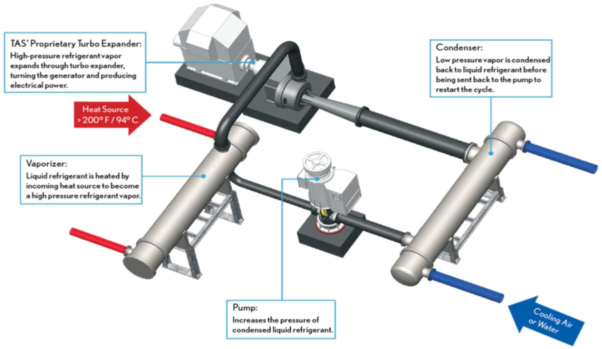
NRG worx

ADVANCED HEAT RECOVERY TECHNOLOGY

Neil Robinson



Introduction

- NRG WORX,
  - A newly formed group of industry specialists which brings together over 40 years of power plant development experience and capability
  - Our niche market is the provision of specialized technology to the power generation industry that will
    - Reduce Fossil Fuel Consumption
    - Reduce Emissions
    - Reduce Noise
    - Reduce Capital Expenditure
    - Reduce Operation and Maintenance Burdens
    - Improve Power Plant Efficiency
  - Solutions include
    - Project Development
    - IPP
    - BOOT
    - BOO
    - EPC
    - Technology Provision

Technology Brief

- The technology we are currently offering for your application has been available for several decades albeit, in a much smaller scale,

- The old technology primarily focused on low quality heat sources, such as cooling water circuits in diesel and gas engines, circa 3 to 500KW units,

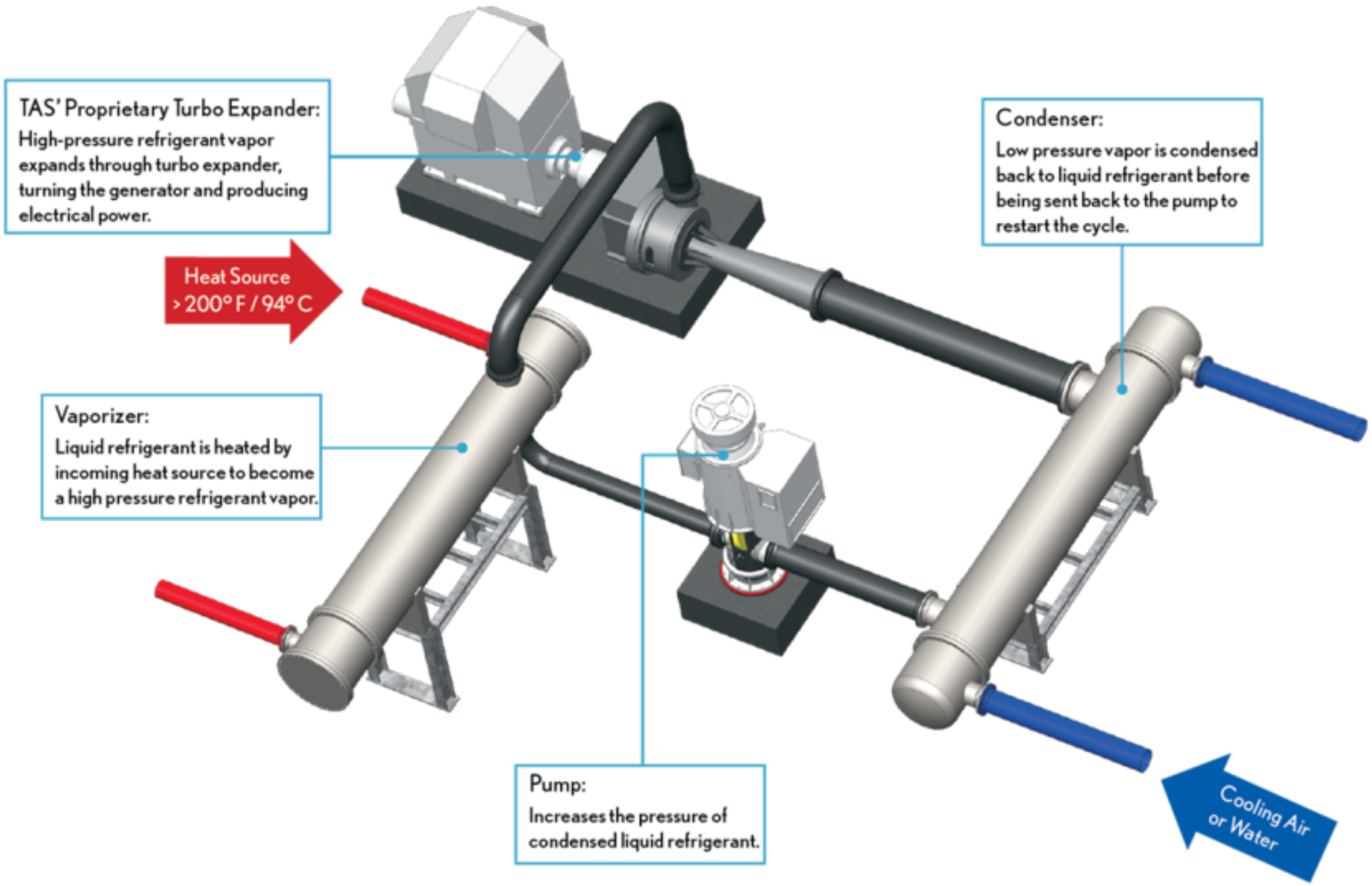
- However In recent times the traditional Organic Rankine Cycle (ORC) technology has undergone a significant ***step change***, and can now compete head to head with traditional Gas Turbine Combined Cycle Technology,

- This ***step change*** has delivered
    - Utility Size Solution modules up to 15MW
    - Improved Process Performance, (circa 51%)
    - Reduced Capital Costs,
    - Full Modularisation
    - Rapid Site Installation

ORC Process

- Overview
  - The technology uses an organic fluid, in this case Oil to absorb the waste heat exiting the Exhaust Stack of a Gas Turbine via a heat exchanger
  - The Oil is circulated from the exhaust heat exchanger to the skid mounted ORC unit, which via a second heat exchanger allows the heat to be transferred from the oil to a closed loop gas circuit, in this case a refrigerant which expands when heated.
  - The energy in the expanded gas is utilized via an expander to drive the generator, and produces electrical energy at 11KV
  - The energy depleted expanded gas is then circulated through a cooling loop, (air cooled condenser) and is delivered back to the skid mounted heat exchanger to begin the cycle again

ORC Module



TAS' Proprietary Turbo Expander:
High-pressure refrigerant vapor expands through turbo expander, turning the generator and producing electrical power.
Condenser:
Low pressure vapor is condensed back to liquid refrigerant before being sent back to the pump to restart the cycle.
Heat Source
›200° F / 94° C
Vaporizer:
Liquid refrigerant is heated by incoming heat source to become a high pressure refrigerant vapor.
Pump:
Increases the pressure of condensed liquid refrigerant.
Cooling Air
or Water

CCGT v ORC Comparison

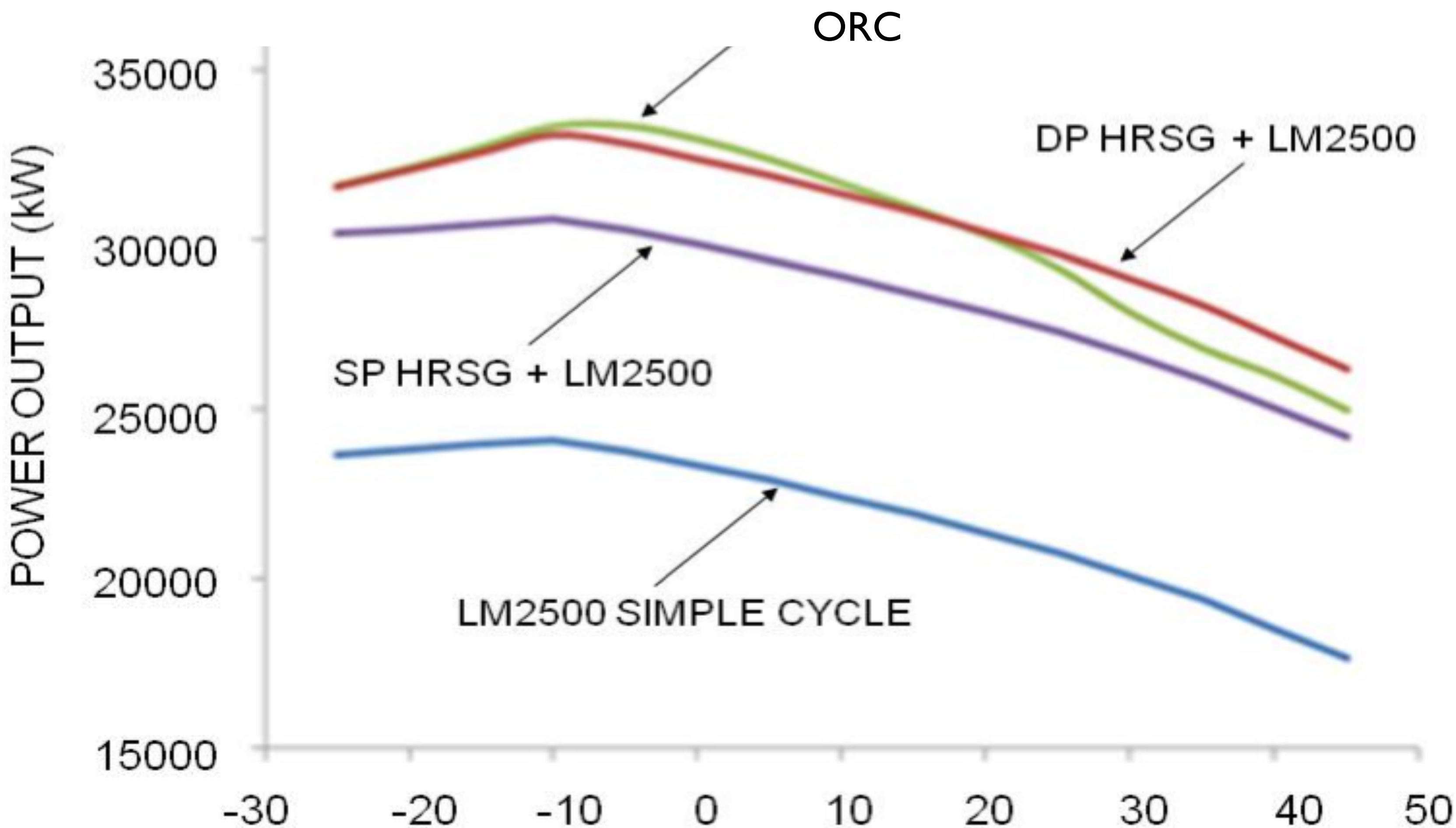
NRGworX

- Conventional CCGT v Heat To Energy Technology (ORC)
  (Based on a 120MW CCGT 2-2-1 configuration)

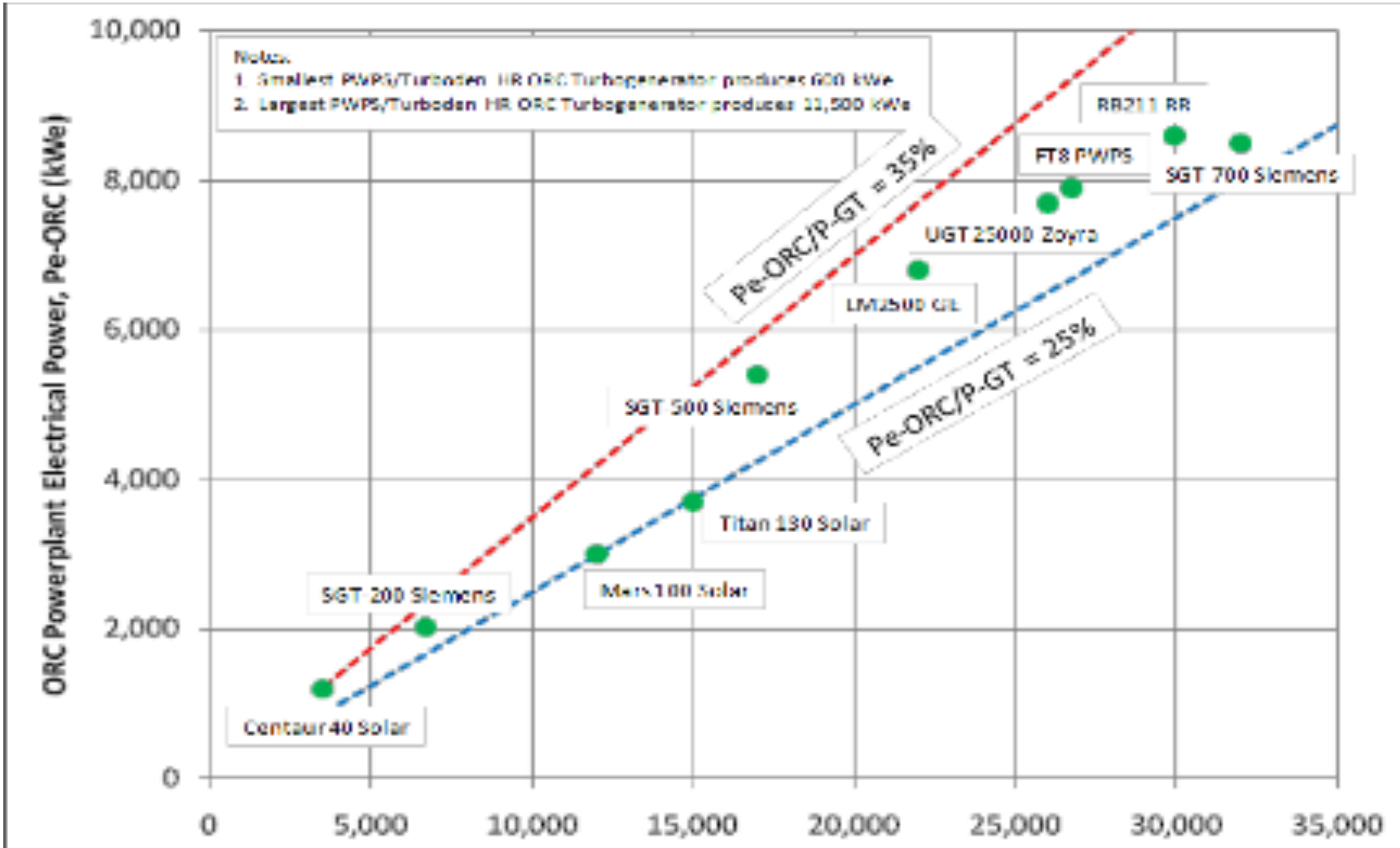
	CCGT	ORC
Capex	100%	90%
Installation Time	26 Months	16 Months
Consumes Water	Yes	***No***
Efficiency (LM6000PD)	51%	51%
Operations Resources	18 (3 shift systems, 6 men per shift)	***0(Unmanned)***
Maintenance Cycles	8760	hrs
50 to 70,000 hrs		

NOTE COMPLETELY UNMANNED COMBINED CYCLE POWER PLANT, OPERATED AND DESPATCHED REMOTELY

Performance Review



ORC Recovery Model



Typical Performance

		LM6000	Frame 6B	FT8-3
Resource inlet temp	℃	480	477	420
Expected outlet temp	℃	149	137	135
Resource Flow	kg/s	136.4	143	108
Capacity factor	%	90%	90%	90%
Condensers		Air-cooled	Air-cooled	Air-cooled
Heat capacity	**MW_{net}**	**10.5**	**11.5**	**11.3**

Operational Features

- UNMANNED OPERATION
  - Simple start stop procedures
  - Automatic and continuous operation
  - Partial load operation down to 10% of nominal power
  - Partial load conditions are obtained by modulating a 3 way valve to enable the ORC to automatically respond to external load variations
  - High efficiency even at 50% of nominal load, (electrical efficiency is circa 90% of nominal electrical efficiency)
  - No operator Attendance needed, due to the absence of a high pressure vapor generator (HRSG)
  - Quiet operation
  - High Availability circa 98%
  - Low Maintenance requirements, circa 3 – 5 hrs per week
  - Long Life, more than 20 years

Technical Features

- Low Complexity
  - Low RPM, i.e. no reduction gears needed for the generator
  - No raw water treatment plant needed
  - No demineralized water treatment plant needed
  - No Chemical dosing plant
  - No working fluid superheating
  - No high pressure steam generator
  - No corrosion issues
  - Added thermal Stability
  - Simpler control system architecture
  - Three simple blocks construction
    - Heat Exchanger
    - ORC unit
    - Air cooled condenser

Commercial Overview

Levelised Cost of Energy (LCOE) = $150/MWhr (Gas $10/GJ)

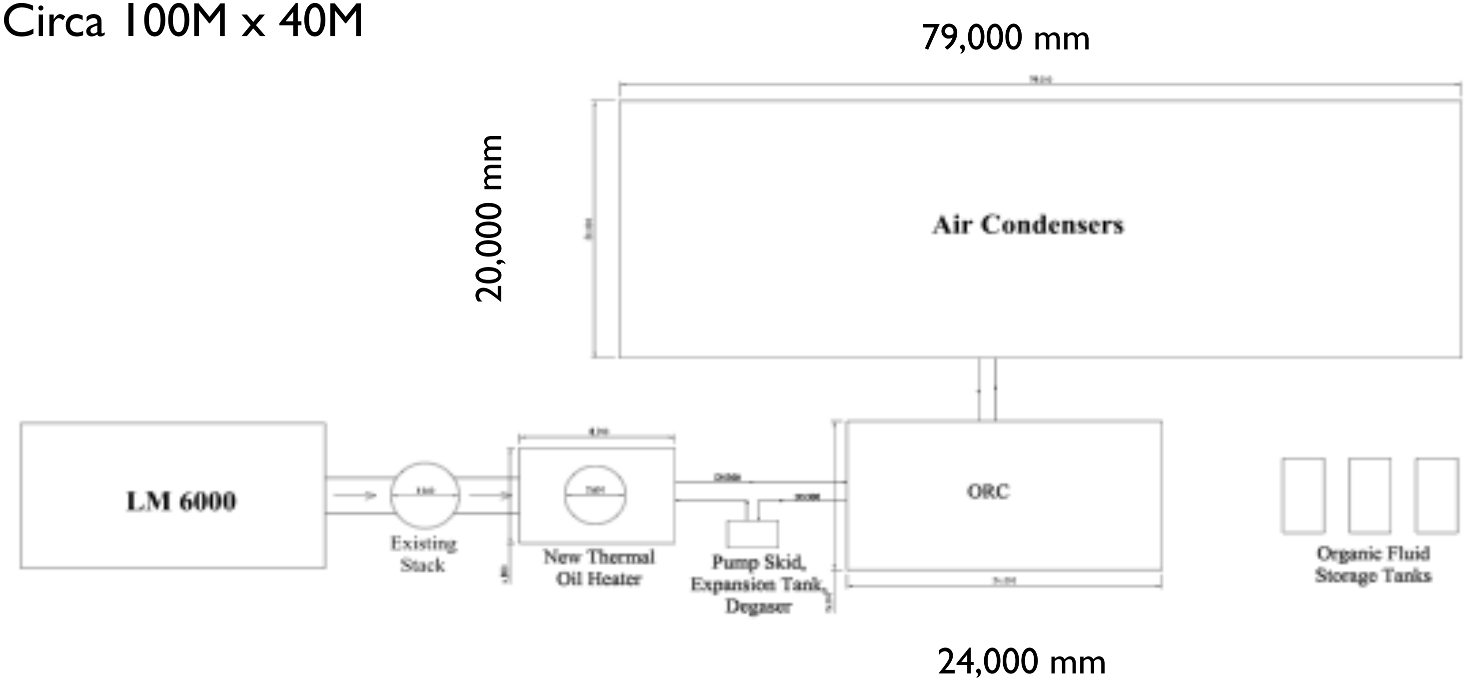
- *LCOE =(b*c) / (P*H) + f/h + OM/H + m *OM (n,b)*
  - *Where*
    - » *b = Levelised carrying charge factor of cost of money*
    - » *c= Total plant cost*
    - » *H = Annual operating hours*
    - » *P = Net rated output (kw)*
    - » *F = Levelised cost of fuel ($/kwh)*
    - » *H = Net Rated efficiency of the plant (LHV)*
    - » *OM = Fixed O&M costs for base load operation ($/kwhr)*
    - » *(n,b) = Variable O&M costs for base load operation, ($/kwhr)*
    - » *M = Maintenance cost escalation factor*

Annual Fuel saving circa $7.25M

- Basis of Comparison
  - 2 LM6000PD
  - Gas Fuel @ $10/GJ
  - Location North West of WA
  - Base Load Operation

Typical Site Layout

Overall Space Required,
Circa 100M x 40M



Modular Design

- Designed for easy transport
- Simple install and assembly
- Phased Capital Spending Matched to Resource Availability

Typical Heat Exchanger