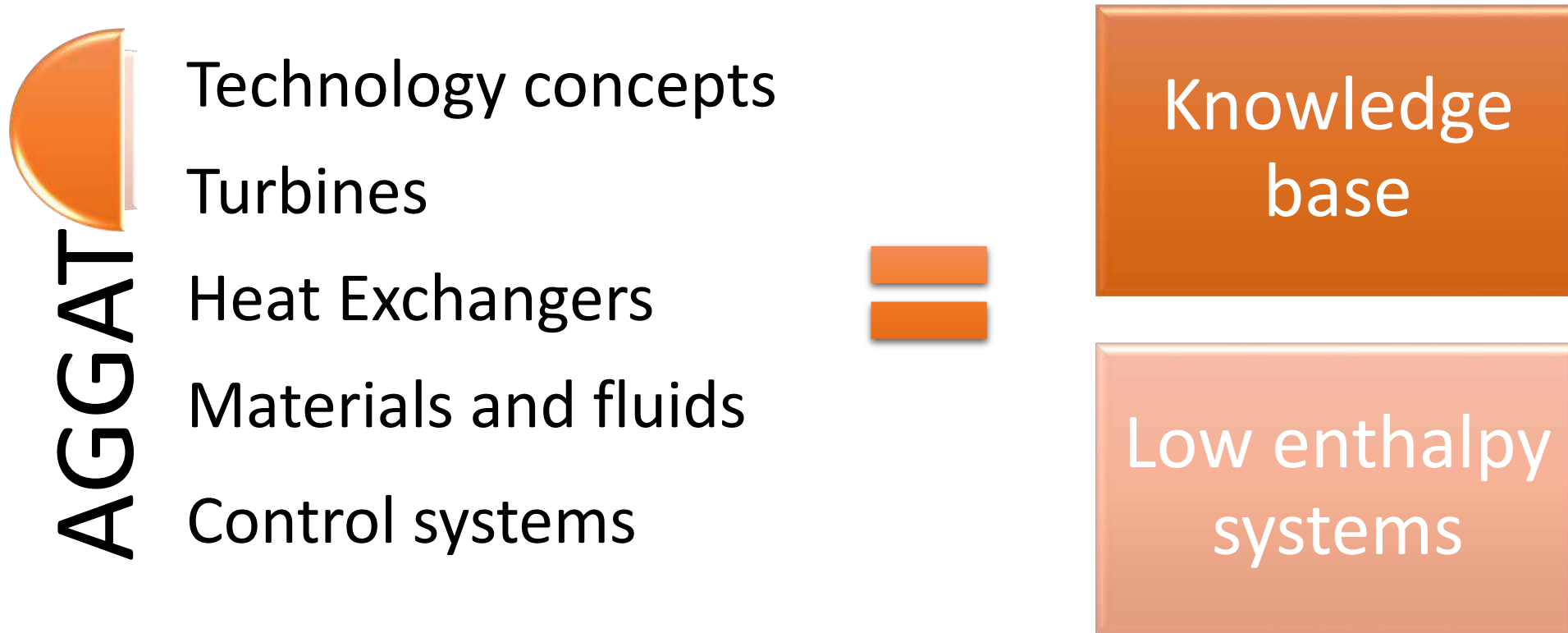
Knowledge base development - Our own workshops and conferences



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

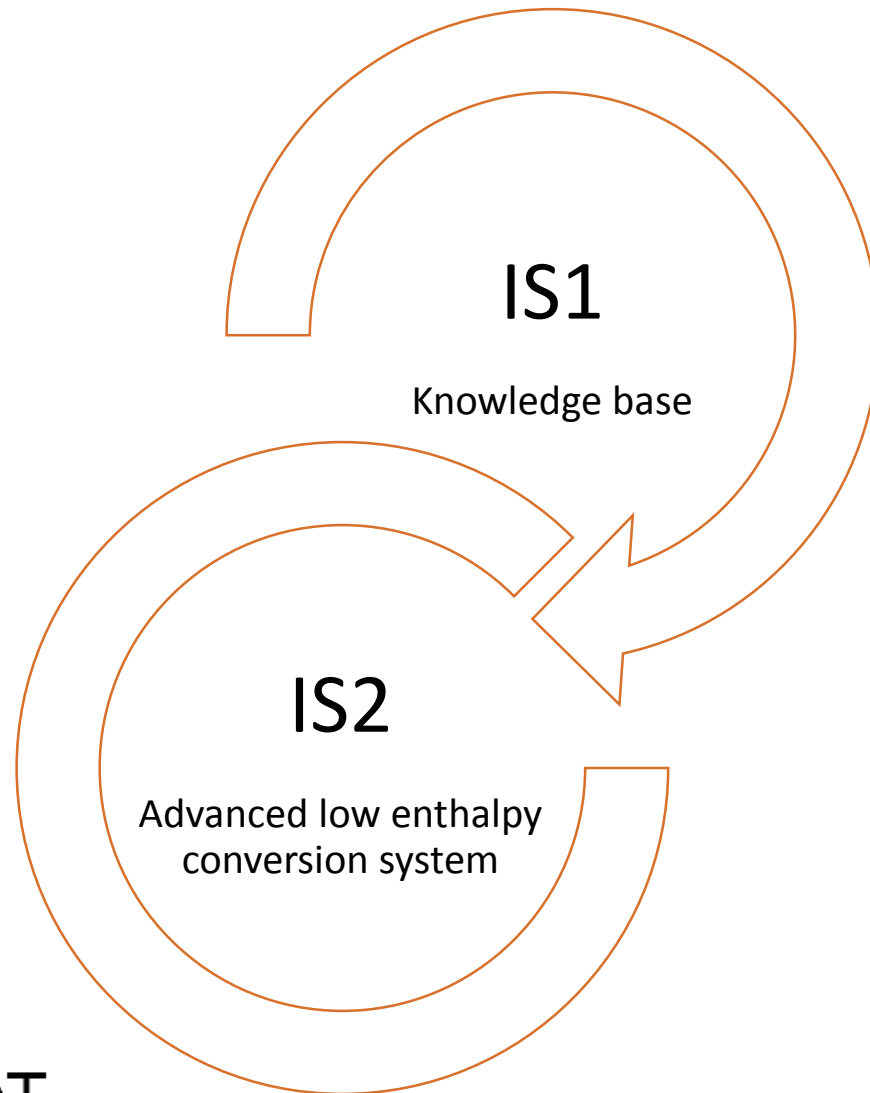
Research agenda

Above Ground Geothermal and Allied Technologies



Research agenda

Above Ground Geothermal and Allied Technologies



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

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

Research team - AGGAT Technical Advisory Board



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

Input
screen

Results
pages

Simple ORC

Enter data into the text fields. Components can be selected by clicking on a component on the process diagram. When ready, click "Generate simple report" to continue.

Please select the heatsource

Exhaust gas

Inlet temperature of the heat source, °C

400.0

Flow rate of the heatsource, kg/s

2.0

Pressure of the heatsource, Bar

1.0

Please select the cooling medium

Air

Inlet temperature of cooling medium, °C

20.0

Pressure of cooling medium, Bar

1.0

Please select a working fluid

R245fa

Please specify the assumptions for the simulation

Turbine efficiency (%)

85

Pump efficiency (%)

85

Heat exchanger efficiency (%)

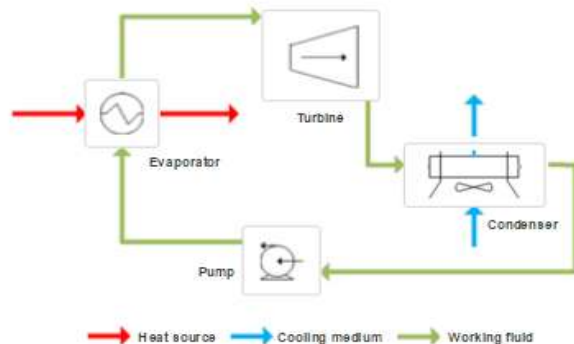
85

Pinch temperature (°C)

5

Super heat temperature (°C)

3

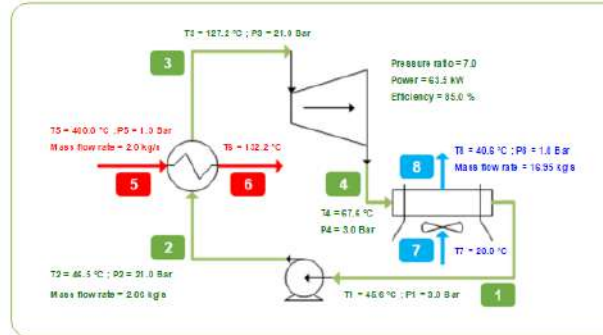


Generate simple report

Summary

Heatsource:	Exhaust gas	Mass flow rate of working fluid (kg/s):	2.00
Inlet temperature of heat source (°C):	400.0	Thermal power of heat source (kW):	555.4
Mass flow rate of heat source (kg/s):	2.0	Net electric power (kW):	60.1
Cooling medium:	Air	Thermal efficiency (%):	10.0
Inlet temperature of cooling medium (°C):	20.0	Energy efficiency (%):	22.3
Working fluid:	R245fa	Internal Rate of Return (%):	32.3

Process Flow Diagram



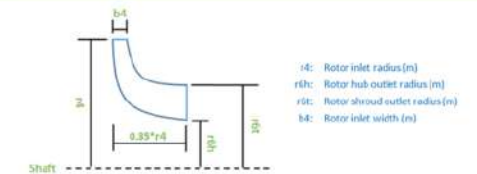
Key Financial Data

Key Financial Data

Output power (kW):	60.1	Discount rate (%):	10.0
Plant lifetime (Year):	20	Annual electricity price escalation (%):	1.0
Electricity price (NZD/kWh):	0.053	Initial investment (NZD/kW):	120.2
Operating and maintenance cost (NZD/kWh):	0.013	Net Present Value (NZD/kW):	256.1
Specific cost per net power output (NZD/kWh):	2000	Internal Rate of Return (%):	32.3

Preliminary Equipment Design

Turbine



Turbine type:	Multiple radial turbine	r4 (m):	0.009
Power (kW):	60.1	rth (m):	0.026
Pressure ratio:	7.0	rdt (m):	0.054
Efficiency (%):	10.0	b4 (m):	0.0004
Mass flow rate (kg/s):	2.00	Rotational speed (rpm):	1000.7

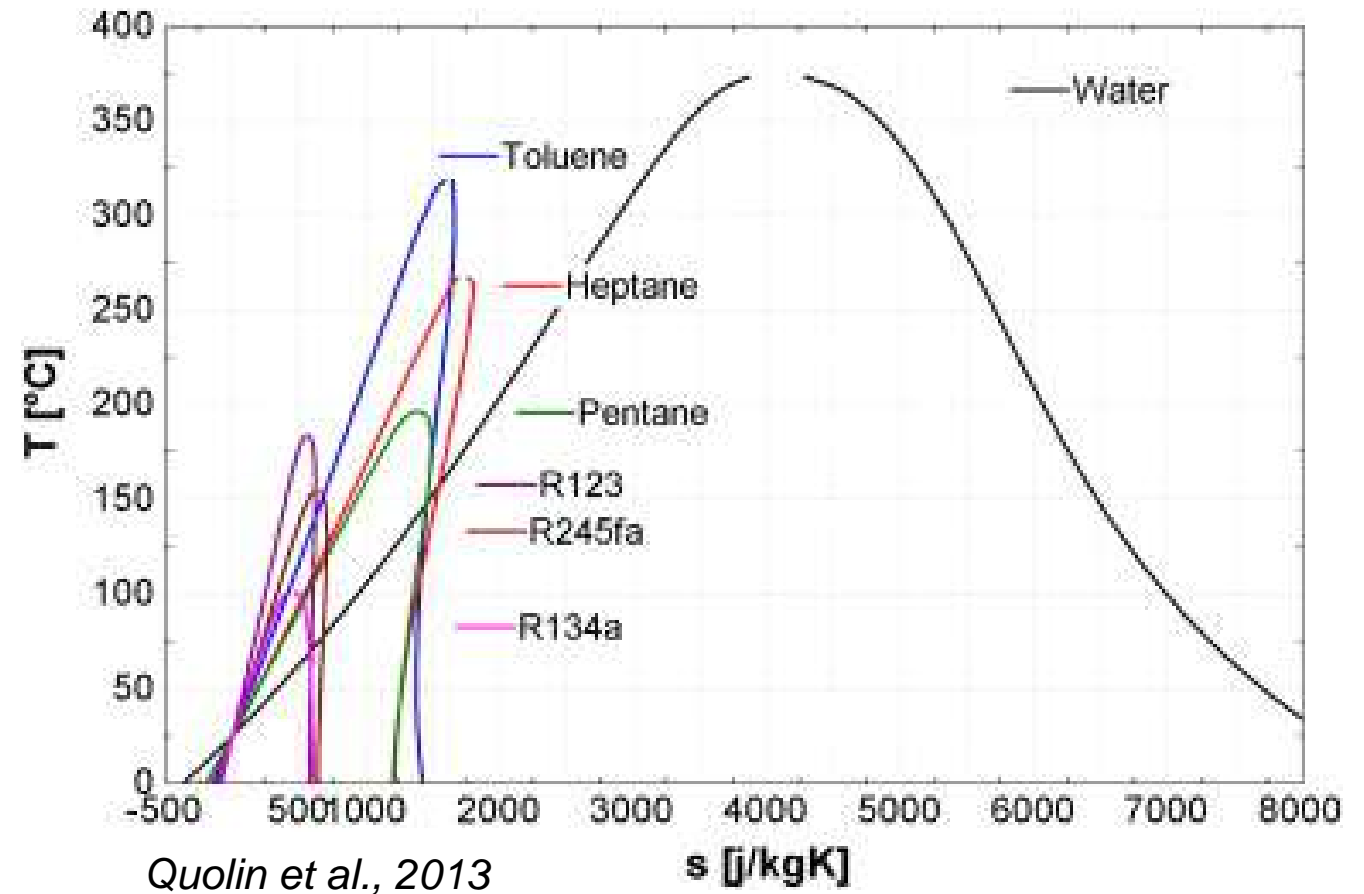
Research outcomes – Technology concepts

NZ manufactured ORC plant



Research outcomes – Heat exchanger ORC fluid

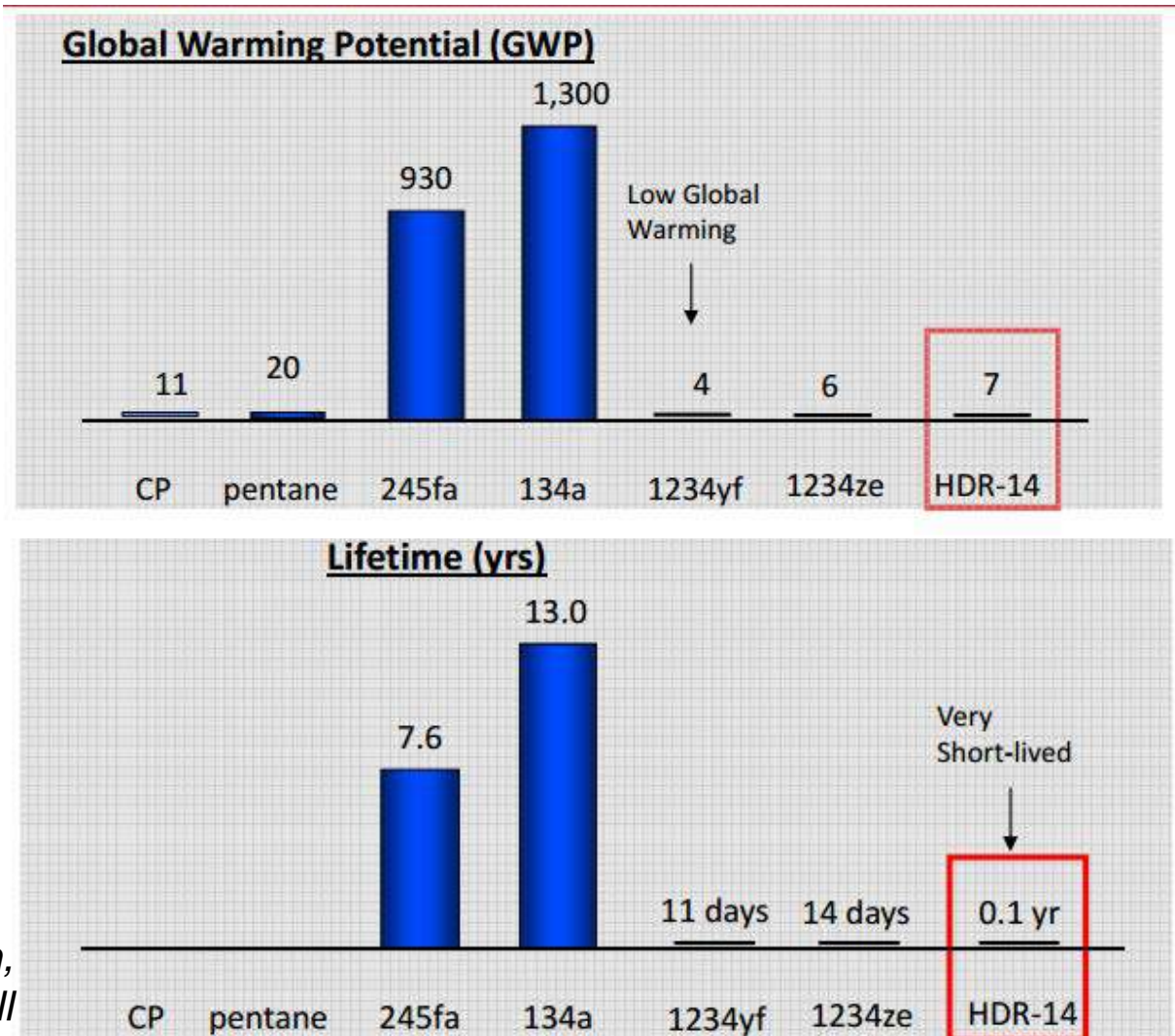
- R245fa
 - Not flammable, dry fluid
 - Reduced equipment costs
 - Average thermodynamic properties
 - GWP ~ 930-1030
 - Phasing out



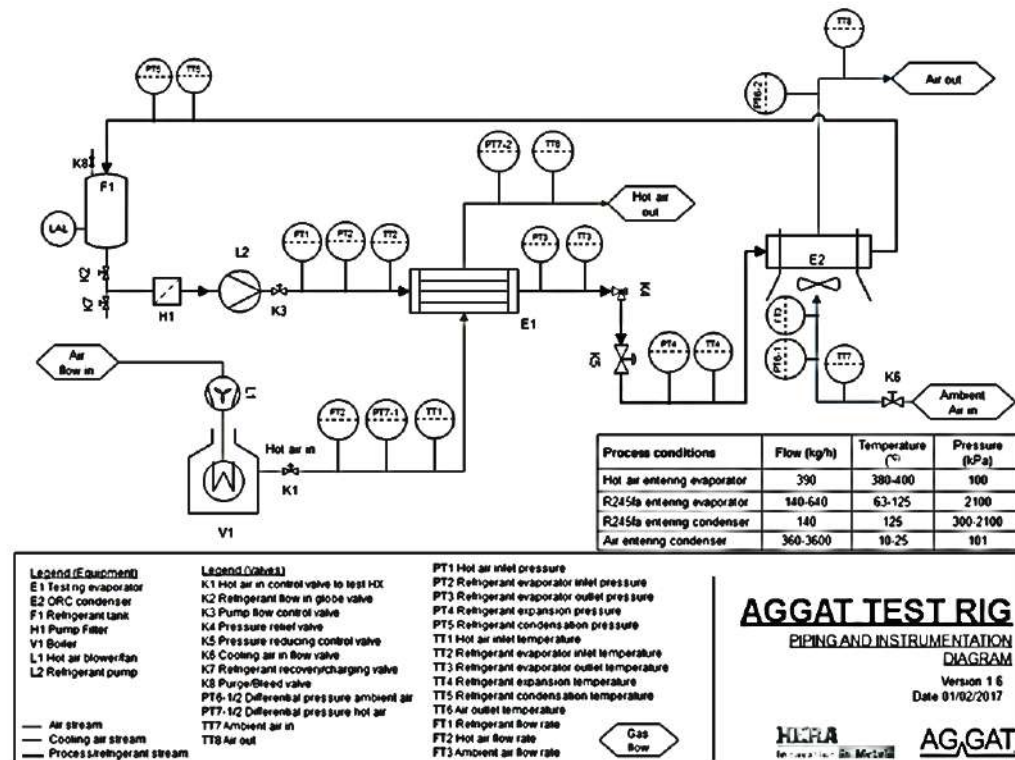
Research outcomes – Heat exchanger ORC fluid

- R245fa research
 - Temperature limits
 - Thermodynamic performance in expander vs. turbine
- New fluids research
 - HFO-1234ze
 - HDR-14

*Zyhoswki & Brown,
Honeywell*

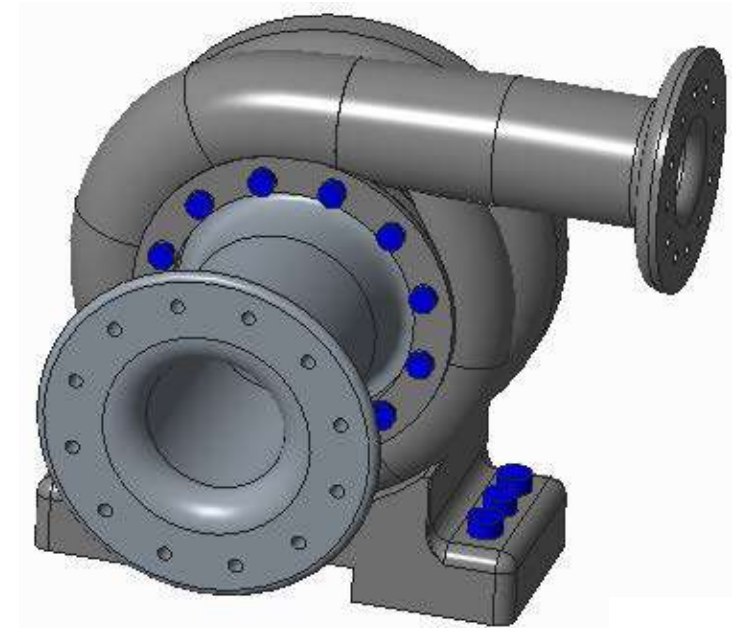
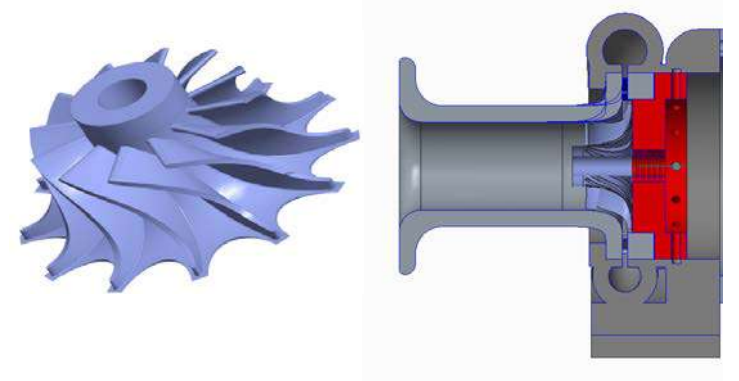
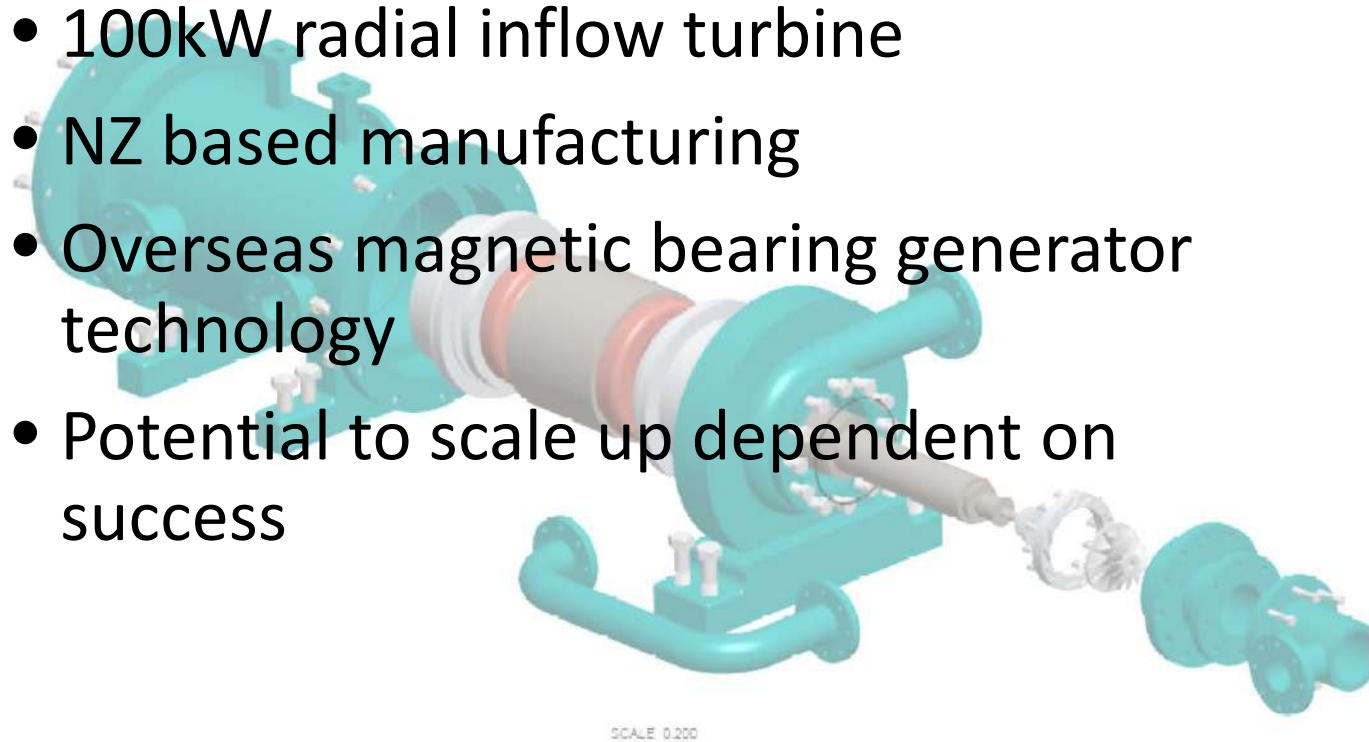


Research outcomes – AGGAT Heat Exchanger Test Rig

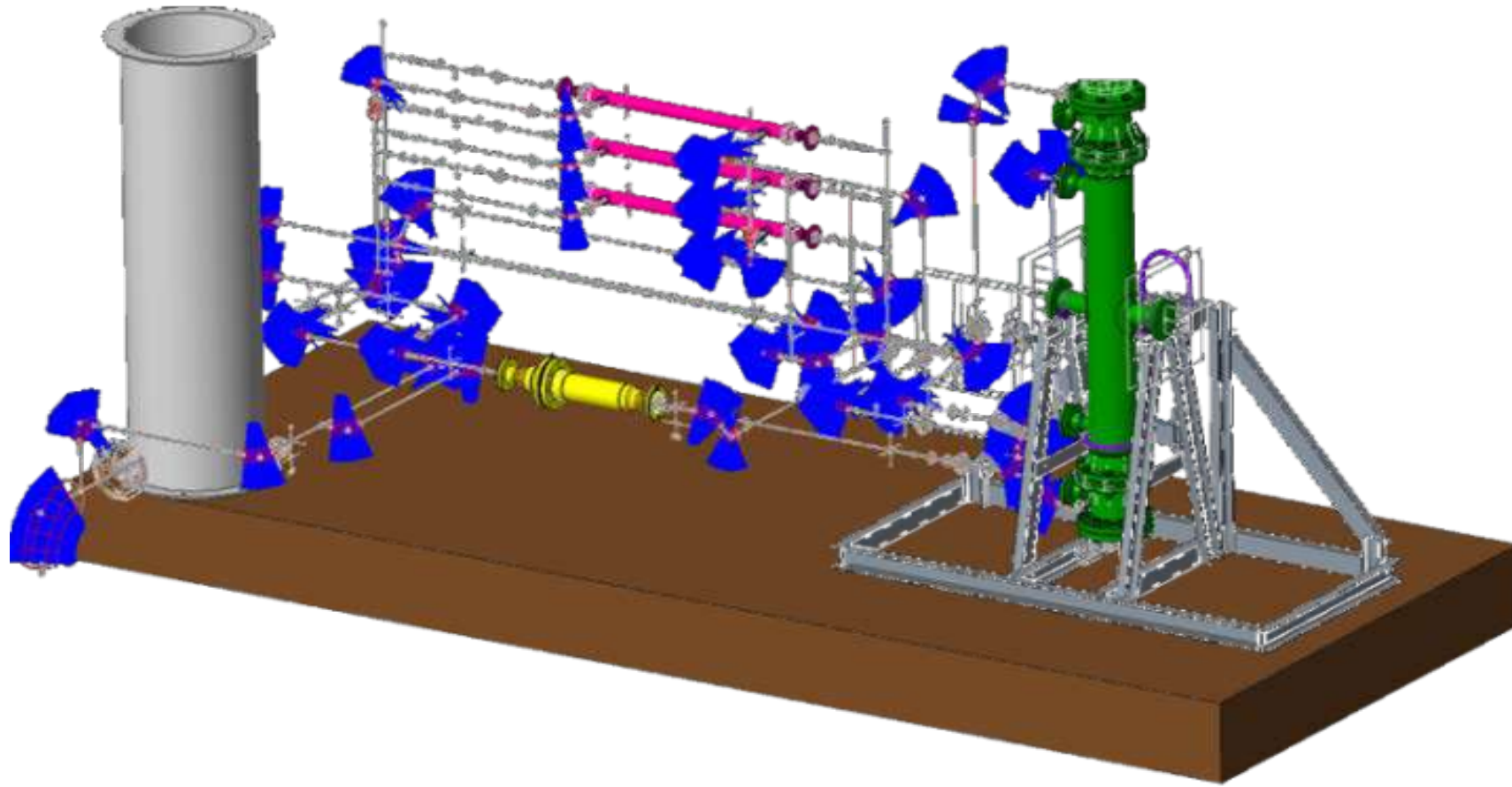


Research outcomes – NZ turbo-generator technology

- 100kW radial inflow turbine
- NZ based manufacturing
- Overseas magnetic bearing generator technology
- Potential to scale up dependent on success



Research outcomes - Materials test rig





Collaborations



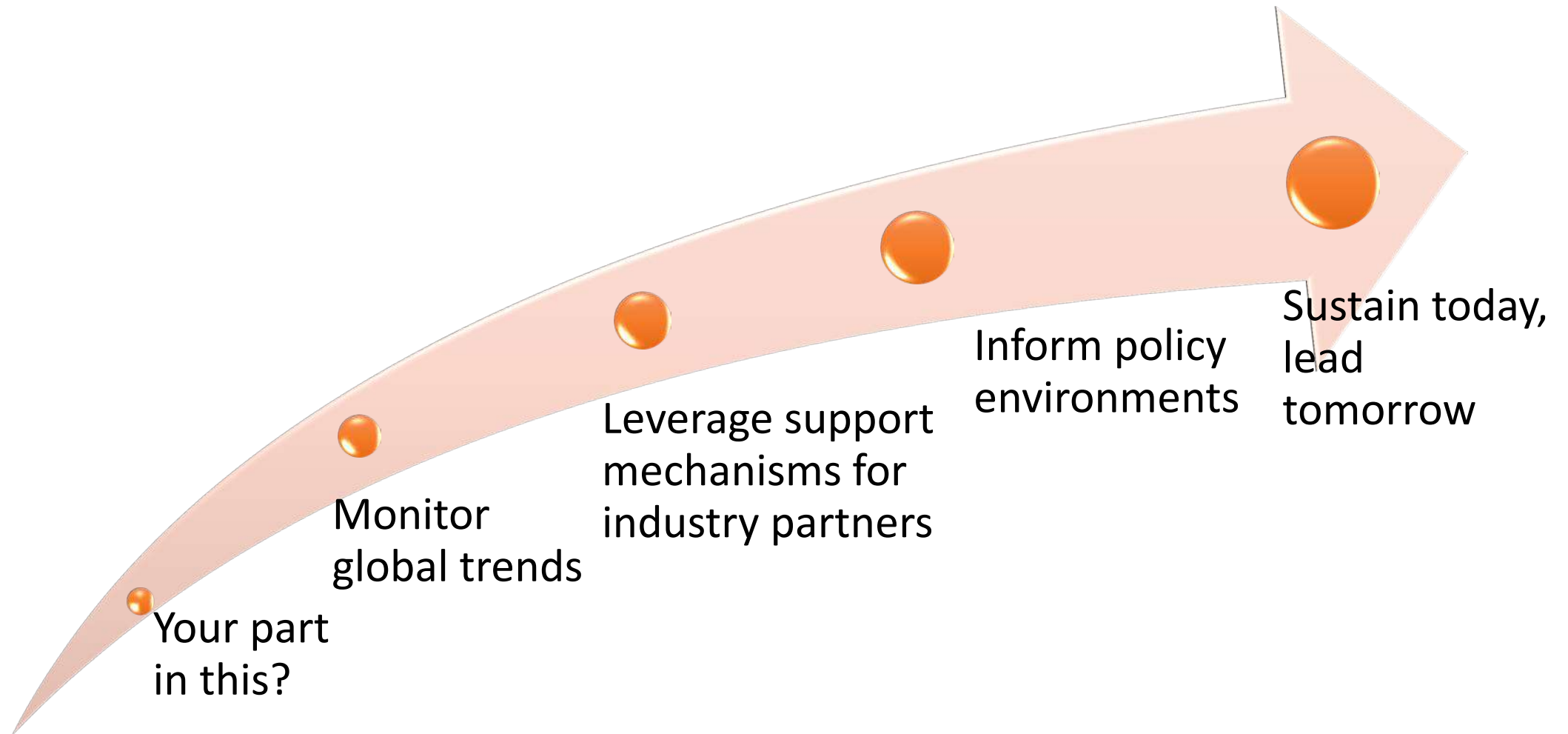
Now what?

Research partnerships

NZ manufacturing and research capability

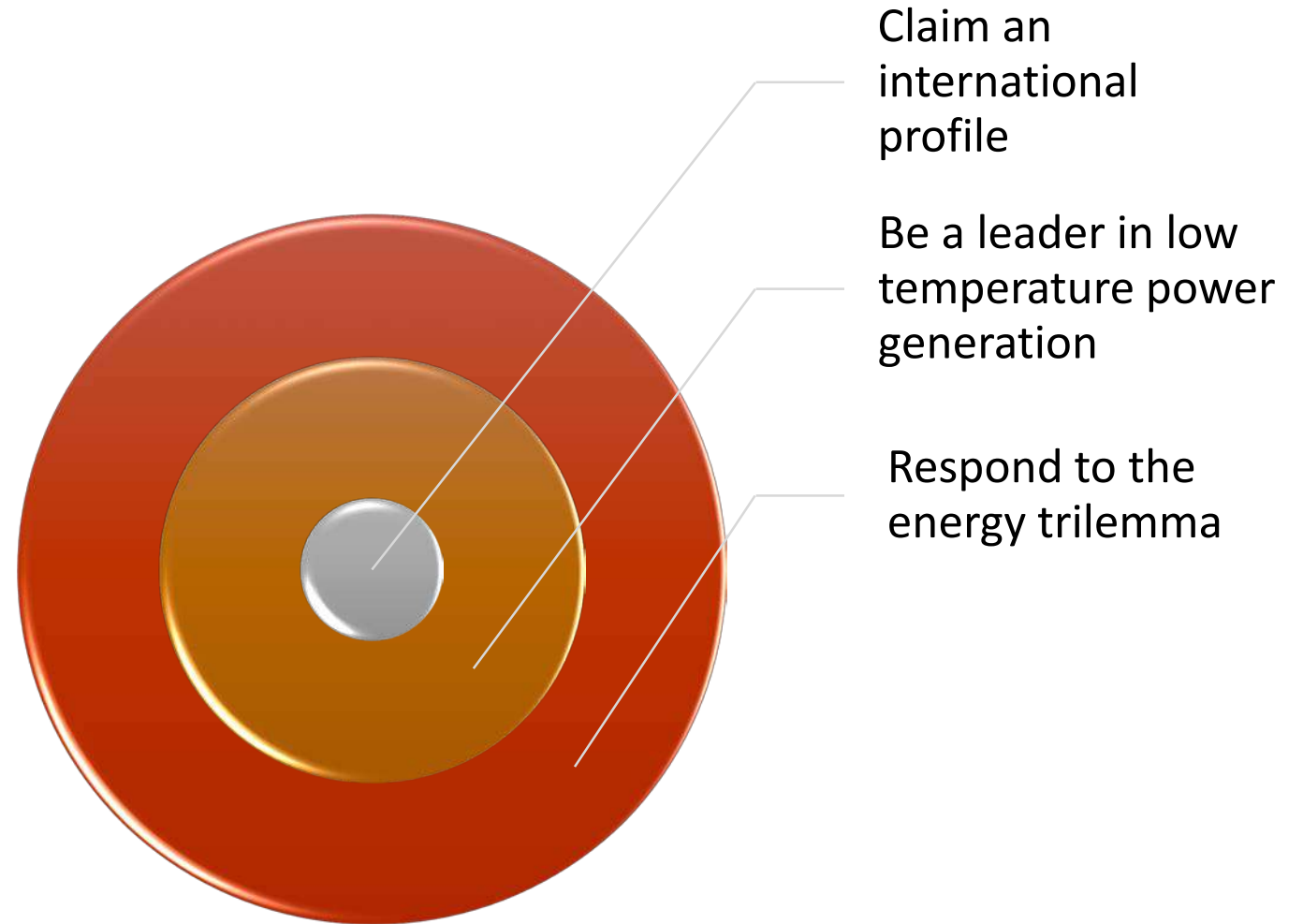
Realities of SME environment

Where to from here?



What's in it for the NZ geothermal sector?

The opportunity
The 'NZ Story'





Let's do this man!