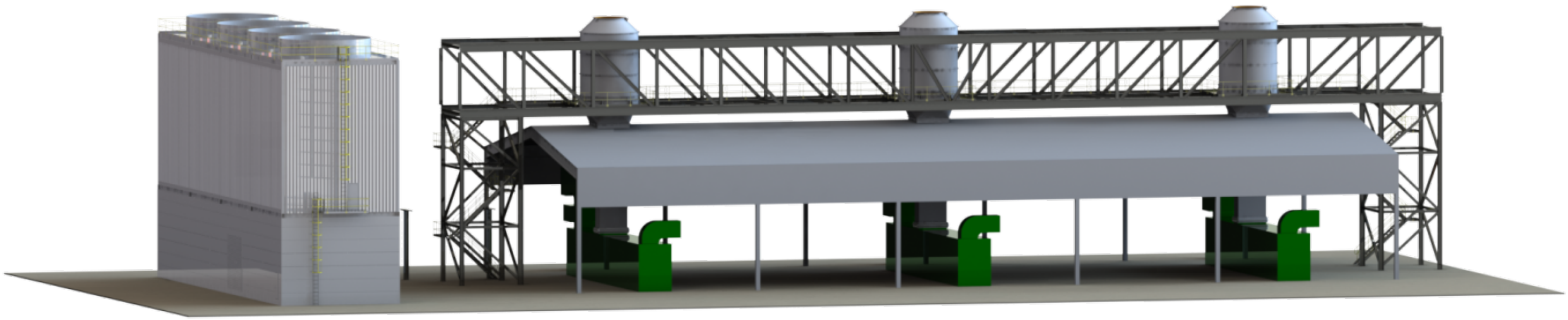
Examining Applications Of Offshore Technology To Onshore Gas Compressor Stations For The Profitable Generation Of CO2-Free Power

HEAT RECOVERY SOLUTIONS

Innovative Clean Energy Equipment

HRS

PROFITABLE, CO_2 FREE, POWER GENERATION BASED ON OFFSHORE TECHNOLOGY



BUSINESS INTRODUCTION

- **Provider of innovative energy recovery solutions to the Oil, Gas and Power Industries worldwide, specialising in Gas Turbine Heat Recovery and Clean Energy**

- **Head office is in London, with a regional office in Houston and Mexico City**

- **Our people have been responsible for engineering and supplying over 250 WHRU's, Fired Heaters, Waste Heat Boilers and Power Modules over the past 30 years, mostly for offshore applications**

- **Our business is built on a wealth of experience, new technology development and total customer commitment and support**

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HOW OFFSHORE TECHNOLOGY CAN BE SUCCESSFULLY APPLIED TO ONSHORE GAS COMPRESSOR STATIONS FOR THE PROFITABLE GENERATION OF CO2-FREE POWER:

- OVERVIEW OF THE ENABLING TECHNOLOGY
- HOW THE TECHNOLOGY CAN BE APPLIED TO ONSHORE COMPRESSOR STATIONS TO ACHIEVE LOW COST, EMISSIONS FREE POWER
- THE EXTENT TO WHICH ONSHORE COMPRESSOR STATIONS CONTRIBUTE TO ACHIEVING THE US GOVERNMENT's TARGET ON CO_2 REDUCTIONS
- EVALUATING THE PROFITABILITY OF ONSHORE APPLICATIONS
- CONCLUSIONS

INTRODUCTION

- Oil and Gas Platforms need power and heat, to extract and process hydrocarbons

- On early platforms, power was produced by gas turbines and heat produced by fired heaters

- In the 80's gas turbine waste heat recovery units (WHRU's) replaced fired heaters on Tyra West and East Platforms in the North Sea and since then WHRU's are standard practice

- Benefits of using waste heat is fuel saving, reduced emissions and improved safety

INTRODUCTION (cont)

- **On many platforms, particularly those producing gas, there is a limited requirement for heat, exception being amine units for gas sweetening**
- **In 1999 the Norwegian Government introduced a carbon tax which encouraged developers to consider higher efficiency from their turbines and 3 platforms were built with combined cycle**
- **On Conoco Phillips Eldfisk platform HRS supplied circular HRSG's which produce 10MWe from a steam turbine. The main feature of the design is small footprint and low weight**
- **The technology developed by HRS for offshore has a number of features which could be of benefit onshore - modular approach, small footprint, standardisation, fast build and lower cost**

INTRODUCTION (cont)

- The intent of this presentation is to provide awareness to onshore developers that there may be a different approach, especially on gas compressor stations in the U.S. of which there are more than 1,200 providing a vast source of CO_2 free power that cannot, under traditional methods, be recovered economically

- The methodology developed for HRSG's offshore has also been used to develop a steam turbine power module to complete the steam cycle and make it a simple and cost effective package

REVIEW OF THE ENABLING TECHNOLOGY

WHY IT WAS DEVELOPED

- To save cost offshore topside weight and size has to be minimised
- Early gas turbine waste heat recovery units (WHRU's) were designed to API 560
- Exhaust gas bypass dampers required for start up and to control the amount of heat recovered
- Silencer required between the gas turbine and the WHRU
- Result was a set of casings, ducts, dampers and stacks that had to be assembled on the platform with large structures to support them.

REVIEW OF THE ENABLING TECHNOLOGY

WHY IT WAS DEVELOPED (cont)

•Late 80’s improvements made to make WHRU’s more compact with the introduction of the integral bypass - the dampers, bypass and heat exchanger made as one assembly - silencer and stacks still supplied separately

•WHRU’s still designed to API 560, but only applies to the heat exchanger and method of support ie tubesheets. Internal refractories were changed to ceramic fibre with stainless steel shroud to protect the fibres from erosion

•However continuing demand for reduced weight, plot space and shipyard assembly time required a complete rethink and a radical new designed evolved, developed by the people at HRS

REVIEW OF THE ENABLING TECHNOLOGY

HOW IT WAS DEVELOPED

- This had to be a single assembly to reduce installation time and cost

- Had to incorporate the heat exchanger, bypass, silencer and stack

- Had to minimise the amount of steel and be the smallest footprint possible

- Support structures were also a big issue, motions, blast and wind loading, especially on FPSO's

- Question – what shape?. Circular appeared to be ideal, however finned heat exchanger tubes had never been coiled before

REVIEW OF THE ENABLING TECHNOLOGY

HOW IT WAS DEVELOPED (cont)

- WHRU's size is determined by exhaust gas velocity and pressure drop (typically 110ft/s and 12" water gauge)

- On this basis a circular WHRU would require 12% less steel to contain the gas and only 15% stiffening compared to 30% on rectangular units. It would also have a wind load factor of 0.6 instead of 1.0 for traditional units

- Overall weight savings of up to 25% were possible.

- Advantages of a circular coils:

  - No return bends, as in rectangular units – lower pressure drop, less weight, less welding

  - 70ft tubes could be used requiring one weld per tube, typically 20ft tubes with two welds per tube - reducing welding and radiography by 86%, improve the integrity of the coil.

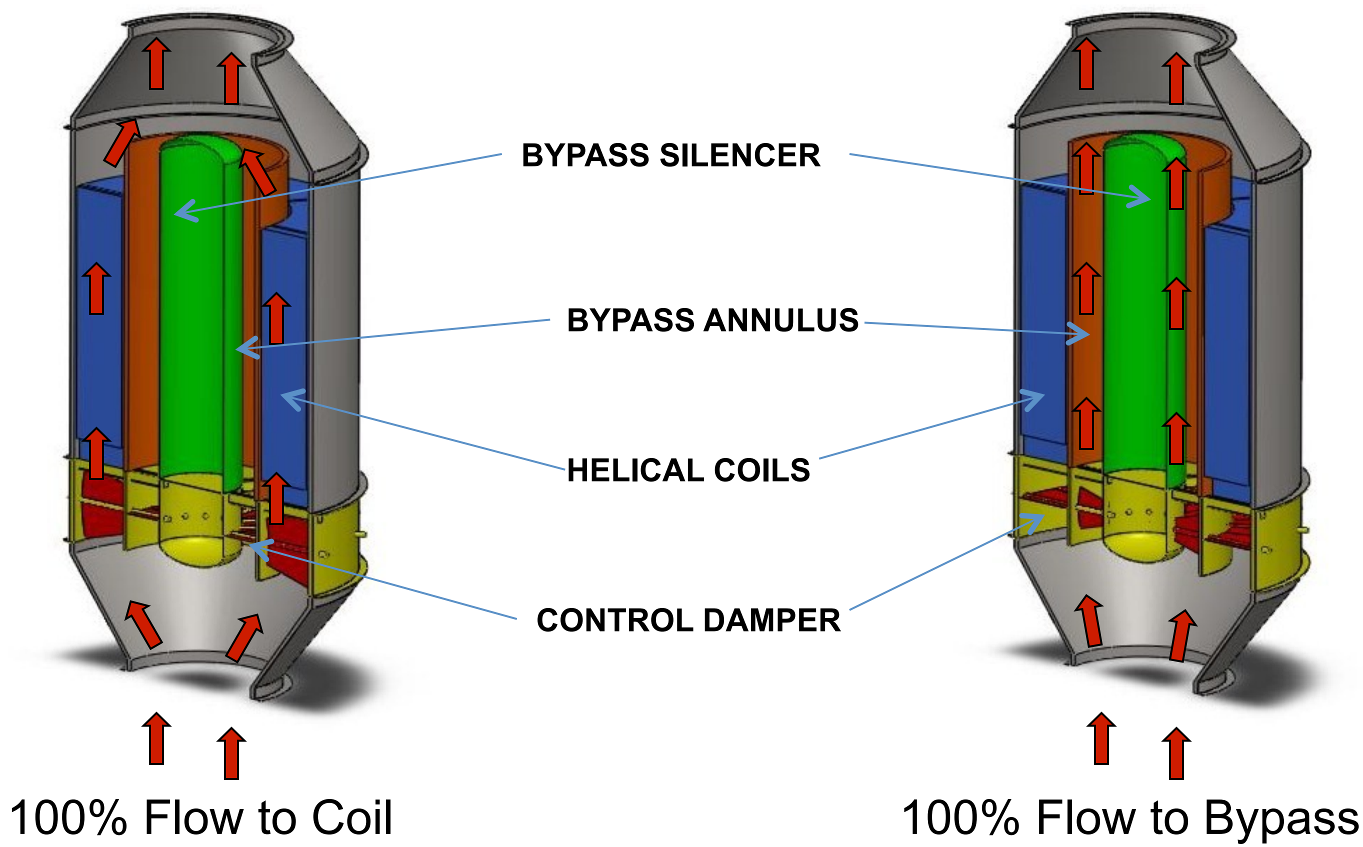
REVIEW OF THE ENABLING TECHNOLOGY

HOW IT WAS DEVELOPED (cont)

- Bypass could be positioned internally concentric with the coils and also incorporate a silencer

- To facilitate the concept it was necessary to develop a coiling machine and a new damper that was circular to control gas flow.

CIRCULAR WASTE HEAT RECOVERY TECHNOLOGY



REVIEW OF THE ENABLING TECHNOLOGY

HOW IT WAS DEVELOPED (cont)

- The benefits of the circular concept were overwhelming, the challenges had to be overcome

- After several years of development a coiling process was achieved and after much research and testing a multilouvre radial vane damper was established as the preferred choice

- Designs were developed for vertical exhausts and with a tangential inlet for axial exhausts

- Although developed specifically for offshore the first commercial units were employed on a land based location at Le Grange, Texas on Solar Centaur 40 gas turbines four years ago

- Since then over 29 units have been installed offshore worldwide including 3 units on LLOG Delta House Platform in G.O.M.

REVIEW OF THE ENABLING TECHNOLOGY

HOW IT WAS DEVELOPED (cont)

AUDUBON ENGINEERING, Circular WHRU'S for Le Grange Gas Plant, Texas, 2011

2 x 4.6MW Circular WHRUs on Solar Centaur 40 GTs

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REVIEW OF THE ENABLING TECHNOLOGY

HOW IT WAS DEVELOPED (cont)

3 X CIRCULAR WHRUs on SOLAR TAURUS GT's FOR LLOG DELTA HOUSE PLATFORM, GoM, 2012

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REVIEW OF THE ENABLING TECHNOLOGY

HOW IT WAS DEVELOPED (cont)

- In addition to Circular WHRU's, Circular HRSG's have been installed on Eldfisk platform, in the Norwegian Sea to produce high pressure, high temperature steam for power generation with a steam turbine

- These units on LM2500 and LM1600's combine multiple gas turbine exhausts into single units using a patented tangential inlet which reduces pressure drop, distributes exhaust gas evenly to the coils and overcomes the potential problem of GT interaction resonance

- Two units were installed in a single lift module to replace hot casing rectangular units that suffered stress induced cracking of the casings and supports. These two units produce enough steam to generate 10MWe and powers the complete platform

REVIEW OF THE ENABLING TECHNOLOGY

HOW IT WAS DEVELOPED (cont)

CONOCO PHILLIPS CSG INSTALLATION - ELDFISK PLATFORM

REVIEW OF THE ENABLING TECHNOLOGY

HOW IT WAS DEVELOPED (cont)

- **To compliment the Circular Steam Generators HRS developed, based on the same modular and compact offshore principles, a steam turbine power module to produce electricity from the steam generated.**

- **First introduced at Chinook Sciences plant near Birmingham, England - contains all plant and equipment necessary to run a steam based power island**

- **'Black Box' approach means a steam tail can be added to any gas turbine easily, taking up little space and at low cost, making it suitable for retrofitting to existing gas turbines or new installations**

REVIEW OF THE ENABLING TECHNOLOGY

HOW IT WAS DEVELOPED (cont)

INTEGRATED POWER MODULE – includes steam turbine generator, air cooled condenser, control system and all balance of plant. Feedwater pumped to steam generators, superheated steam returned for power production

(PATENTED PRODUCT)

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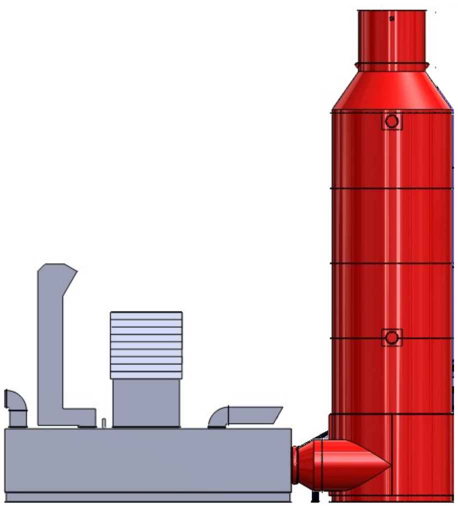
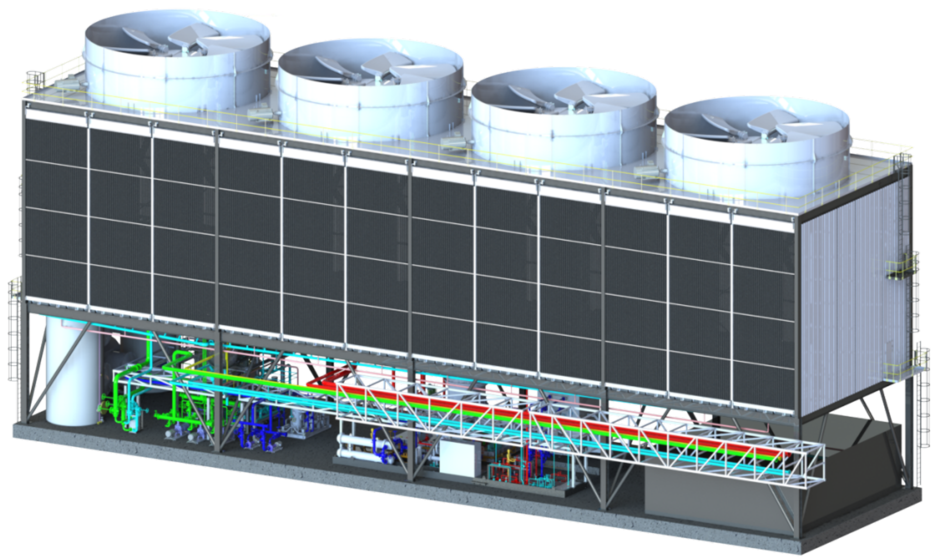
COMBINED CYCLE – AXIAL or SIDE EXHAUST GT's

Gas Turbine stack is replaced with Steam Generator and Power Module contains all other equipment required for Combined Cycle





Circular Steam Generator

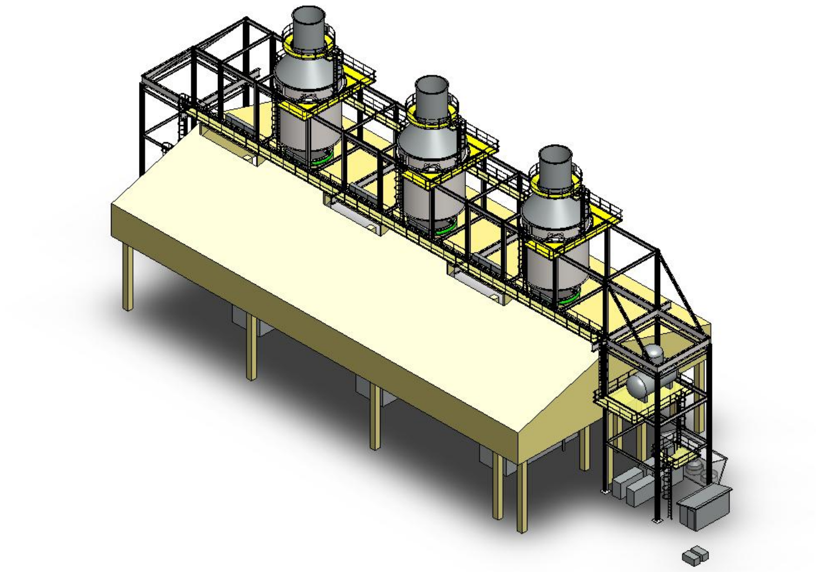
Gas Turbine

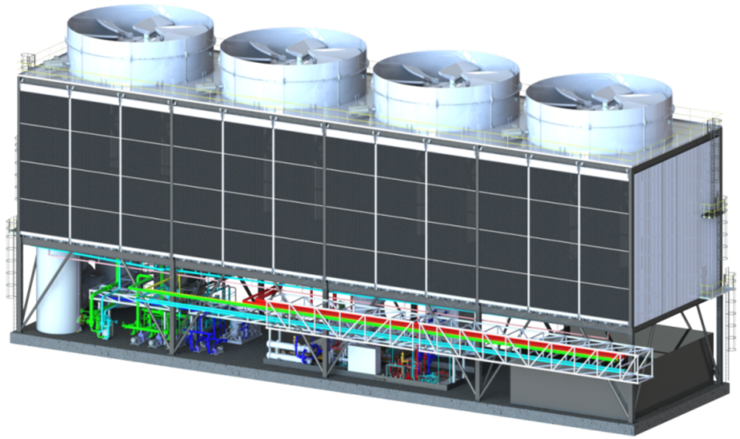
Power Module

Patented Products

COMBINED CYCLE – UPWARD RADIAL EXHAUST GT's

Gas Turbine stacks are replaced with Steam Generators and Power Module contains all other equipment required for Combined Cycle





Patented Products

REVIEW OF THE ENABLING TECHNOLOGY

TRANSFERABLE APPLICATIONS

- Technology can be installed on any waste heat source with a temperature above 800°F

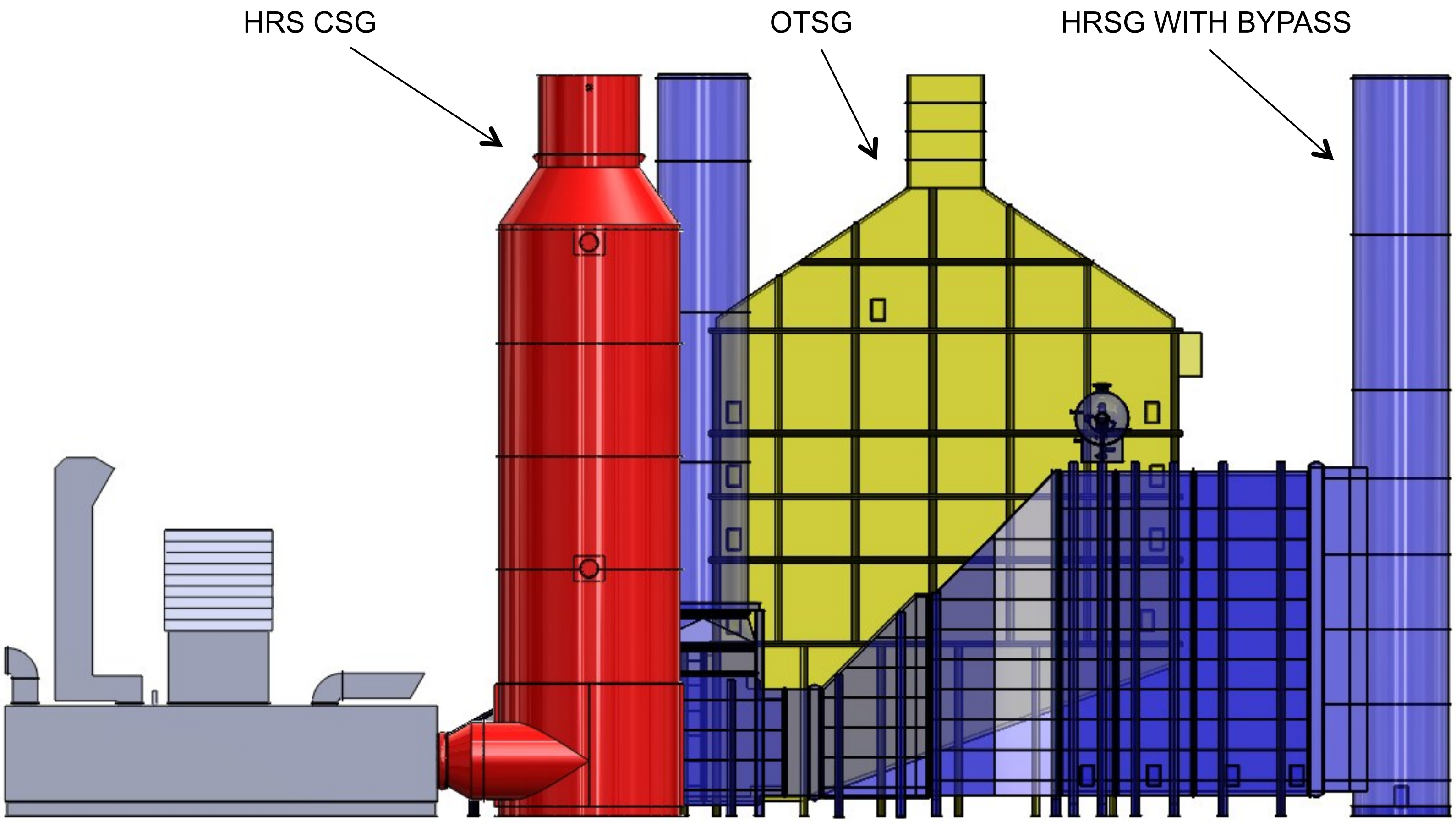
- Particularly applicable to existing gas turbines where space is an issue for a conventional HRSG and steam turbine configuration. The circular design can fit into the space where the stack is installed with minimum modification to the foundations

- Circular Steam Generators based on once through technology are delivered to site fully assembled and tested and can be installed in a day, after which the gas turbine can be put back into full operation

- Traditional HRSG’s require several months site work involving considerable cost before normal operations could be resumed.

REVIEW OF THE ENABLING TECHNOLOGY

CIRCULAR STEAM GENERATOR (CSG) TECHNOLOGY



TRADITIONAL STEAM GENERATORS ARE LARGE, EXPENSIVE AND NOT SUITABLE FOR RETRO FITTING TO MOST GAS TURBINES DUE TO SPACE CONSTRAINTS. CSG's ARE DELIVERED FULLY ASSEMBLED AND CAN BE INSTALLED IN A DAY, WITH MINIMUM DISRUPTION TO GT OPERATIONS.

ASSESSMENT OF HOW THE TECHNOLOGY CAN BE APPLIED TO ONSHORE COMPRESSOR STATIONS TO ACHIEVE LOW COST, EMISSIONS FREE POWER

BACKGROUND ON US COMPRESSOR STATIONS

•In the US alone there are more than 1200 compressor stations transporting natural gas through interstate and intrastate pipelines, the majority of which have no form of heat recovery. Of these 90 – 100 stations are identified by INGAA (Interstate Natural Gas Association of America) as being large enough to be viably converted to combined cycle with power exported to the electricity network or heat used for district or process heating.

•The report produced by Bruce A Henman for INGAA in 2009 concluded that heat recovery to power systems are economically viable in areas where power purchase prices include some incentive for clean energy and where compressor capacity and load factor are both above certain minimums.

ASSESSMENT OF HOW THE TECHNOLOGY CAN BE APPLIED TO ONSHORE COMPRESSOR STATIONS TO ACHIEVE LOW COST, EMISSIONS FREE POWER

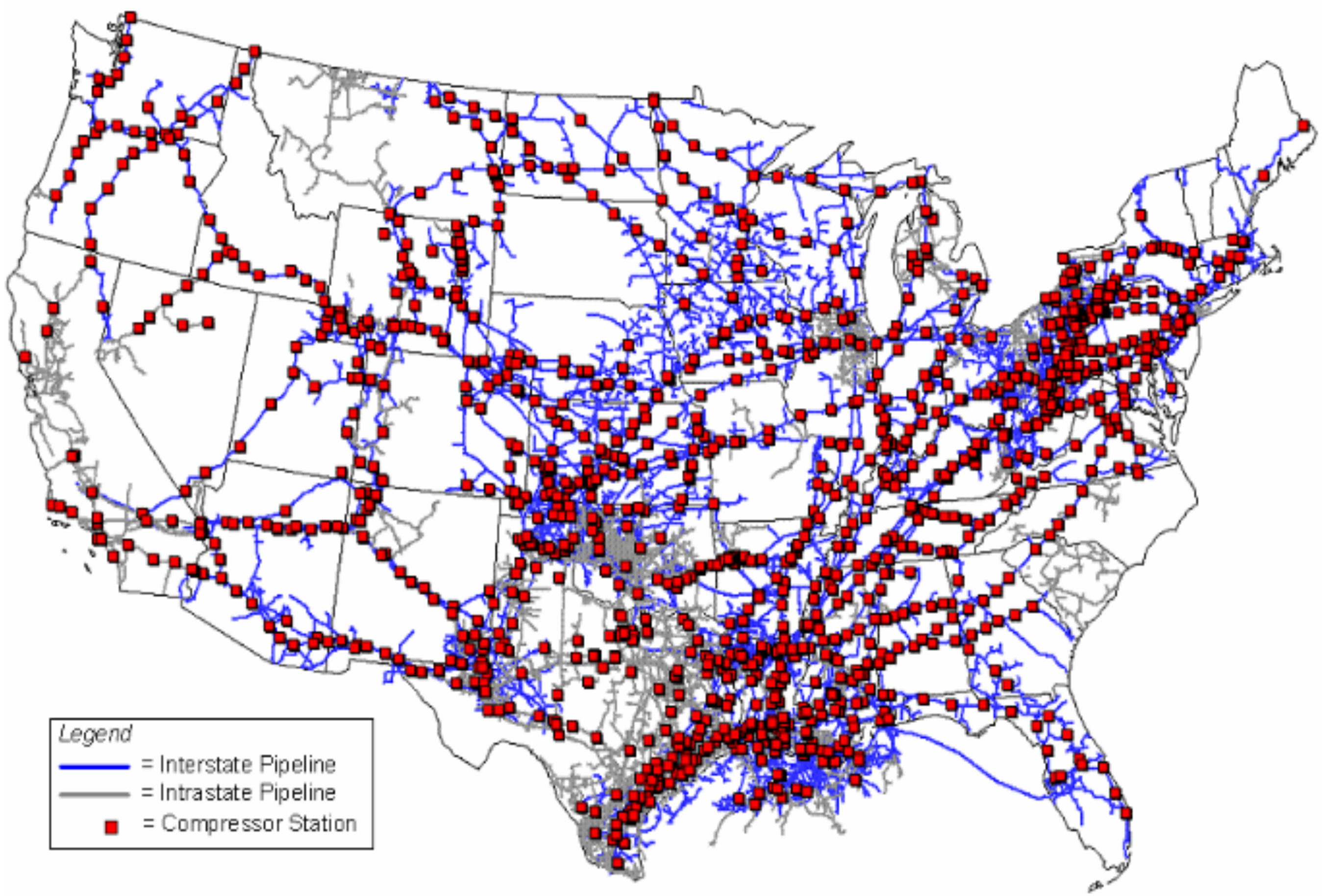
BACKGROUND ON US COMPRESSOR STATIONS (cont)

- The report mentions that viability is limited to stations with compressors of 15,000hp and above and that also operate for more than 5,250 hours per year. It is estimated that 500-600MWe of emissions free power could be generated from this heat source.

- The report assumes a capital cost of \$2,500 to \$3,500/kWe which in 2015 would be nearer to \$3,000 – \$3,500/kWe. This cost and low wholesale electricity prices means long term investments would be necessary which has made funding difficult to obtain, however several states have introduced RPS (Renewable Portfolio Standards) which provide incentives for generating clean energy that can make projects more viable and additionally there are various tax and grant benefits.

ASSESSMENT OF HOW THE TECHNOLOGY CAN BE APPLIED TO ONSHORE COMPRESSOR STATIONS TO ACHIEVE LOW COST, EMISSIONS FREE POWER

BACKGROUND ON US COMPRESSOR STATIONS (cont)



ASSESSMENT OF HOW THE TECHNOLOGY CAN BE APPLIED TO ONSHORE COMPRESSOR STATIONS TO ACHIEVE LOW COST, EMISSIONS FREE POWER

BACKGROUND ON US COMPRESSOR STATIONS (cont)

- **There are a number of compressor stations that generate power from the waste heat - all are based on ORC (Organic Rankine Cycle) systems which is a low pressure system that can be operated unmanned without the presence of a Steam Engineer.**

- **ORC systems however are not as efficient as the Steam Rankine Cycle**

- **The HRS CSG does not have a steam drum and as such can also be operated unmanned**

ASSESSMENT OF HOW THE TECHNOLOGY CAN BE APPLIED TO ONSHORE COMPRESSOR STATIONS TO ACHIEVE LOW COST, EMISSIONS FREE POWER

POTENTIAL IMPACT OF HRS TECHNOLOGY

- **The installed cost of HRS technology is $2,000 - $2,500 per kW/h, less than ORC technology and with much higher efficiency**

- **This means that the 90 – 100 projects identified by the INGAA could increase significantly, making stations with less running hours and smaller than 15,000hp compressors viable**

- **The INGAA database includes over 1,000 gas turbines at 473 U.S. compressor stations**

- **These turbines have an average capacity of about 6,600 hp (5.0 MW)**

- **Over 50 percent of the gas turbine drives are less than 5,000 hp in size. A little over nine percent of compressor gas turbines are greater then 15,000 hp in size; these units, however, represent over 25 percent of total gas turbine capacity**

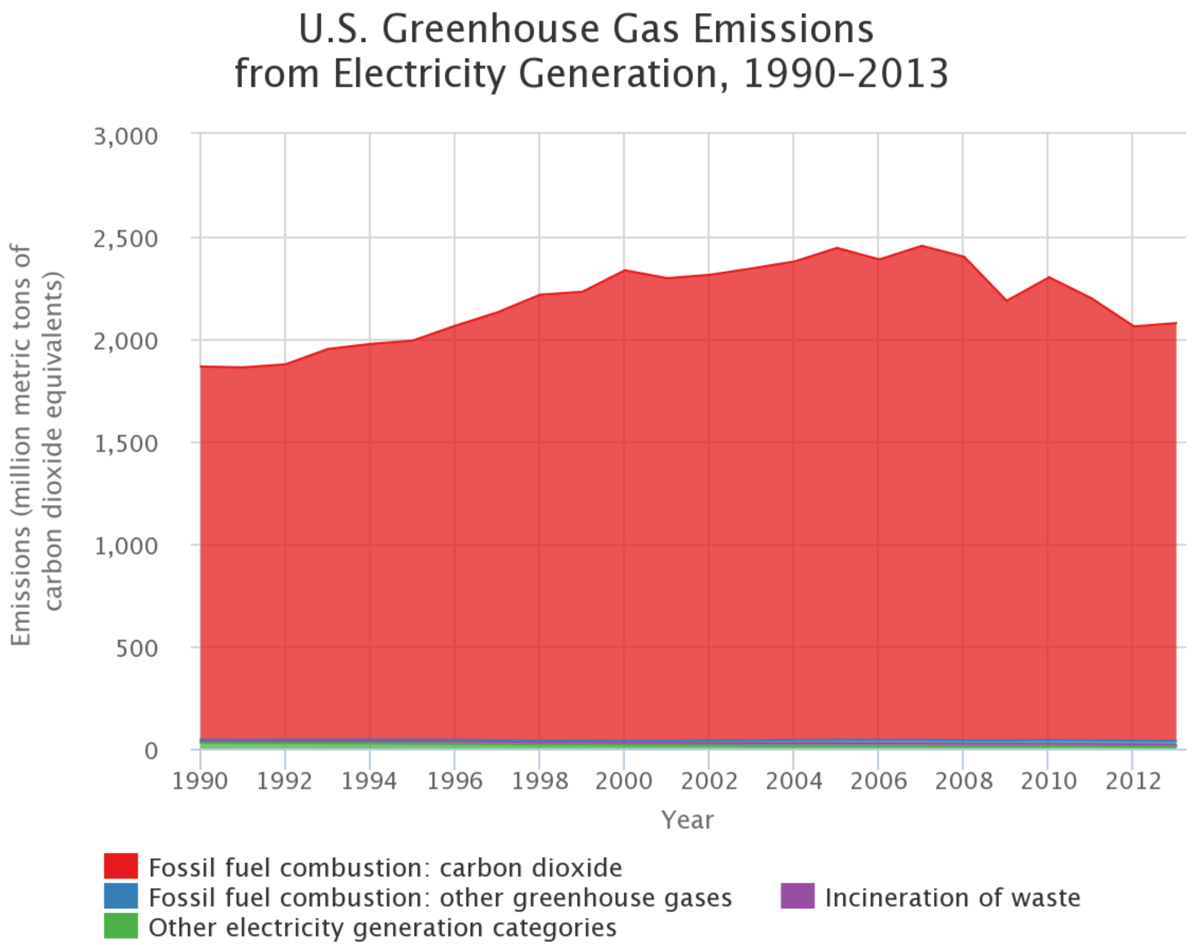
ASSESSMENT OF HOW THE TECHNOLOGY CAN BE APPLIED TO ONSHORE COMPRESSOR STATIONS TO ACHIEVE LOW COST, EMISSIONS FREE POWER

POTENTIAL IMPACT OF HRS TECHNOLOGY

- **A thorough investigation of compressor stations would be necessary to quantify the lower threshold and number of viable projects. However, on the assumption that 50% of the 1000 gas turbines were commercially viable at an average of 2MWe each on the steam cycle, this would be sufficient to produce 1000MW of electricity with zero emissions, displacing 8.1m tonnes of CO_2 per annum from burning 3.1m tonnes of coal.**

EXAMINING THE EXTENT TO WHICH ONSHORE COMPRESSOR STATIONS CONTRIBUTE TO ACHIEVING THE U.S. GOVERNMENT's TARGET ON CO_2 REDUCTIONS

THE EXTENT TO WHICH CONVERTING TO COMBINED CYCLE COULD AFFECT THE TARGET



Source: U.S. EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2013.
http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html

THE EXTENT TO WHICH CONVERTING TO COMBINED CYCLE COULD AFFECT THE TARGET

- **Carbon Dioxide levels for Power Generating Stations were 2,450 million tonnes in 2005. To reach the target of 32%, 784 million tonnes per annum would have to be saved**

- **Converting 500 gas turbines on Gas Compressor Stations would contribute 1% to the required savings**

EVALUATING THE PROFITABILITY OF ONSHORE APPLICATIONS

PROFITABILITY ONSHORE

- **Unless initiated on business needs, a waste heat to energy project has to be profitable to be financed and profitability is dependant on a number of factors:**
  - **CAPEX Cost**
  - **Power Sales Revenue**
  - **Operating Cost**
  - **Maintenance Cost**
  - **Payments to heat provider**
  - **Renewable energy credits**
  - **Renewable energy tax incentives**

- **If CAPEX is lower, operating and maintenance costs similar, electricity revenue the same, efficiency higher and renewables benefits the same then more projects could be realised with the HRS compact technology**

EVALUATING THE PROFITABILITY OF ONSHORE APPLICATIONS

TYPICAL EXAMPLE - 2 x 15,000HP GAS COMPRESSOR STATION

TYPICAL PROJECT - 9MWe from 2 x 15,000HP COMPRESSORS, 5,250 OPERATING HOURS A YEAR	
	USD
CAPITAL COST	18,000,000
GROSS REVENUE	
Wholesale - 9,000kW @ $0.05/kWh	2,362,500
Clean Energy Benefits - 9,000kW @ $0.03/kWh	1,417,500
TOTAL GROSS REVENUE	3,780,000
OPERATING COST	1,250,000
NET REVENUE	2,530,000
PAYBACK	10 YEARS
ANNUAL INCOME AFTER PAYBACK	2,530,000

Note: Profitability is heavily dependant on running hours, the amount of power generated and also power selling price. Compressor stations that operate longer hours would be more profitable, ie those operating continuously could have a payback within 4 years.

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CONCLUSIONS

- **HRS experience of developing compact and lightweight technology specifically for offshore applications, suggests there could be benefits onshore**

- **Smaller and reduced weight means less materials and less materials means less cost**

- **Smaller means it is possible to provide standardised packages, built in controlled conditions in the workshop which can be fully tested**

- **Workshop conditions improves productivity and quality and modularised packages means faster construction time and reduced risk at site and during operations.**

- **In this particular application there would appear to be benefits, although it is uncertain whether the same would be applicable for other types of equipment used on offshore platforms.**

- **With lower CAPEX cost it appears economically viable to convert at least 500 gas turbines on compressor stations to combined cycle, which would contribute more than 1% to the U.S. CO_2 reduction targets.**

THANK YOU FOR YOUR INTEREST

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