

ORegen™ Waste Heat Recovery: Development and Applications

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ORegen™

ORegen™ is GE Organic Rankine Cycle
System designed to recover waste heat energy from GT
or similar waste heat sources water & CO₂ free
Developed for power gen & mechanical drive application

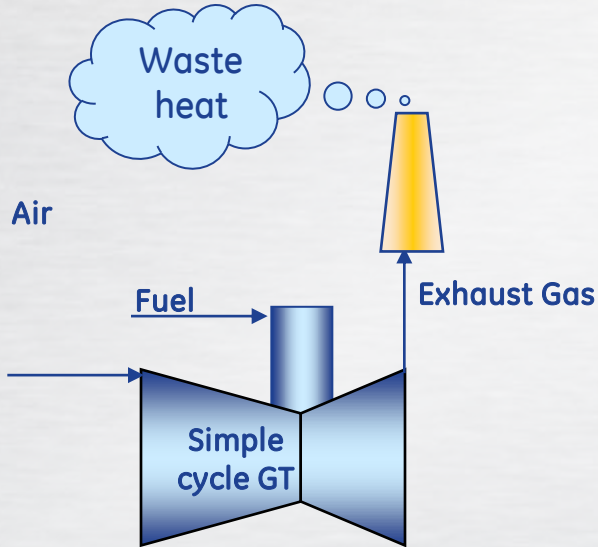


References

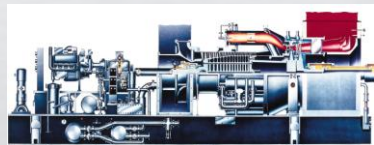
- #1 17MW system sold in Canada on a pipeline station – delivered in December 2012
– COD Fall 2013
- #3 17MW systems sold in China on 3 pipeline stations - delivery in March 2015 –
COD August 2015
- #1 17MW system sold in Brunei on a powergen station – delivery in December 2014
– COD June 2015
- #1 17MW system sold in Thailand on a pipeline station – delivery in February 2015 –
COD Summer 2015

Why waste heat recovery?

GT simple cycle efficiency: 25÷40%
O&G GT mainly in simple cycle
Global trends: CO₂ emission reduction
Increase efficiency
Increase in power demand



Gas Turbine



ORegen™



Up to 17MW of power recovery

Waste heat

- Electricity production ... sell back to grid
- Help comply with CO₂-related regulations
- Increase plant efficiency

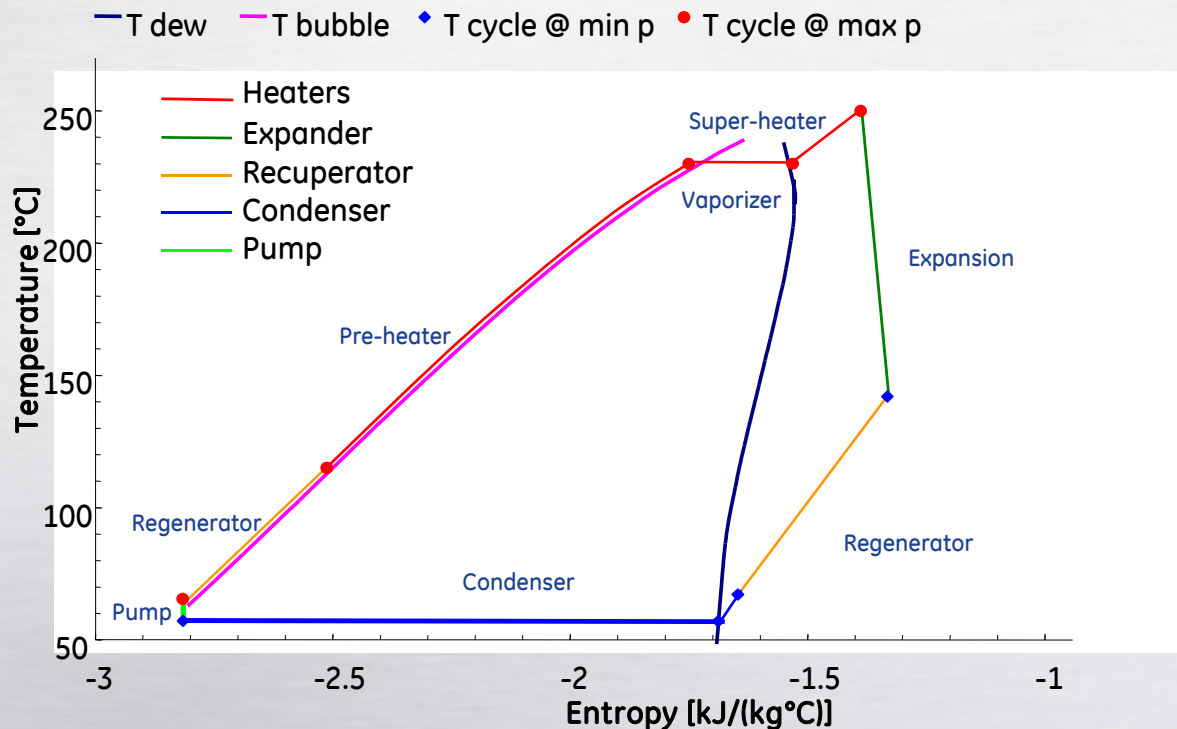
77% of Oil and Gas installed Gas Turbines are in simple cycle

The ORC concept

The Organic Rankine Cycle is a thermodynamic cycle based on the Rankine classic cycle using an organic working fluid

GE selected cyclo-pentane as working fluid

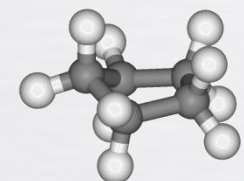
ORC cycle T-S diagram



Working fluid selection by GRC Munich

Cyclo-pentane main characteristic

- Boiling point: 121°F (49.3°C)
- Freezing point: -137°F (-94 °C)
- Molecular Weight: 70.1
- Appearance: clear, colorless liquid
- No corrosion issue on plant equipment

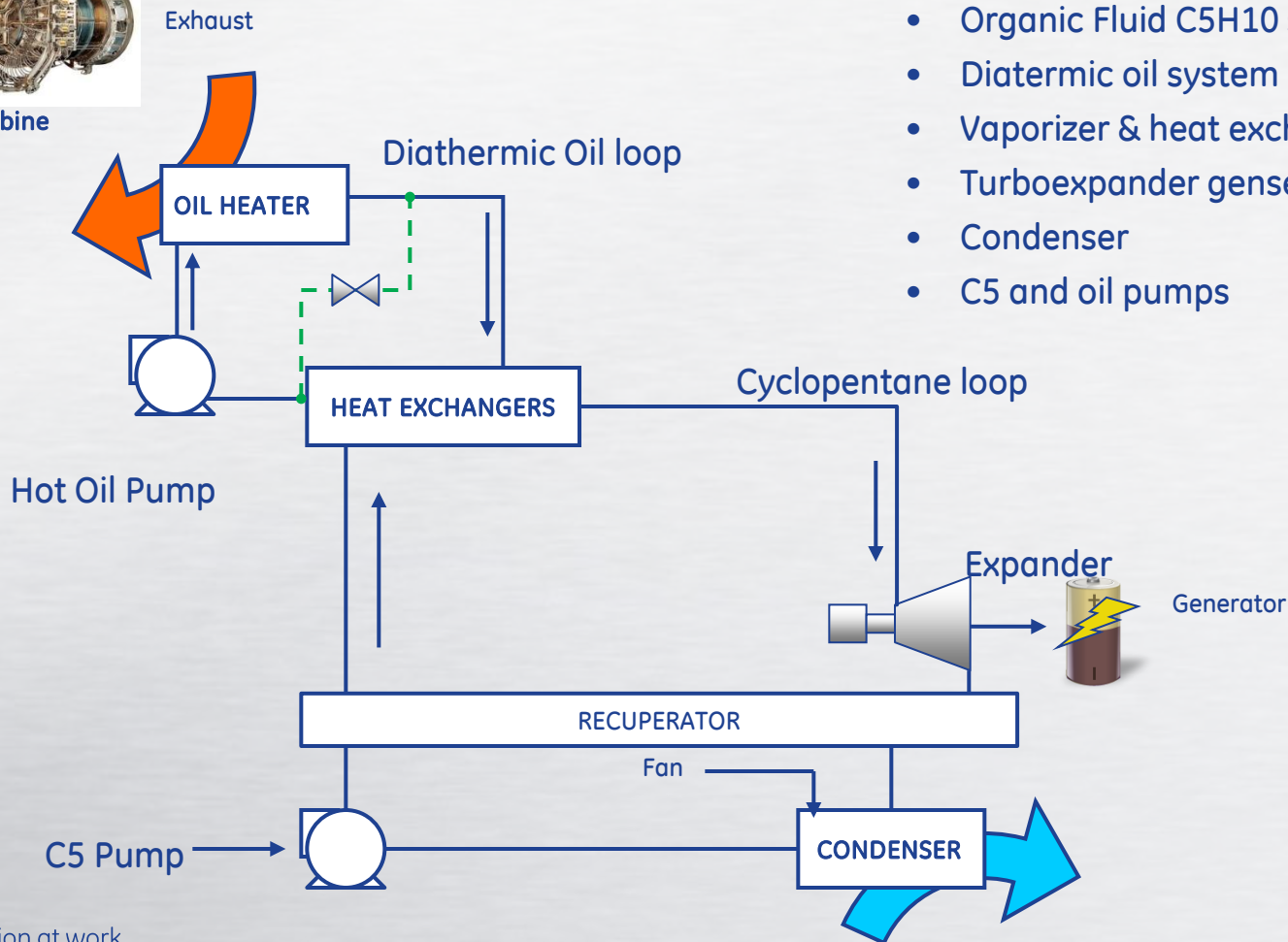


ORegen™ plant schematic & scope of supply

PGT25+ case study ... overall plant efficiency up to 51%



Gas Turbine



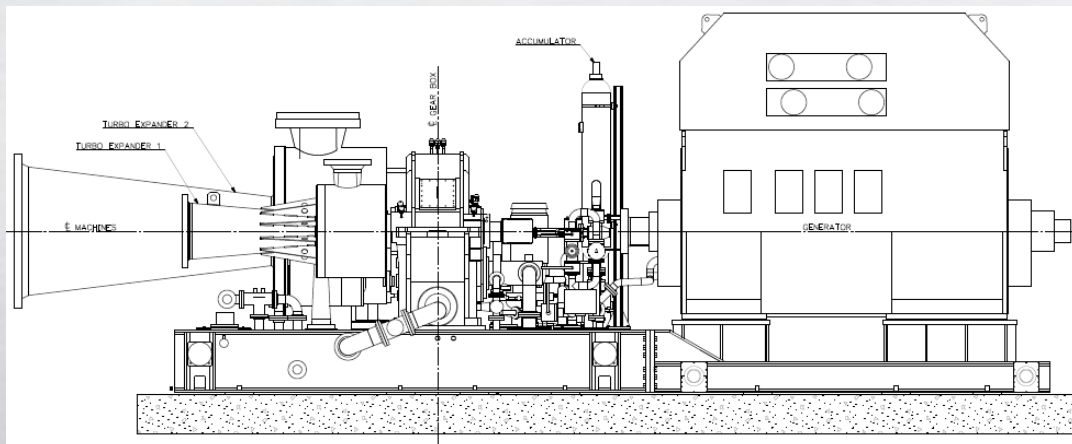
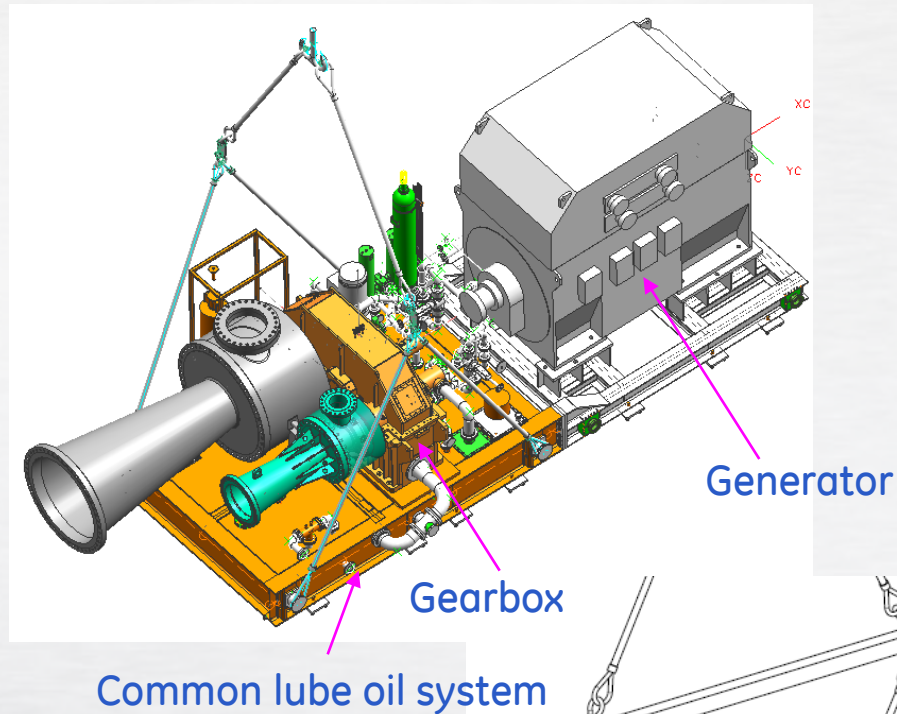
The basic scope of supply for a typical conversion includes the following:

- Organic Fluid C5H10 system
- Diathermic oil system
- Vaporizer & heat exchangers
- Turboexpander genset
- Condenser
- C5 and oil pumps

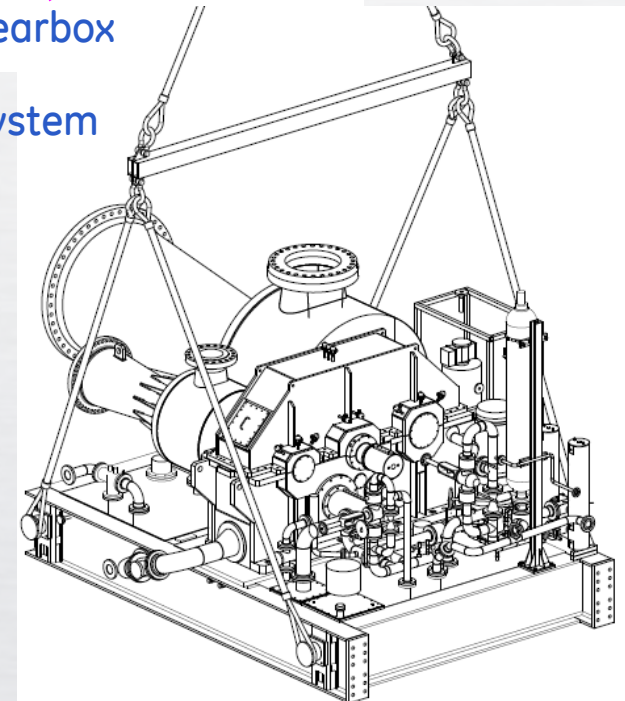


TE Generator Arrangement (17MW)

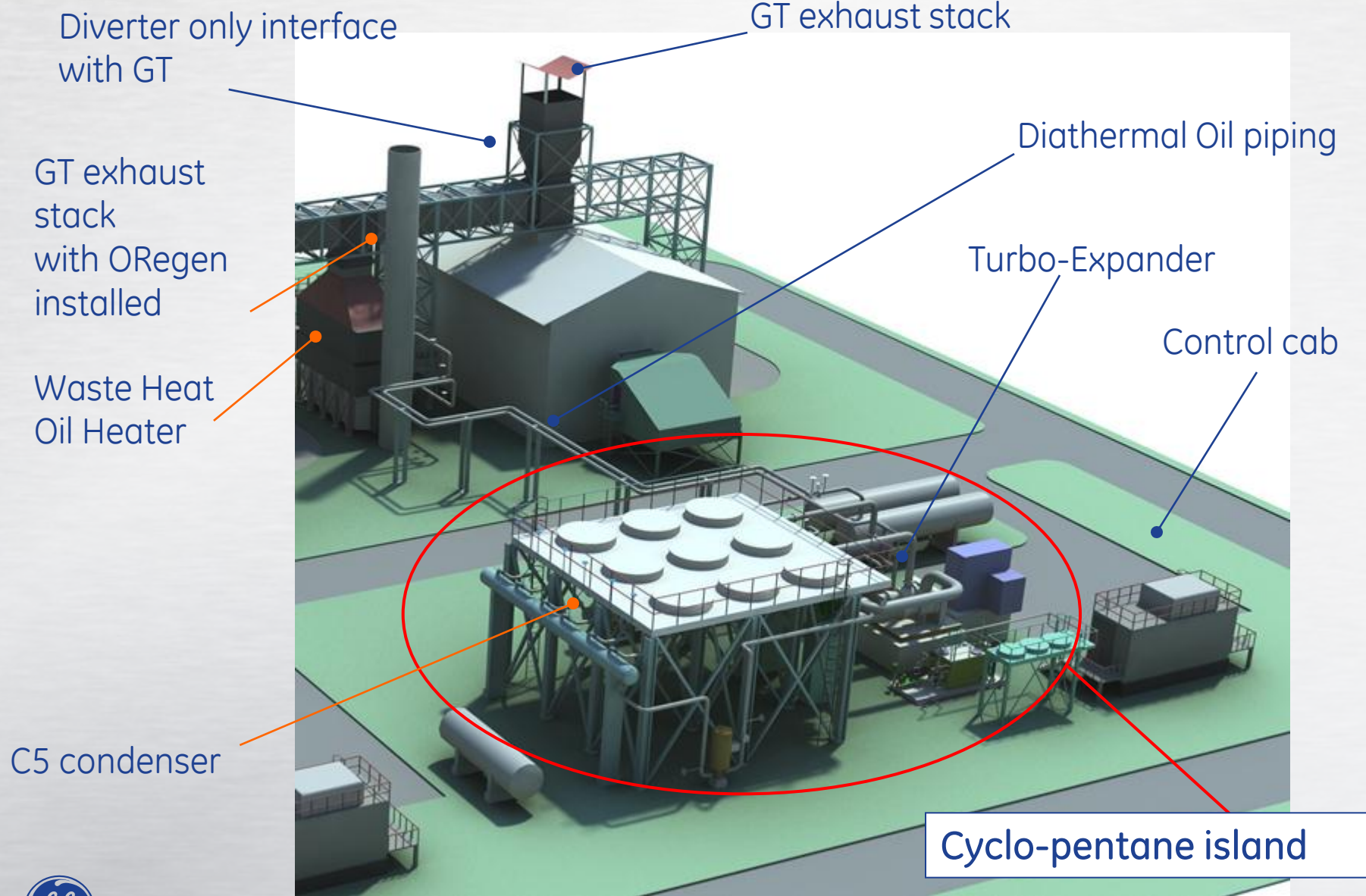
- Scalable Size from 5MW to 17MW
- Outdoor installation w/ thermo-acoustic insulation
- Two separate Basements:
 - Ease of transportation
 - Reduced Installation cost
- Equipped with DGS & IGV on both stages



LxWxH:~ 13x4x5.5m



ORegen™ Typical Layout

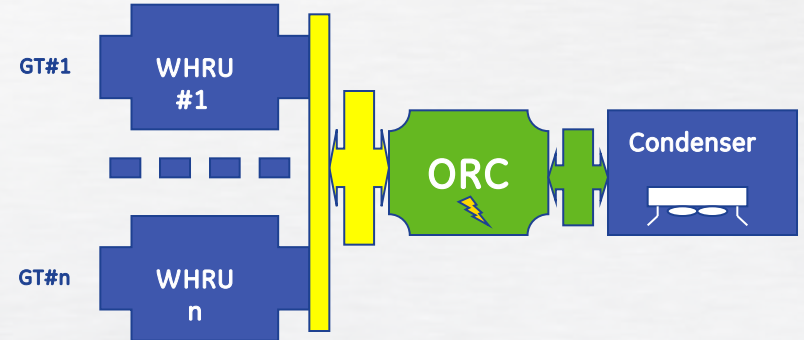


ORegen™ configurations

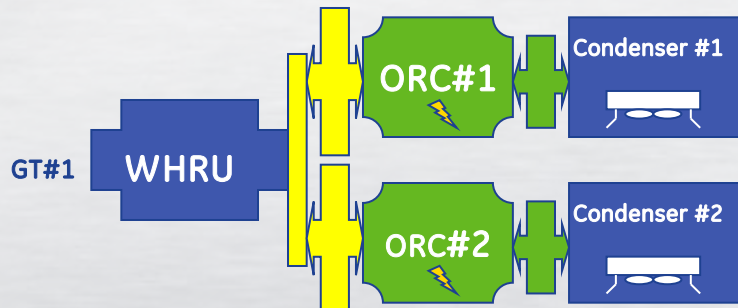
Direct



Parallel Oil



Multi cycles



Parallel Gas



 To be defined as typical arrangement

 To be scaled up / down from a standard design.

 To be selected case by case. depending from the site conditions and project requirements

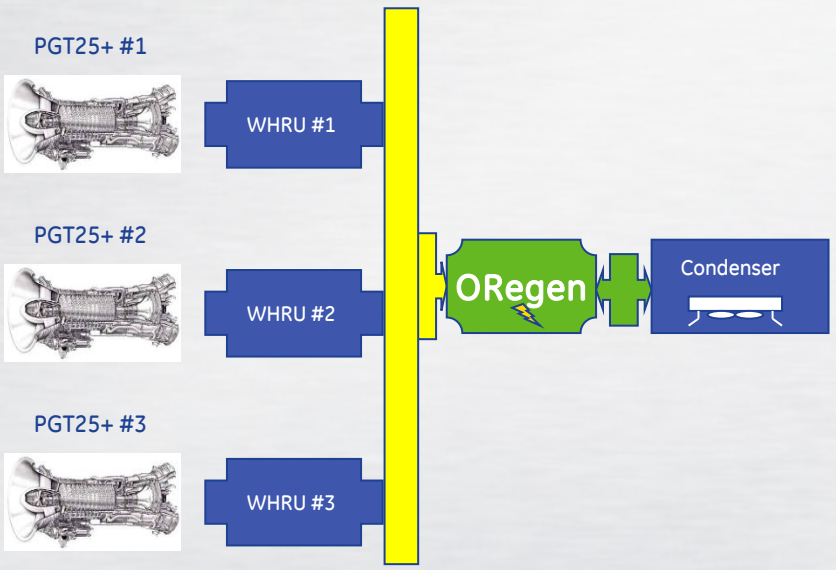
ORegen™ output

GT Model	GT Power (KW)	Exhaust Flow (Kg/sec)	Exhaust Temp (°C)	GT Efficiency (%)	ORC Output (MWe)	System Efficiency (%)
PGT25 (*)	23 261	68.9	525	37.7%	6.9	48.9%
PGT25+ (*)	31 364	84.3	500	41.1%	7.9	51.5%
PGT25+ G4 (*)	33 973	89.0	510	41.1%	8.6	51.5%
MS5001 (*)	26 830	125.2	483	28.4%	11.3	40.4%
MS5002B (*)	26 100	121.6	491	28.8%	10.8	40.7%
MS5002C (*)	28 340	124.3	517	28.8%	12.4	41.4%
MS5002D (*)	32 580	141.4	509	29.4%	13.8	41.9%
MS5002E (*)	32 000	101.0	510	36.2%	9.8	47.2%
MS6001B (*)	43 530	145.0	544	33.3%	15.6	45.2%
MS7001E (*)	87 300	302.0	535	33.1%	31.1	44.9%
LM6000 (**)	43 397	125.6	454	41.7%	9.7	51.1%
LMS100 (**)	100 700	216.8	423	43.8%	15.7	50.8%



Case study ORegen™ benefits

First system sold in Canada in a pipeline application



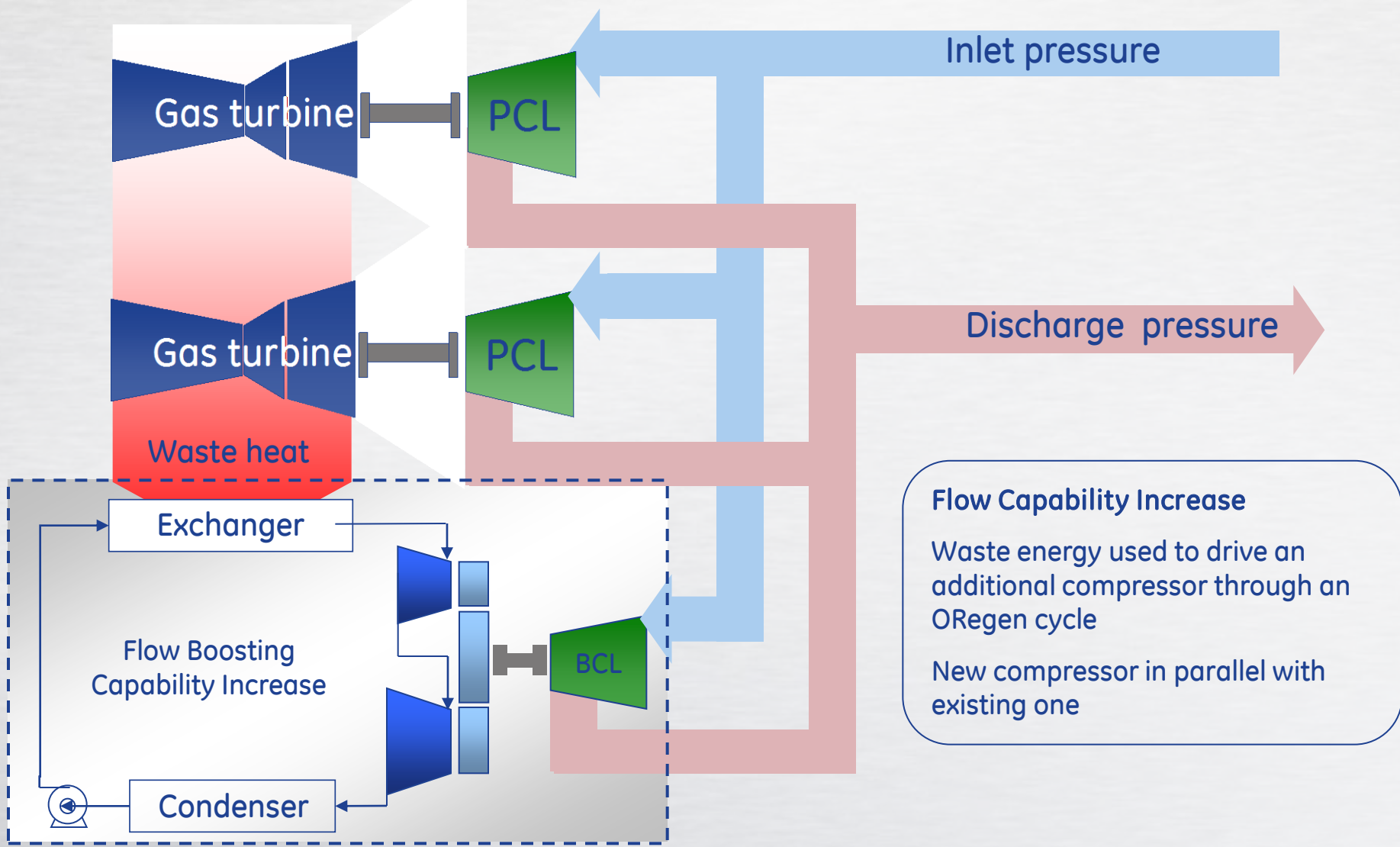
3 GT connected to #1 ORegen
2 units running – 1 stand by

Net Output Power ~14 MW
Produced Power ~119,000 MWhr/y
Equivalent to ~1,100,000 MM BTU/y

Equivalent to ~38,000 ton/y CO₂ cut

14 MW Recovered power / +9 efficiency points

ORegen™ for Mechanical Drive application

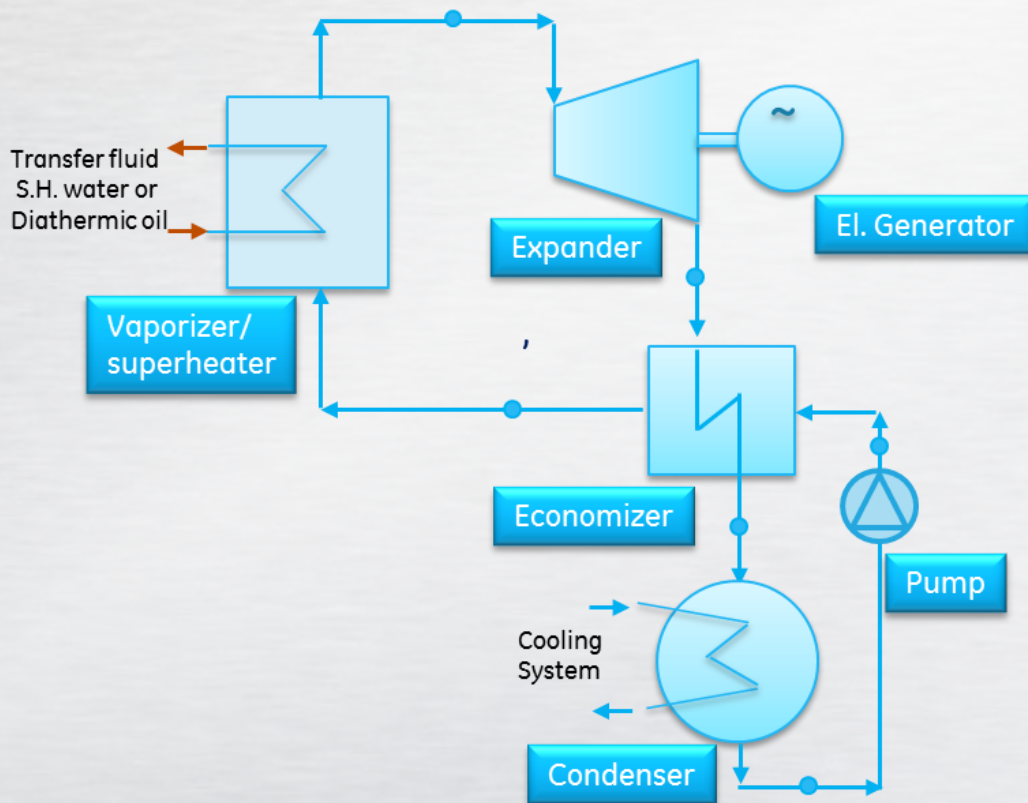


Increase NG flow capability using GT waste heat



GE imagination at work

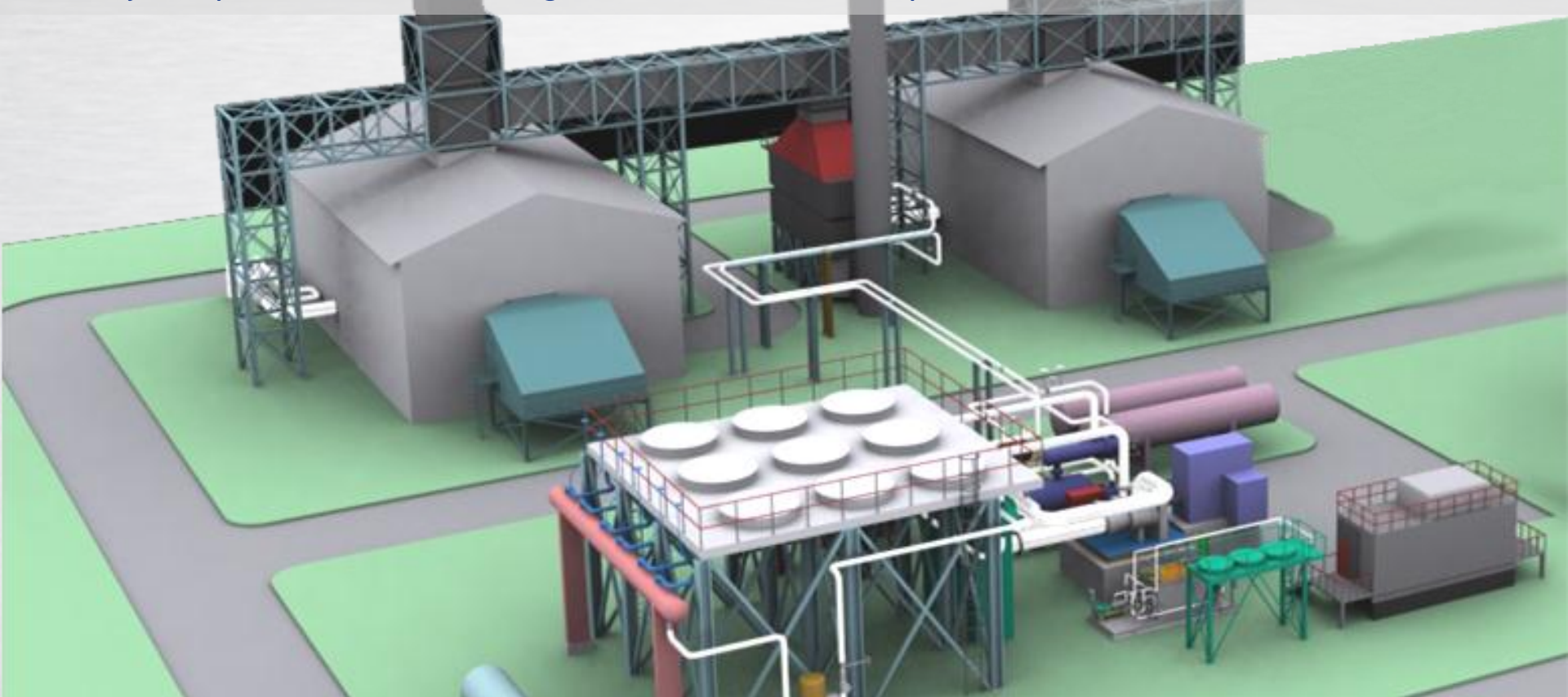
Mini ORC 2 MW size



- Modular approach 2 MW size
- Minimum waste heat temp 220°C
- Applicable to small to medium size waste heat sources
- Different working fluid
- Different cycle parameters
- Optimized solution for small gas turbines and low grade waste heat sources

Alternative solution to ORegen from 0.5÷2 MW size

- Efficiency improvement $\uparrow 20\%$... CO₂ footprint $\downarrow 20\%$
- Carbon credits ... singular enabler
- Cyclo-pentane as working fluid in a closed loop ... no water!



ORegen™

Produce up to 17MW electric power with no additional fuel by recovering heat from GT exhaust