Gas Turbines and Reciprocating Engines

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Gas Turbine, Reciprocating Engine IIoT & Remote O&M Overview

- Gas turbine rotating parts are already being remotely monitored
- The IIoT systems can be extended to include all GTCC components
- A number of third parties are already providing remote O&M
- Utility systems such as owned by Luminant, Southern and Duke are providing their own fleet wide IIoT and remote monitoring systems.
- The biggest IIoT revenue potential is for large scale power generation
- The IIoT and remote monitoring percentage of OPEX will be higher for small gas turbines and I.C. engines
- ROI is highest for remote compressor stations and offshore platforms
- Distributed generation with CHP is a very big potential
- Remote monitoring services such as offered by Luminant can be expanded to provide IIoT for the complete CHP system
- Gas engines delivering heat, power and CO2 for indoor agriculture offer a small but very rapidly growing opportunity

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Markets

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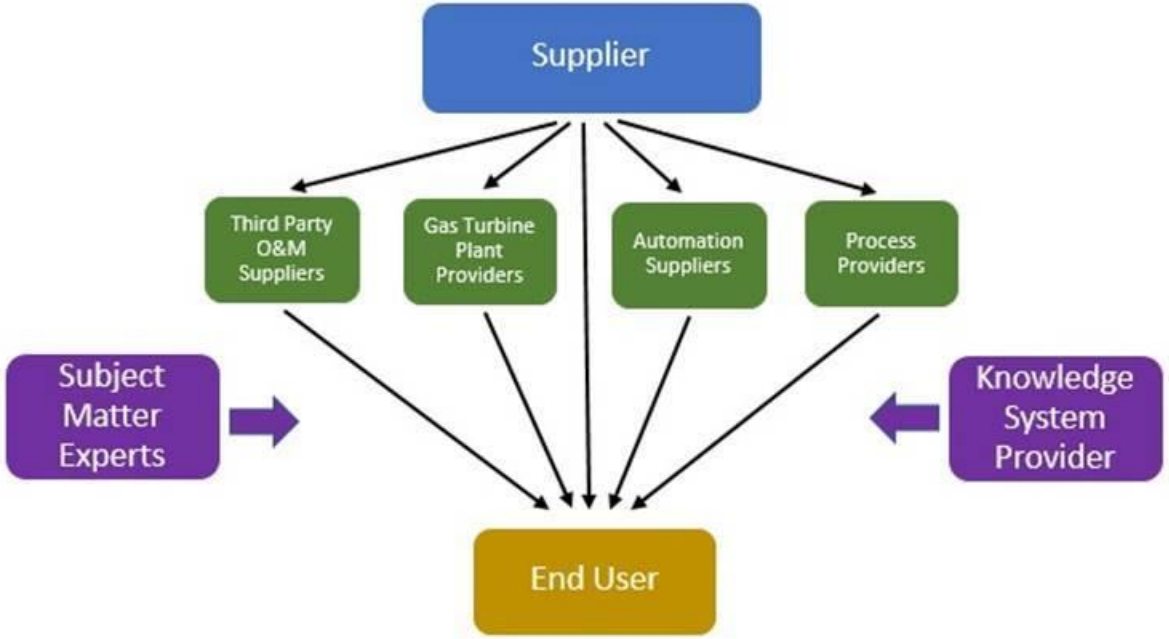
Gas Turbine and Reciprocating Engine IIoT and Remote Markets for Components

There is a new route to market with higher revenues for component suppliers who can expand services subject matter expert revenues by working with five different entities.
The global service, replace, and repair opportunity in GTCC is

- Gas turbines and all components $100 billion/yr
- Liquid cartridge $400 million/yr
- Pumps $1 billion/yr
- Valves $1.5 billion/yr
- Air filters $700 million/yr



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IIoT is Creating New Market Paths to the $100 Billion Gas Turbine Repair, Replace and Service Market

- The Industrial Internet of Things (IIoT) is a powerful new force shaping the way gas turbine products are purchased. The impact of IIoT is being continually assessed in ***59EI Gas Turbine and Reciprocating Engine Supplier Program***.
- The inventory of existing gas turbine plants is growing at six percent per year and in the next few years the base will grow to two million MW. There are 30,000 individual units which routinely require service, replacement or repair of instrumentation, valves, pumps, filters, nozzles, and other components. There is a continual need for filter elements, treatment chemicals, lubricants, catalysts, reagents and other consumables. The market for replacement products, repair and services is $100 billion per year and will grow by more than six percent per year.
- IIoT provides remote delivery of comprehensive information about the operation and health of individual components. This data can be analyzed to identify problems and will create opportunities for the sale of better products to replace the existing ones. IIoT is creating new channels to market in contrast to the sale of products directly to a single end user.

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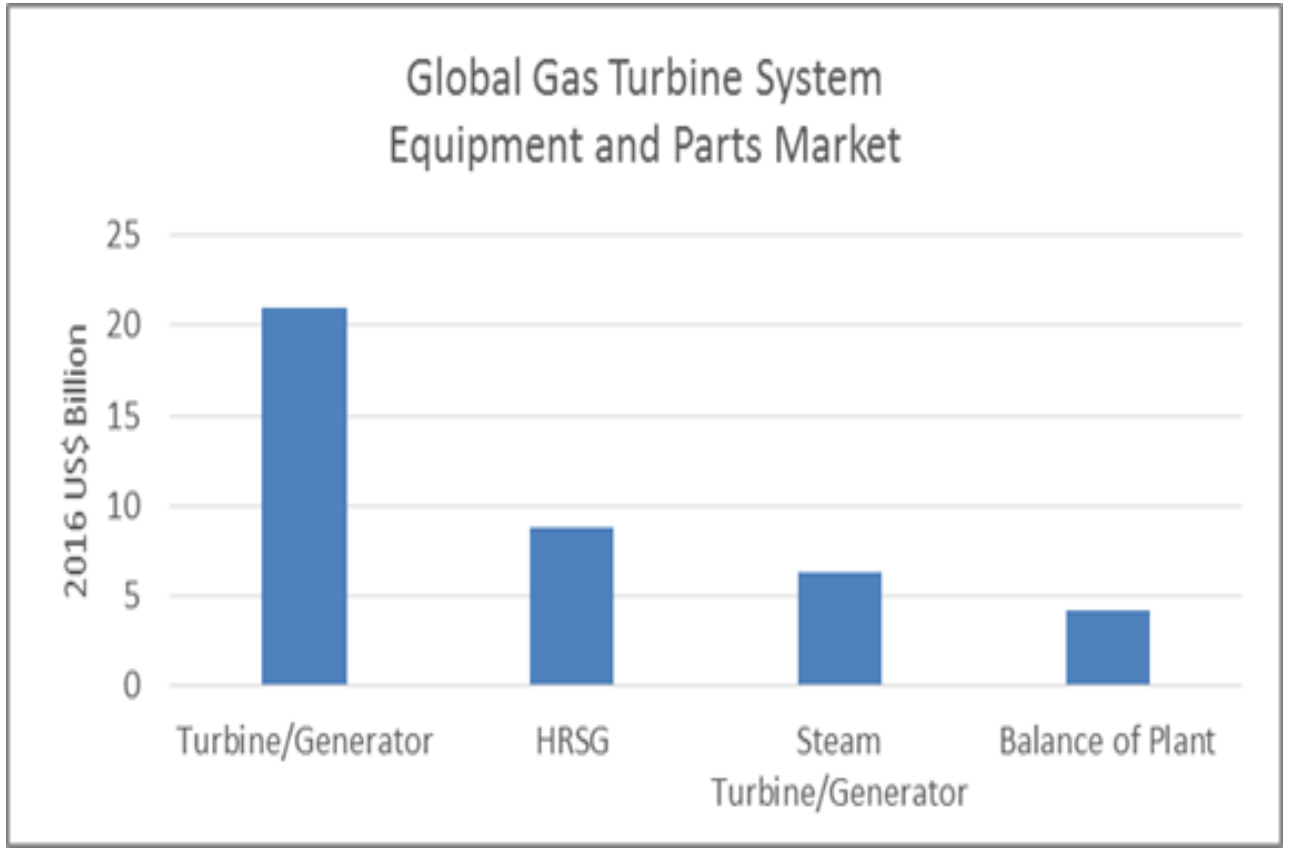
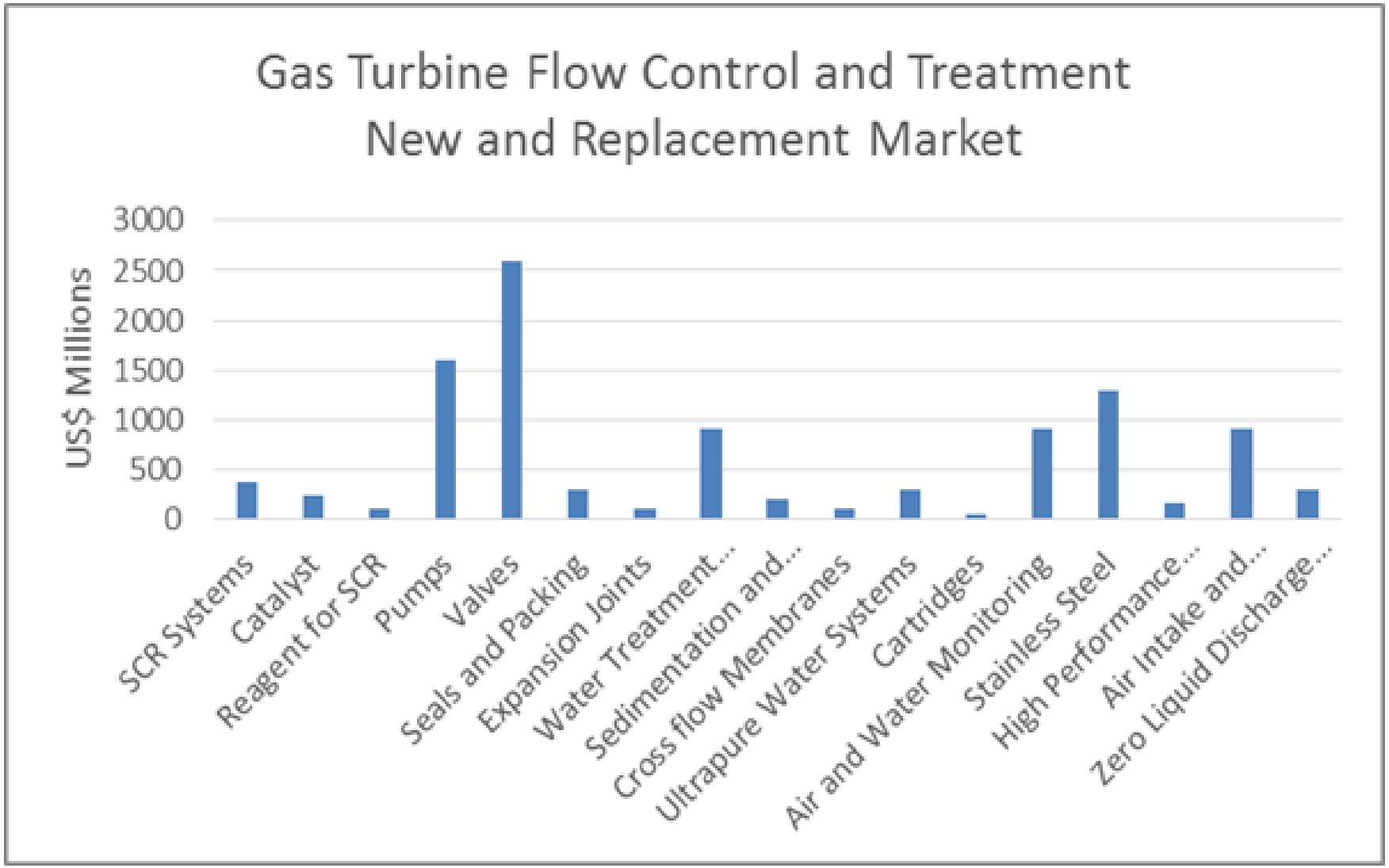
Market Segmentation by Major Component



Valves and Pumps Lead Component Purchases



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Drivers Impacting Product Markets

Product	Driver	Market Impact
Air Intake Filters	Higher efficiency for turbine protection	Could boost market by 50%
SCRs	Regulations in Europe and elsewhere	Big increase in market where required
Pumps	FAC and other cycling challenges	Market growing faster than total GT market
Valves	FAC and other cycling challenges	Market growing faster than total GT market
Seals	Pump, valve, compressor and new turbine designs	Market growing faster than total GT market
Zero Liquid Discharge (ZLD) Systems	Regulations, aridity and reluctance to wait for water permits	Growing market in U.S., China and elsewhere
Stainless Steel	New turbine designs	Continuing opportunity for high performance materials
Steam Turbines	Addition of steam turbine to existing peakers to meet energy and greenhouse gas goals	Substantial market impact as many plants are upgrading
HRSG	Fast start needed	New design needed

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Regulatory Drivers

Pollutant	Driver	Market Impact
Greenhouse gases	Limits or penalties on CO_2 emissions	Negative impact on market vs. renewables but positive vs coal
Harm to aquatic life	Regulations forcing less intake and less once through water	ZLD, dry cooling, municipal water reuse
Water discharge limits	U.S. has new regulations	More ZLD
NO_x emissions	Tough regulations in U.S. and potential new regulations in Europe	Steady positive impact on SCR and urea markets as prices are lowered in various countries

IIoT programs need to take into account the local regional, and national regulations affecting each plant. In the BHE beta site created by Mcilvaine the air and water permits for each plant are provided. Any optimization program has to take into account regulatory details such as whether there are hourly or daily limits along with yearly limits. The cost of IIoT programs created by individual suppliers such as Accenture or Genpact can be greatly lowered in that IIoW data is already organized and available.

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Gas Turbine Opportunities for Valve Companies Shaped by IIoT

- There are many new gas turbine combined cycle power plants (GTCC) under construction and in operation. This represents a market potential of $3.5 billion/yr. for valve suppliers. However, the Industrial Internet of Things (IIoT) is creating a metamorphosis in the route to market and profitability. This market is being continually assessed in ***N028 Industrial Valves: World Market***. Each gas turbine project is tracked in ***59EI Gas Turbine and Reciprocating Engine Supplier Program.***
- Smart valves provide a route to increase revenue and profitability. Both on/off and control valves have "smart" capabilities. An on/off valve can be supplied with a controller which is intelligent, having digital communication and a microprocessor capable of on-board diagnostics. The controller can detect deteriorating valve performance. Diagnostics also include high and low temperature monitoring. The on/off valve diagnostics make it possible to more accurately predict the need for maintenance based on how hard the valve is working and how it is performing.
- Control valves are critical components in plant automation. Their intelligence can be leveraged to maximize plant improvements. Emerson is incorporating smart valve technology to provide a control Valve Condition Monitoring diagnostic service performed by certified Fisher valve and instrument product experts focused on providing predictive analysis of a facility's control valves. Its purpose is to identify potential failures and avoid them before they cause unsafe operating conditions and/or unplanned downtime.
- Emerson has partnered with software company, Seeq, to improve the data visualization tools used to predict future valve problems. Seeq expertise has helped Fisher Valve Division build a collaborative environment connecting customers with local Fisher service experts and global valve experts. This environment enables data from multiple sources to be visualized and aggregated. It allows authorized people located around the world to look and work on the same data for predictive maintenance and operational improvements.

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Multiple Gas Turbine Valve Purchasers with IIoT

End Users

- Large end users are creating fleetwide monitoring systems. Southern Company operates over 280 power generation units at 73 power plants including gas turbine, combined cycle, steam (coal), hydro and solar. Southern Company implemented the first phase of their fleetwide monitoring and diagnostics (M&D) center in 2007.
- Duke Energy is growing its fleetwide monitoring and diagnostics center. Duke's efforts promise to result in maintenance savings and availability improvements, while increasing equipment health visibility and optimizing logistics of maintenance.
- The one hundred largest operators of gas turbines around the world account for the majority of valve purchases. Therefore, working with them should be a high priority.

Gas Turbine Plant Providers

- Gas turbine suppliers have remote monitoring centers primarily focused on the health of rotating parts such as turbines. However, this is being expanded. MHPS just opened a remote monitoring center in the Philippines. It is monitoring the balance of plant in addition to the turbines.

Process Providers

- Suppliers of heat recovery steam generators, ultrapure water, emission controls and water treatment are also purchasers or influencers relative to valves. Nalco has a water quality remote monitoring center which operates around the clock.

Automation Suppliers

- ABB can provide all required gas turbine control and protection functions utilizing the very same ABB DCS platform that controls the rest of the plant. The typical gas turbine functions implemented include fuel control, startup sequence, speed-load-temperature closed loop control, overspeed protection, anti-surge protection, generator protection, auxiliary control, condition monitoring, auto-synchronization, excitation, frequency control, etc.
- Yokogawa has various programs including one which monitors the wastewater from the plant. The automation supplier can be working directly with the end user and not necessarily through the process supplier.

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Inlet Air Filter Monitoring can be combined with Digitized Sourcing Programs

- The inventory of existing gas turbine plants is growing at six percent per year and, in the next few years, the base will grow to two million MWs. There are 30,000 individual units which routinely require service, replacement or repair of air filters used for intake air in gas turbines and for inlet air filtration of compressors, diesel and gas engines. The market for replacement filters and services is $700 million per year and will grow by more than six percent per year.
- IIoT provides remote delivery of comprehensive information about the operation and health of air filters. This data can be analyzed to identify problems and will create opportunities for the sale of better filters, media, coatings and smarter filters to replace the existing ones. There is much controversy on whether high efficiency microfiberglass filters for GT intakes justify the extra cost. With IIoT the answers for each specific plant will be available.
- Details on inlet air filter performance are continuously tracked in the Mcilvaine ***Gas Turbine, Reciprocating Engine Decisions.***
- Niche expertise is available from third party consultants such as Laborelec.
- Air filters along with lubrication and other filters used in gas turbines can be included in digitized sourcing programs available along with digitized process management

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Support Program

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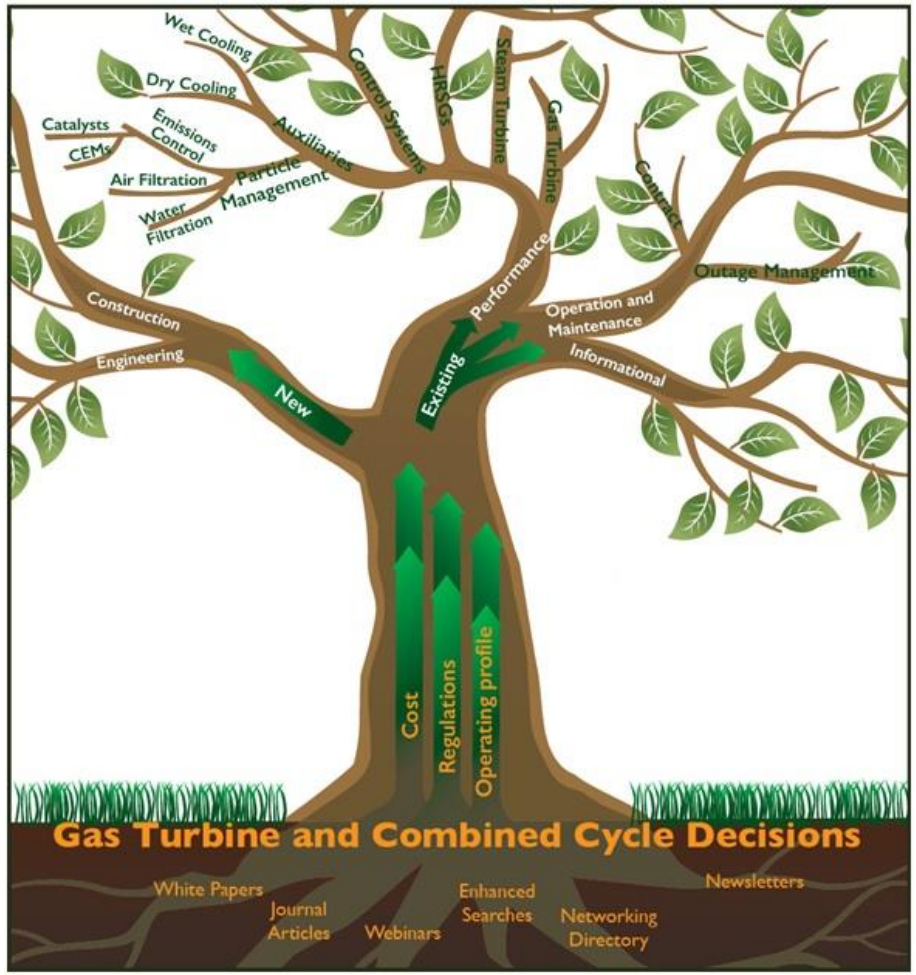
Gas Turbine Product and Services Enhanced by IIoT

Suppliers can pursue the IIoT and Remote O&M market for gas turbines by use of the Mcilvaine ***IIoT and Remote O&M Service*** in conjunction with the ***Gas Turbine, Recipro- cating Engine Supplier Program***. The GTRE program provides forecasts for each gas turbine-combined cycle and reciprocating engine product and service while identifying all the plants and projects.

The analysis of new technology is essential to determining future markets. Digital tools such as webinars provide the opportunity for cross pollination of insights from end users and suppliers.

A ***Decision System*** for end users is a critical segment of the program. A third service entitled ***GTRE Decisions*** is provided free of charge to gas turbine owners. It includes the IIoT newsletter. So this becomes a route from IIoT suppliers directly to turbine operators.



This Program will help You make the Paradigm Shift caused by IIoT and Remote Monitoring

- The gas turbine industry is leading the way in the new world of the Industrial Internet of Things (IIoT) and remote operations and maintenance.
- If you sell turbine systems, you will increasingly be selling packages with remote O&M services.
- If you sell components you will be selling to third party O&M operators.
- If you sell valves and pumps you will be selling smart versions and will have remote monitoring contracts.
- If you sell software and instrumentation you will be selling to a wide range of customers who are identified in this supplier program.
- The information avalanche generated by IIoT will only be valuable to the extent IIoT is married to IIoW (the Industrial Internet of “Wisdom). Knowledge rather than salesmanship will be the key to success.
- This supplier program is your guide to this new world.

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Example of Bi Weekly GT Supplier Alert

U.S. GAS TURBINE PROJECTS

- NRG Completes Four Coal to Gas Projects and Continues Fleet Optimization Strategy
- CALIFORNIA: Ares EIF to Sell Pio Pico Energy Center
- MICHIGAN: EthosEnergy awarded Seven-Year Contract for Operations Maintenance Services by Rockland Capital
- NEW YORK: Siemens to supply Additional Aero-Derivative Gas Turbines to help Power New York City
- PENNSYLVANIA: Ameresco and PIDC Partner on an Innovative Project at the Navy Yard in Philadelphia

WORLD GAS TURBINE PROJECTS

- CHINA: MHPS Wins Order to Provide Gas Turbine Preventive Detection Services in China
-

RECIPROCATING ENGINE PROJECTS

- ARGENTINA: Wärtsilä to supply a 101 MW Power Plant to Argentina
  U.S. VIRGIN ISLANDS: APR Energy Awarded LPG-Fired Project in U.S. Virgin Islands

BUSINESS

- Sulzer to Acquire Control of Rotec's Gas Turbine Service Business Mitsubishi Hitachi Power Systems Unveils Revolutionary JAC Gas Turbine

MARKETS

- Gas Turbine Owners Will Spend $313 Billion for Equipment, Repairs and Service Next Year

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Monthly GTRE Update

SOFTWARE

- New GE Analysis: Software and Hardware Upgrades could cut Global CO_2 Emissions from Coal and Gas Power Plants by 1 Billion Metric Tons
- ABB Champions the Power of Intelligent use of Plant Data at Power-Gen Asia

- **RECENT POSTINGS IN GRTE DECISIONS**
- More Efficient Filters are justified says Carlos Conti of Vokes
- Colfax Oil Pumps for Power Generation
- Richard Winslow is a Niche Expert on Power Plant Lubrication
- Bacterial Contamination of Turbine and Circulating Lube Oil Systems
- Interconnecting Compressor Initiatives at BHE
- Mann & Hummel spin-on Filters are used for the Filtration of Lube Oil
- BHE -Safety Relief Valves needed by Many BHE Plants

O & M CONTRACTS

- Wood has O&M contract for Bethel Energy Centre
- ProEnergy renews Contract with Ameren for O&M at GTCC Facilities
- IHI has a Range of O&M Services for Power Plants
- MHPS combining OSIsoft Monitoring Software with Cloud-based Analytics in Strategic Alliance
- Nalco providing 24/7 Water Monitoring for Gas Turbine Plant
- Ansaldo is Remotely Monitoring 17,000 Sites

EQUIPMENT

- Clarcor has 5 Step Plan to Help Turbine Operators Select Filters
- MHPS has New Enhanced Air Cooled Gas Turbine

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Projects Updated Every Few Weeks. Here is Update for November 26, 2016

Project Title	First Entry Date	Location	Startup Date
Porto de Sergipe CCGT - Golar Power	**10/24/2016**	Brazil	2020
Hattar CCGT - Khyber Pakhtunkhwa Economic Zone Development Co	**8/9/2016**	Pakistan	2017
Soma Port CCGT - Fukushima Gas Power	**11/14/2014**	Japan	2020
Heartland CCGT - ATCO Power	**10/1/2013**	Canada	2022

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Details on GTCC in Each Country

Afghanistan - Ministry of Energy and Water
Albania - Korporata Elektroenergjitike Shqiptare
Algeria - Algerian Energy Co
Algeria - New Energy Algeria (NEAL)
Algeria - Sharikat Kahraba Berrouaghia (SKB)
Algeria - Sharikat Kahraba Hadjret En Nouss
Algeria - Shariket Kahraba Skikda (SKS)
Algeria - Shariket Kahraba Terga (SKT)
Algeria - Shariket Karhaba Koudiet Eddraouch (SKKE)
Algeria - Sonelgaz Production de l'Electricite
Angola - Empresa Nacional de Electricidad
Argentina - AES Argentina
Argentina - Albanesi
Argentina - Albenesi S.A.
Argentina - Aluar Aluminio
Argentina - Capex SA
Argentina - Central Vuelta de Obligado SA (CVOSA)
Argentina - Centrales de la Costa Atlantica SA
Argentina - Centrales Termicas NOA SA
Argentina - Centrales Termicas Patagonicas SA
Argentina - Empresa Provincial de Energía de Cordoba
Argentina - Energia del Sur SA
Argentina - ENERSA
Argentina - Fideicomiso Central Termoelectrica
Argentina - Foninvemem
Argentina - I Sqared Capital
Argentina - Pampa Energia SA
Argentina - Petrobras Electricidad
Argentina - Pluspetrol SA
Argentina - Sociedad Argentina de Energia SA
Argentina - Tenaris
Armenia - GazProm
Armenia - Yerevan Thermal Power Plant CJSC
Australia - AGL Corp
Australia - Alcoa of Australia
Australia - Alinta Energy
Australia - Anaconda Nickel Ltd
Australia - Arrow Energy
Australia - ATCO Power Australia

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IIoT and Remote O&M Programs allow the Large Owners to Coordinate Operations Across the Fleet

Largest Gas Turbine Power Developers in the U.S.

Rank	Power Producer	Gas-Turbine Power Projects	
		Total Capacity (MW)	Number of Facilities
1	**Panda Power Funds**	5,206	6
2	**Dominion**	2,958	2
3	**Exelon**	2,400	3
4	**Competitive Power Ventures**	2,075	3
5	**Advanced Power**	1,742	2
6	**Duke Energy**	1,640	1
7	**Coronado Power Ventures**	1,400	2
8	**NTE Energy**	1,290	3
9	**NextEra Energy**	1,277	1
10	**PSEG**	1,275	2

These are the largest power producers based on the capacity of proposed gas turbine power projects which are currently still on track – either in the approval or permitting process or currently under construction.

Half of top ten are private equity or private investment companies which develop merchant power plants in deregulated markets with a profit motive

Utilities such as Duke Energy operate only regulated plants, where rates are set through ratemaking proceeding

- Their motive is still profit, but income is effectively capped by the set rate
- Operating cost effectiveness become the key to profit

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Lots of data relative to each component has to be gathered in a digital process management program. If the owner already has that information, the cost of program implementation with be far less.

Components at one plant-Chuck Lenzie Generating Station

- **Commercial operation:** Power block 1, January 2006; power block 2, March 2006
  EPC contractor: Fluor Energy & Chemicals Group
  Owner's engineer: Washington Group International (now part of URS Corp)
  Type of plant: Combined cycle (two 2 x 1 power blocks)
  Key personnel
  Regional director: Tom Price
  Asst regional director: Brian Paetzold
  Operations manager: Forrest Hawman
  Maintenance manger: Dave Hall
  Plant engineers: Shane Pritchard, Andy Gaither
  Environmental manager: George Brewer
  Safety manager: Ernie Wilson
  Gas turbines
  Manufacturer: GE Energy
  Number of machines: 4
  Model: 7FA (PG7241)
  Control system: Mark VI
  Combustion system: DLN 2.6**Fuel:** Gas only
  Water injection for NOx control? No
  Water injection for power augmentation? No
  Air inlet house: GE Energy
  Air filters: Donaldson Company Inc
  Inlet-air cooling system, type: Chiller
  Generator, type: Hydrogen-cooled
  Manufacturer: GE Energy
  GSUs: Alstom
  HRSGs
  Manufacturer: Aalborg Industries (now CMI EPTI LLC)
  Control system: DeltaV (Emerson Process Management)

- **Duct burner:** Coen Company Inc
  SCR: Peerless Mfg Co
  CO catalyst: Englehard Corp (now BASF Catalysts LLC)
  Water treatment
  HRSG internal treatment, type: AVT
  Chemical supplier: Nalco Co
  Reverse osmosis system: Aquatech International Corp**Demineralizer:** Aquatech International Corp
  Cooling-water treatment system: Aquatech International Corp
  Cooling-water chemical supplier: Nalco Co
  Wastewater treatment system, type: ZLD
  Steam turbine
  Manufacturer: GE Energy
  Number of machines: 2
  Model: D11
  Generator, type: Hydrogen-cooled
  Manufacturer: GE Energy
  GSUs: Alstom
  Balance of plant
  DCS: DeltaV (Emerson Process Management)
  Condenser, type: Air-cooled
  Manufacturer: GEA Power Cooling Inc
  Wet cooling towers: Baltimore Aircoil Co
  Boiler-feed pumps: KSB Inc
  Condensate pumps: Flowserve Corp
  Circulating-water pumps: Flowserve Cor

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Operating ZLD Systems from McIlvaine GTCC Supplier Program

Operating Facilities	ZLD Supplier	Location	Size (MW)	Startup
Altamonte – Edison	Degremont	Italy	757	2006
Colusa – Pacific Gas & Electric		California	712	2010
Jack County – Brazos Electric	Aquatech	Texas	620	2011
Magnolia – City of Burbank		California	387	2005
Sherman – Panda Power	GE	Texas	750	2014
Red Hawk – Arizona Public Service	Veolia	Arizona	1,060	2002
Riverside – City of Riverside		California	96	2011
Rocky Mountain – Xcel		Colorado	705	2004
Roseville – City of Roseville		California	162	2007
Russell City – Calpine		California	635	2013
Temple – Panda Power	GE	Texas	760	2014

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New ZLD projects from Mcilvaine GTCC Supplier Program

Project	Location	Size (MW)	Expected Startup
Bowie CCGT - Southwestern Power Group	Arizona	500	2016
Stonewall CCGT - Green Energy Partners/Panda	Virginia	778	2017

A large number of ZLD systems are anticipated for the arid areas of the Middle East and China but also for areas with plentiful water where there is difficulty or delay in obtaining water discharge permits. Local cities, states, and provinces often have tougher limits than the national standards.

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Software

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AEP Monitoring with IBM Maximo and Siemens PrismMoni

- American Electric Power, but only recently has the technology advanced enough to justify the investment. “The potential is huge,” says Tim Riordan, whose company is deploying both IBM’s Maximo asset management platform and Siemens’ Prism system to monitor its fossil fuel plant performance. But he cautions that “to truly integrate all of this, to take it to a grand level.”
- Decisions on whether and when to retire plants for good “go all the way to senior leadership,” says Michael Reid, the general manager of technical programs for fossil and hydro operations at Duke Energy. Duke has retired or converted to natural gas 16 coal plants since 2011 and plans to shut down nine more by 2020. Digital technology can improve the efficiency, flexibility, and emissions profile of aging plants, Reid adds, but “substantial design changes are required to make significant gains in these areas.”
- Digitizing power plants can help integrate renewables onto the grid by making existing fossil fuel plants more flexible and better able to respond to fluctuations in power.

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ABB Symphony Plus DCS for Collection and Analysis of Plant Data

- **ABB's Power Generation** unit explains how the intelligent use of data now available in power plants can not only deliver a competitive edge, but provide a solution to current and future challenges .
- Plant owners can lower risks in their projects, reduce costs and throughput times, and improve asset performance and profitability by the careful collection and analysis of plant and engineering data.
- "We believe the success of our power generation customers will be more and more supported by the intelligent use of data generated by ever increasing connectivity of devices. The integration of those data with people expertise and knowledge will create additional services (IoTSP) in a cycle delivering unprecedented knowledge of the behavior and potential of their assets," said Marco Sanguineti, Head of Technology for ABB's Power Generation business unit. "The ability of ABB's Symphony® Plus distributed control system to add customer value by utilizing the data in their systems is the result of our careful analysis of the evolving power generation market, and our customers' changing needs driven by global mega trends."
- Repowering, modernizing and upgrading power plants will prolong plant life and increase efficiency, and the emergence of these dynamics in Asian countries opens the door to limitless opportunities for ABB, where a commitment to 'evolution without obsolescence' protects customer investments.
- Symphony Plus is the latest generation of ABB's Symphony family of control systems. With more than 6,700 systems installed in the past 30 years and more than 50 GW of additional power capacity installed during the last five years, much of it in the power generation and water sectors, ABB has one of the largest installed bases of distributed control systems (DCS) in the world.

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Schneider Electric is Providing Comprehensive Services for Power Plants

- Invensys is helping the Power Industry meet the challenges of the 21st century • Growth – the increase in demand created by emerging countries and the replacement of existing power plants • Aging – the need to modernize obsolete control & safety systems, and capture the knowledge of an aging workforce • Sustainability – reduce energy usage/carbon emissions, and improve plant safety and reliability • Cost – minimize maintenance costs, optimize production and operating costs, achieve greater productivity and efficiency • Adjust load to demand – economically balance changing demand with the volatility in fuel costs Invensys Solutions • Integrate Instrumentation on Control & Safety Systems for Coal-Fired Power Plants, Combined Cycle Gas Turbines, and Nuclear & Renewables • Rapidly upgrade or migrate existing systems, minimizing disruption to control and protecting Turbo-Machinery • Manage the system lifecycle • Make coal cleaner by using advanced generation technology (IGCC – Integrated Gasification & Combined Cycle, Oxyfiring, Supercritical or Ultra-Supercritical technologies) • Increase overall plant efficiency with Advanced Process Control for optimizing boiler combustion • Coordinate boiler and turbine operation • Reduce and control emissions • Manage the fleet of power generation stations • Increase operator effectiveness with advanced solutions such as Operator Training Simulation and Alarm Management • Provide Enterprise Asset Management

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C3IoT Platforms used at all 24 ENGIE Business Units

- Global energy leader ENGIE is implementing an ambitious digital transformation strategy that is vital to the Fortune Global 500 company's plan to confront the major challenges posed by climate change and promote people's access to reliable, innovative, socially responsible, low carbon, and decentralized energy. To do this, ENGIE plans to invest €1.5 billion in new businesses and digital over the next three years.
- After a thorough review process, ENGIE selected C3 IoT as its strategic partner to provide the technology foundation for its enterprise-wide digital transformation. Since the joint press conference in Paris announcing the agreement in June, ENGIE and C3 IoT have initiated an aggressive roadmap enabling ENGIE to immediately leverage C3 IoT's high-performance, integrated, enterprise-scale IoT analytics and application development platform. In addition to using C3 IoT's pre-built SaaS applications, ENGIE will develop and deploy custom applications on the C3 IoT Platform across all of ENGIE's 24 business units worldwide.
- This unified application suite and shared IoT platform will accelerate business integration and leverage economies of scale by capturing functional best practices and expertise within and across business lines and providing the ability to benchmark, rationalize, and share the benefits of comprehensive data across geographies and industries.
- Additionally, ENGIE and C3 IoT are partnering to establish ENGIE's Digital Factory, a global Center of Excellence that unites highly skilled data scientists, developers, and business analysts to create a self-sustaining group of 100 experts knowledgeable in analytics and data – as well as ENGIE's organization and operations – to propagate techniques and expertise across ENGIE worldwide.
- C3 IoT is training a dedicated ENGIE team to become expert implementers of the C3 IoT Platform and applications in order to meet ENGIE's goal of increasing shared functional expertise, unifying product strategy, and delivering operational data consistently across ENGIE's lines of business.

AECC replaces CEMS with Predictive System for Seven Gas Turbines

- AT AECC in Little Rock analyzers that monitor emissions on seven multi-stage gas turbines needed replacement. The company considered options to either replace their analyzers with new, costly analyzers or replace their hardware-based continuous emissions monitoring system with an alternate solution. AECC recognized that replacing their current system with another hardware-based CEMS would require a significant capital investment. In addition, the ongoing maintenance needs of a hardware CEMS would produce considerable expenses over its lifetime
- AECC thoroughly evaluated the option to implement a software-based system and chose a Software CEM from Rockwell Automation to help achieve its emissions compliance requirements. The model-based, Predictive Emissions Monitoring System (PEMS) utilizes powerful hybrid models of the process with real-time sensor validation to provide predictive emissions values with unparalleled accuracy. The use of hybrid modeling, through empirical models and first principles knowledge, gives AECC the best representation of its process behavior.
- The project has been successful and the system was certified through a Relative Accuracy Test Audit (RATA) as per 40CFR Part75. Software CEM certified its initial RATA at better than 7.5% relative accuracy and surpassed the US EPA, CAMD requirements of +/- 10%.
- *With expanded IIoT will it be relatively easy to incorporate predictive systems?*

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Third Party O & M

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Turbine Services Supports Sites with Different Make Turbines

- Turbine Services supports sites with different make turbines
- Monitoring and diagnostic systems supplied by independent service providers rather than turbine manufacturers can be deployed to suit the operators' requirements, rather than what might suit the manufacturer. And they can be used with different turbine makes and models, and for other types of plants. This is the argument made by **Jonathan Aylett**, of Turbine Services, a Chromalloy company
- For example, a power utility has a fleet of peaking turbines from different manufacturers and of different types, such as heavy industrial and aeroderivative. The utility company uses the same system via the internet to monitor all turbines remotely, and the system can send diagnostic messages to cell phones and email reports to company staff. It has a flexible client-server architecture which can be used in a centralized monitoring center, or decentralized to any location able to connect a client remotely to a server. It can also support remote clients running in web browsers.
- A site data server acquires and archives data from the turbine controllers. Any number of remote clients can connect to it using the company’s internal network, or remotely via internet or modem connection.
- Data update rates for the remote clients can be configured for the bandwidth of the network connection. This can be at once per second over fast LAN or internet connections, or once per hour for slow modem connections. For slow connections, remote clients can be configured to only download trend data and diagnostic messages each day, reducing data transfers.
- A typical data set of 400 analogue and 1500 digital tags is acquired each second and analyzed 24/7. It is impractical to analyze this manually, so the system analyzes the data in real time using diagnostic rules and pre-alarm checkers, generating diagnostic messages which are archived on site.

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ProEnergy is One of Many Third Party O&M Firms and the Trend is Accelerating

- In September 2016 ProEnergy was awarded a contract renewal for the operations and maintenance of five Ameren Missouri facilities including Goose Creek Power Plant, Raccoon Creek Power Plant, Kinmundy Power Plant, Pinckneyville Power Plant and Audrain Power Plant. Under these contracts, ProEnergy will continue to provide site management, planning, scheduling and maintenance services.

  The Goose Creek Power Plant, located near Monticello, Illinois, is a 450 MW facility consisting of six GE 7EA combustion turbines. Raccoon Creek Power Plant is a 300 MW facility located near Flora, Illinois, operating four GE 7EA combustion turbines. Kinmundy Power Plant, near Patoka, Illinois, is operating two W501D5A combustion turbines with a generating capacity of 234 MW. Pinckneyville Power Plant in Perry County, Illinois has a generating capacity of 320 MW, operating four GE LM6000 and four GE 6B gas turbine generators. The Audrain Power Plant is located in Vandalia, Missouri and has a generating capacity of 600 MW, consisting of eight GE 7EA combustion turbines.
- ProEnergy is responsible for the construction, management, operations, maintenance, and repair services for energy generation facilities and equipment around the world. ProEnergy has U.S. offices in Sedalia, Missouri; Houston, Texas; and Fort Collins, Colorado; and international locations in a number of countries including Canada, Argentina, Venezuela, Brazil, Panama, Pakistan and Angola.

McILVAINE

IHI has Flexible Suite of O & M Services

- IHI Power Services Corp. (IPSC) supports power plant owners with a flexible suite of operations & maintenance services.
- IPSC acts as a third-party operator to help plant owners achieve the full economic potential of their plant resources. IPSC is built to provide U.S. power generators with experienced professionals who can utilize their years of hands-on power industry experience to ensure optimal operation of power plant fleets. An example of the company's power plant operations & maintenance services is their training guidance. The company's experts work with plant teams to ensure they are committed to and capable of meeting the industry's best practices. Through customized training programs aligned with the client's plant objectives, the IPSC team guides plant workers on their roles within the organization. It's a service that assures companies of consistently productive working environments and focused personnel.
- IPSC also has experience in the area of maintenance planning. Their team can help plant operators understand the costs of shutdowns and mitigate these costs utilizing a set maintenance program. The IPSC staff crafts customized maintenance programs for plant operators designed to take into consideration the current market environment and the potential long-term operational issues the company may face regarding their equipment. This expert planning guidance empowers proactive decision-making and helps prevent shortfalls in productivity due to unexpected plant downtime.
- Another key area in which IPSC specializes is staffing. Because of the company's experience at the helm of a large number of power plants, they have developed an understanding on plant staffing requirements.

McILVAINE

NRG Energy Services can provide Digital Process Management and Remote Monitoring of its Own and Client Facilities

NRG Energy Services provides nationwide services to operate, maintain and repair electric-generation facilities. Using a proactive approach expert technicians pursue innovative solutions. Capabilities range from minor repairs to complete overhauls.

Total plant O&M services help companies run better, smoother, stronger and more reliably. Clients include operators of power plants, landfills, hospitals, stadiums, universities, and chemical plants.

Services include

- Provide complete operations and maintenance of energy systems augmented with the experience, expertise, resources and support necessary.
- Reduce costs while minimizing downtime, thus reducing total cost of ownership.
- Offer specific and proven services for oil, gas, steam, combined heat and power (CHP) facilities, solar and wind turbines.
- Combine established experience with deep technical expertise for addressing all issues of plant operations and maintenance.
- Supply maintenance and services for gas, wind and steam turbines, reciprocating compressor and diesel engines.

McILVAINE

NRG Energy Services providing O&M to Golden Spread for Two Large Gas Turbine Plants

- NRG Energy Services LLC, a subsidiary of NRG Energy, Inc., has entered into an agreement with Texas-based Golden Spread Electric Cooperative, Inc. to provide operations and maintenance (O&M) services for two generating stations owned by Golden Spread.
- Golden Spread Electric Cooperative is a consumer-owned public utility with 16 member systems providing service to approximately 287,000 customers located in the Oklahoma Panhandle and an area covering 24 percent of Texas, including the Texas Panhandle, South Plains and Edwards Plateau Regions.
- The two Golden Spread facilities – Mustang, a 958 MW natural gas turbine plant in Denver City, TX, and Antelope Elk Energy Center, a 744 MW natural gas facility in Abernathy, TX – will join with nine other generating stations under the O&M responsibilities of NRG Energy Services, representing a 9,200 megawatt portfolio. Leveraging the experience and expertise of NRG, which operates more than one hundred power plants, NRG Energy Services is able to provide first-rate support to owners of large and small generating fleets.
- NRG Energy Services delivers custom-tailored O&M solutions to companies that want to match their plants with the expertise of a premier operating company. NRG Energy Services brings the extensive skills and experience acquired by supporting the leading integrated power company in the United States.
- In addition to providing O&M services, NRG Energy Services' broad technical and engineering expertise and experience allows it to diagnose and recommend effective solutions for plant-related issues. The company's specialized maintenance and repair facilities are designed to restore major rotating equipment, compressors, pumps, and engines and get generating units back online safely and efficiently.

McILVAINE

Wood

- Wood Group has acquired Ingenious Inc., a supplier of proprietary software and consulting services to the global chemical, oil & gas, and energy industries, from its executive leadership team. The acquisition provides a strong manufacturing operations management (MOM) systems capability that builds upon and diversifies the capabilities of Wood Group Mustang's automation and control business, within which it will operate. Ingenious's software products consist of remote performance monitoring, production planning and scheduling, and training, including e-learning and training simulators for the process industries.
- Founded in 2000 by Vibhu Sharma and Bharat Kamdar, Houston-based Ingenious provides consulting and engineering services to support software sales and non-software-related services such as process engineering, design and simulation, and process safety management. Ingenious also has an office in Mumbai, India, that supports regional customers, executes international projects and assists in software development. The Mumbai operations expand the automation and control business's geographic footprint and client relationships in Asia and the Middle East.
- "The capabilities Ingenious provides will enhance the scale and breadth of our automation and control business," stated Michele McNichol, Wood Group Mustang CEO. "Wood Group Mustang has been a client and reseller of Ingenious's products. Together, we can pursue projects that neither could explore independently."
- Vibhu Sharma, CEO of Ingenious, added, "Joining Wood Group Mustang's automation and control business allows us to offer existing and new customers an enviable combination of software and consulting services, from training simulators to performance monitoring, planning, scheduling, environmental, APC, MES and related solutions. It's also a match culturally as we value the same principles that Wood Group embodies. All of us at Ingenious see this as a springboard to establish a strong leadership position in the manufacturing operations management space."
- Wood Group will also be able to leverage Ingenious's strength in the operator training simulator market to enhance its control system simulators, training tools and services.

McILVAINE

Remote Monitoring

McILVAINE

Remote Monitoring

- The large gas turbine suppliers have remote monitoring centers which primarily track the health of rotating parts. This is frequently part of the warrantee program. However, companies such as MHPS are branching out to monitor more of the plant's components. MHPS just opened a remote monitoring center in the Philippines which is monitoring coal-fired power plants. The service center can also provide assistance to power plants not built by MHPS. In addition to its data analysis capabilities, the center can also manage maintenance equipment and dispatch staff in emergency situations. It will, in addition, serve as a training hub for technicians. Every year, around 200 individuals will be picked from both in and outside the company to transfer technical expertise on maintenance and management.
- There is a huge potential for companies such as MHPS and GE to work with other suppliers and incorporate hundreds of individual remote monitoring programs. For example, Nalco operates an around the clock monitoring center on water quality. If companies such as Mann + Hummel can operate filter monitoring centers and, if all the results are integrated for analysis and action, it will greatly improve the support for the operators.
- There is a big potential for interconnection of facilities in large utility organizations. McIlvaine has been involved with a program for Berkshire Hathaway Energy.
- http://home.mcilvainecompany.com/index.php/decisions/28-energy/1185-4s01
- Duke Power has developed central systems which can for example monitor all the pumps at its various stations. However, it is shifting away from the traditional centralized proprietary systems and evolving to support distributed intelligence, interoperability and IoT. Efforts to develop its smart grid have resulted in the enablement of these concepts through what the industry calls OpenFMB (Open Field Message Bus).

McILVAINE

Remote O&M, Data Analytics and Subject Matter Experts

- **Third Party Support for Power Plant Operations and Maintenance**
- Third party operation and maintenance represents the biggest revenue opportunity for IoT in the power industry.
- GE Energy is one of the world's largest third party providers of plant Operation and Maintenance services, currently with more than 16,000 MW at 60 sites in 17 countries under O&M contract. Global resources combined with over 20 years of O&M experience, enable GE to provide complete plant services across the turbine island and balance of plant—for both GE and non-GE equipment.
- Siemens, MHPS, IHI and other turbine suppliers also offer similar services. There are a number of companies specializing in O&M including large companies such as Wood and smaller companies such as Ethos Energy and Proenergy. Uniper and India Power have formed a joint venture to support operations and maintenance at Indian power plants.
- **Data Analytics and Subject Matter Experts**
- The generation of large amounts of data is not of value unless it is properly analyzed for action. XLMPR recommends hybrid data analytics marrying the experience based models with ones based on physics and data. The IoT greatly increases the capability for database models but this data needs to be molded by experience. Subject matter experts are needed to provide the niche expertise in each of thousands of areas. The pool of recently retired people can be tapped for their unique combination of knowledge and availability for short engagements.

McILVAINE

Laborelec (ENGIE) has Remote Monitoring and Niche Expertise Capability

Laborelec offers the full range of power plant monitoring services, including remote monitoring. Experts follow up on alarms, anticipate problems, immediately inform plant operators of potential issues, and advise them on the necessary maintenance interventions.

- Early fault detection. Monitoring enables Laborelec to identify problems at an early stage so that they can be addressed before costly damage occurs.
- Predictive maintenance and condition-based maintenance. The condition monitoring of in-service equipment helps predict when and which type of maintenance should be performed

Laborelec is a research and competence center in electrical power technology. It was established in 1962 in order to support Belgian electricity companies with research, development, and specialized services. Today, it is part of ENGIE, a leader in energy. Its research and support extend to water quality investigations and analysis of air intake filters for 40 gas turbines and analyses to help improve selection and operation for a U.S. power plant operator.

This operation would have the niche expertise and remote monitoring center staffing to support for example gas turbine inlet filter decisions at gas turbines world wide.

McILVAINE

Ethos Energy operates Monitoring and Diagnostic Center

The EthosEnergy Monitoring & Diagnostics (M&D) center monitors the performance of all turbine technologies, including:

- Equipment thermal performance
- Combustion dynamics
- Advanced vibration
- Predictive maintenance
- Dispatch optimization objectives

M&D is offered at three levels:

- Combustion system monitoring (ECOMAX®)
- Full turbine monitoring (turbine, generator & compressor)
- Full plant monitoring

Operating parameters are assessed in real-time for any anomalies using scanning and comparison algorithms as well as equipment performance equations. Whenever an operating parameter is outside of specifications, a real-time alarm is generated and automatically notifies all relevant parties of the anomaly. Additionally, the M&D Center personnel compile operating data and send quarterly reports that document tuning and performance information, data on each tuning event and, if applicable, ECOMAX performance results.

November 2016 Contract

EthosEnergy has been awarded a seven year contract for full operations and maintenance (O&M) services, plus installation of EthosEnergy's proprietary ECOMAX® technology, by Rockland Capital in support of Michigan Power, a 1x1 GE 7EA natural gas fired combined cycle cogeneration plant in Ludington, Michigan. The contract is for full care, custody and control operations, and maintenance including transition services, plus the installation of EthosEnergy's advanced ECOMAX® auto combustion tuning technology. This is the second facility of Rockland Capital's to have ECOMAX® installed in the last twelve months, and third in total.

McILVAINE

Siemens Monitors More Than 9,000 Turbines at its European Data Center

- All technologies for Siemens Digital Services are pooled under the new Sinalytics platform, explained Thilo Libuda, Head of Marketing for Instrumentation, Controls, and Electrical within the Siemens Power & Gas Division: "It combines proven capabilities for remote maintenance and optimization with the latest developments in data analysis, connectivity, and cybersecurity." It can also integrate engineering data or data generated by people, Libuda said.in an interview with *Power* Magazine.
- Sinalytics works both in the cloud and locally — for example, at a Siemens data center in Europe or the U.S. — or by intelligent networked devices in the field, where data are generated.
- Siemens monitors more than 9000 turbines (wind and fossil-fueled) online. Every day, the gas turbines generate some 26 GB of data while wind turbines generate 200 GB. Remotely monitoring turbines can provide multiple benefits, including longer service intervals and predictive maintenance and maintenance planning, which can lead to increased profitability for customers. For wind turbines, Siemens says it can provide remote remedies for 85 percent of all alarm situations.
- Libuda emphasized the company's comprehensive cybersecurity program that allows confidential data to be transmitted and analyzed securely plus technologies to "detect and investigate attacks from the Internet and defend against cyber-attacks on critical infrastructure components."

GE Gas Turbine Remote Monitoring Center

- Every day, at its Monitoring & Diagnostics (M&D) Center, GE collects more than 30,000 operating hours of data from a fleet of more than 1,500 gas turbine and generator assets, supplementing a 40-terabyte database representing more than 100 million fleet operating hours
- The Atlanta-based facility features a team of more than 50 engineers that analyze more than 35,000 operational alarms per year. Among the activities monitored at the center are the inlet temperature of a compressor, thermal performance of a gas turbine, temperature of combustion exhaust, dynamic tones of the combustion system, vibration levels of a rotor and the temperature of bearings. On a GE gas turbine unit there are more than 100 physical sensors/300 virtual sensors.
- “Our monitoring and diagnostics team and capabilities, play a key role in helping GE customers operate their power plants at high levels of performance and reliability,” said Justin Eggart, general manager, fleet management for GE’s Power Generation Services business. “Our team takes a holistic approach to what we call ‘predictive maintenance,’ which focuses on helping customers sidestep operational barriers before they occur, no matter what type of equipment they are managing.”
- The ability to foresee and forestall issues is at the very heart of predictive maintenance. Predictivity solutions for GE’s power generation customers harness massive volumes of data analyzed from one of the world’s largest monitored gas turbine fleet to develop solutions that allow them to make more informed operational and business decisions

McILVAINE

Ansaldo Remote Monitoring and Diagnostic Center

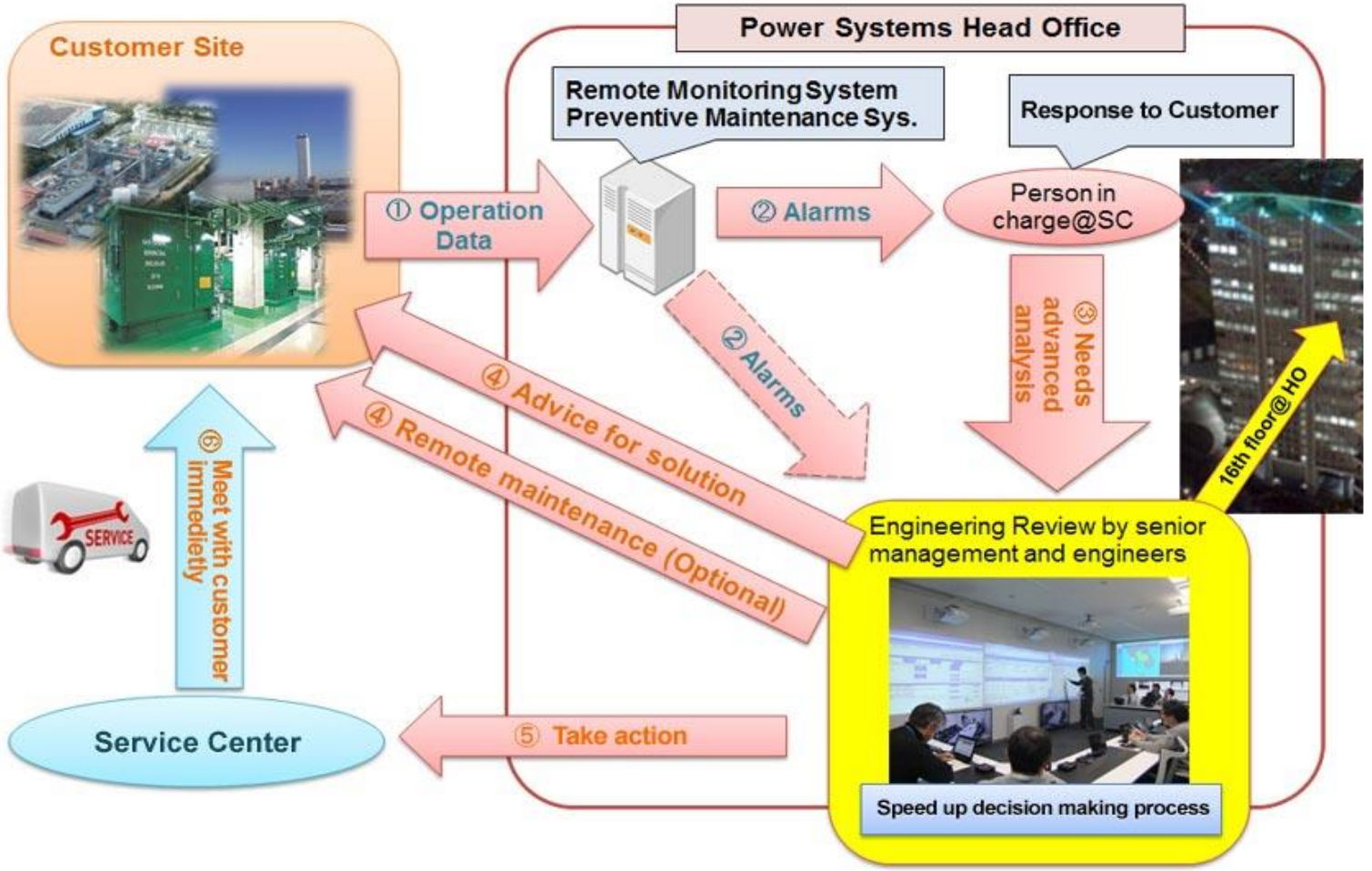
- ADA™ Advanced Diagnostic Analysis is the Ansaldo Energia suite for condition-based maintenance. Based on its modular design, ADA™ allows for advanced monitoring of main equipment parameters like steam and gas turbine performances, gas turbine combustion, machinery vibrations, generator diagnostic, electrical transient and others. Computing modules, automatic report generation, alarms notification, large data storage capabilities are some of the key features of this state of the art product in the field of remote monitoring and diagnostic.

- Through Remote Monitoring, all the relevant data are readily available to experts who, in many cases, can understand quickly the situation and give helpful indications to solve the matter. If additional on-site support is needed Ansaldo can provide at short notice skilled engineers who can assist directly and act as a link with the Operation Support Team.
- Main advantages of Remote Diagnostic and Operation Support are:
- Constant monitoring of your equipment
- Reduction of unscheduled outages
- On condition maintenance, tailored on specific requirements
- Spare parts management support
- Decision support for unexpected trips or events
- Quick response time for site engineering support
- Engineering support for troubleshooting

McILVAINE

IHI Remote Monitoring Center for Gas Turbines

Remo-moni™ is IHI's Remote Monitoring System(RMS) of Gas Turbine Driven Generator Power Plants.Remo-moni™ is an advanced monitoring system for gas turbine power plants.
IHI has the ability to observe the customer's plant from the IHI monitoring center and advise on operations and maintenance.
It is for a) Safe Operations, b) Improving High Availability and c) Save Maintenance Costs of Gas Turbines Power Plant Operation.Remo-moni™ is installed easily by connecting to internet.
since 1995 the number of Installations has grown to 77 units and 47 sites.



MHPS Supplies Records of Daily Activity and Insights on Performance and Availability

- RMC operators and engineers have the ability to trend all of this information, or display it in tabular form, for quick comparison during troubleshooting exercises and root-cause evaluation. RMC-developed troubleshooting guides and a complete library of unit-specific drawings, procedures, and control logic diagrams are used by the RMC staff to assist the customer in everyday plant operations. A unique set of Customer Relationship Management (CRM) tools, including a web-based journal, service request system, and lessons-learned database, are used to document and track the daily events at each site. Standardized reports are used to give the end-user insight into the performance, availability, and efficiency of their power plant and to provide suggestions on how to improve the operating capacity of the monitored equipment.

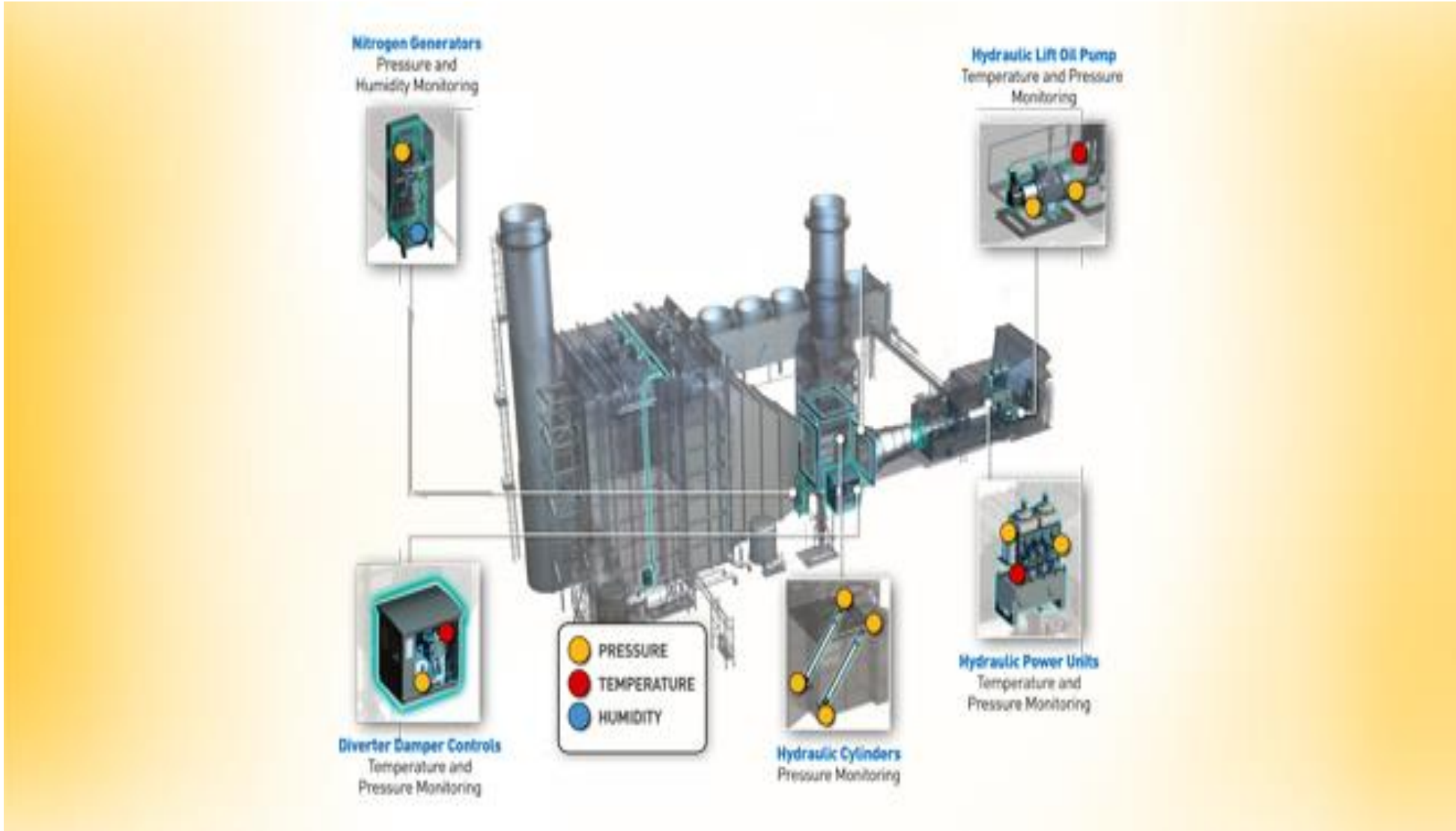
McILVAINE

Parker has Condition Monitoring for Gas Turbines

- Condition monitoring plays a significant role with that. By employing an effective solution that monitors the temperature, pressure, and humidity levels of a plant's assets, operators can diagnose problems or damage to turbines and inconsistencies among processes. Addressing and repairing these issues before they become problems saves downtime and replacement costs.
- Humidity and moisture in the gearbox can cause less than optimal operation of rotary components, leading to corrosion, reduced product quality, and ultimately breakdown. Monitoring a system's performance can be a good indicator of any potential problems with a turbine. By keeping tabs on a system's humidity, as well as the ambient humidity of the plant, operators can gauge any potential effects to a turbine's performance.
- To keep a turbine operating consistently and with minimal chance of overheating, it is necessary to keep components within the gearbox well lubricated and cooled with clean oil. A good filtration package is also important. Monitoring changes of a system's temperature and pressure levels can help operators identify when filters and/or oil in the turbine may need replaced.
- Also, monitoring for increased fuel consumption and/or reduced output could indicate a more serious problem, such as compromised integrity of rotary components within the turbine. Such issues can lead to displacement or damage to toothed gears, blade damage or fatigue failures and other structural damage that will ultimately impact a system's performance.
- Parker's SensoNODE™ Blue sensors and SCOUT™ Mobile software allow users to monitor conditions using multiple sensors simultaneously, each measuring the temperature, pressure, or humidity of specific points within a system. Using Bluetooth technology, the sensors transmit large volumes of data to mobile devices wirelessly, keeping operators out of dangerous situations

McILVAINE

Parker Condition Monitoring for Gas Turbines



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Individual Company Opportunities

Braden

Group	Importance
Gas turbine auxiliaries	The company supplies new equipment and consumables for air treatment and emissions from gas turbines
Inlet turbine filter elements	Monitor pressure drop across filters and supply a maintenance program to replace
Lubrication and other filters	Provide lubrication monitoring and replacement of filters as needed
Emission control CEMS	Monitor CEMS but share data from supplier such as ThermoFisher so that both can review it
Emission control catalyst	Provide catalyst replacement program based on CEMS data
Urea supply	Work with Yara who has remote monitoring and supply on demand for Urea for the SCR
Dampers and valves	Remote health monitoring
Noise suppression	Remote monitoring

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Berkshire Hathaway

Group	Importance
BHE (MidAmerican, NV Energy, PacifiCorp)	7% of U.S. power generation of coal, gas, wind solar, hydro and biomass
BHE Renewables	Producing tomatoes with CO2 from GT plant
BHE Pipeline	Gas engines and turbines at compressor stations
Johns Manville	Insulation for gas turbines and engines
Marmon Filtration	Filters for power plants including condensate filters for HRSG
Intelligent Energy Solutions (IES)	Cloud based service solutions for retail energy and others
Mcilvaine has a Decision System for the power plants with details on each plant and the synergies in equipment. Nine hours of webinars proved the value of wise crowd initiatives. IES could be the foundation of IIoT for the corporation. More details are found at 4S01 Berkshire Hathaway Energy Supplier and Utility Connect	

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Engine Applications

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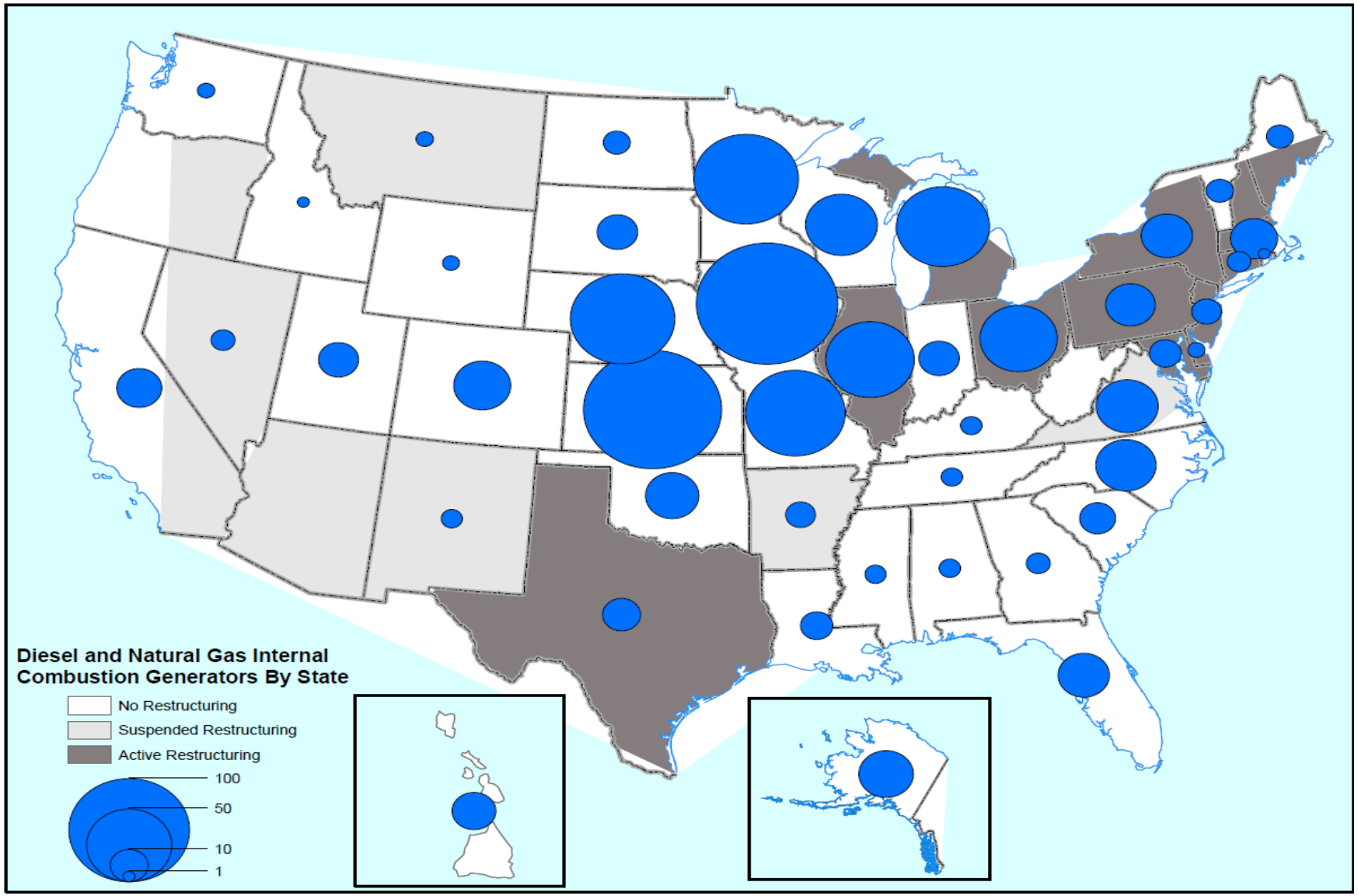
Diesel and Natural Gas Internal Combustion Generators by State



Drivers for the Growth in Use of Gas for Power Generation

- Availability of low cost natural gas (including LNG and shale) in many countries
- Growth in synthetic gas production in China and coal bed methane and biogas use elsewhere
- National and international policies curtailing the use of coal-fired power generation
- Need for grid reliability due to the increasing reliance on renewables such solar and wind

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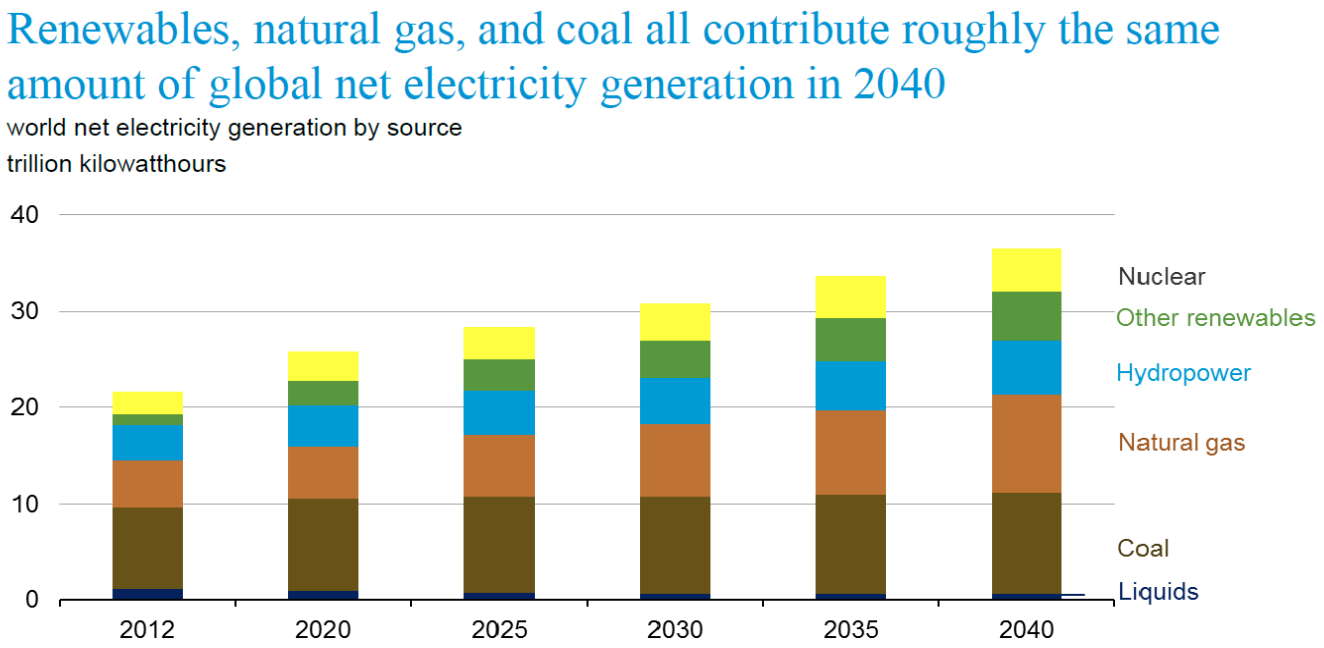
Factors Favoring Growth in the use of Stationary Engines for Power Generation

- Decentralization of power generation due to:
  - Higher relative cost of large, centralized coal and gas turbine combined cycle plants
  - Greater use of on-site or captive power generation at larger power users such as manufacturing facilities and data centers in order to cut costs
  - Flexibility to convert emergency power to standby power at data centers and other major facilities
  - Lack of transmission lines in developing countries and cost of building transmission lines in developed countries
  - Availability of small scale LNG and virtual pipeline technologies
  - Recent improvements in the operation and efficiency of gas reciprocating engines
- Environmental initiatives driving the use of stranded and flared gas
- The high efficiency (up to 90 percent) of combined heat and power
- The fertilization effect of CO_2 from gas engines and impact not only on small greenhouses but large enclosed agricultural operations

McILVAINE

Age of Gas

For the last century coal has been the fuel which provided the electricity and in many cases heat and steam. The next half century belongs to gas with solar and wind becoming more important after 2050. By 2040, natural gas will be used to generate one-third of the world's electricity.



Source: EIA, International Energy Outlook 2016

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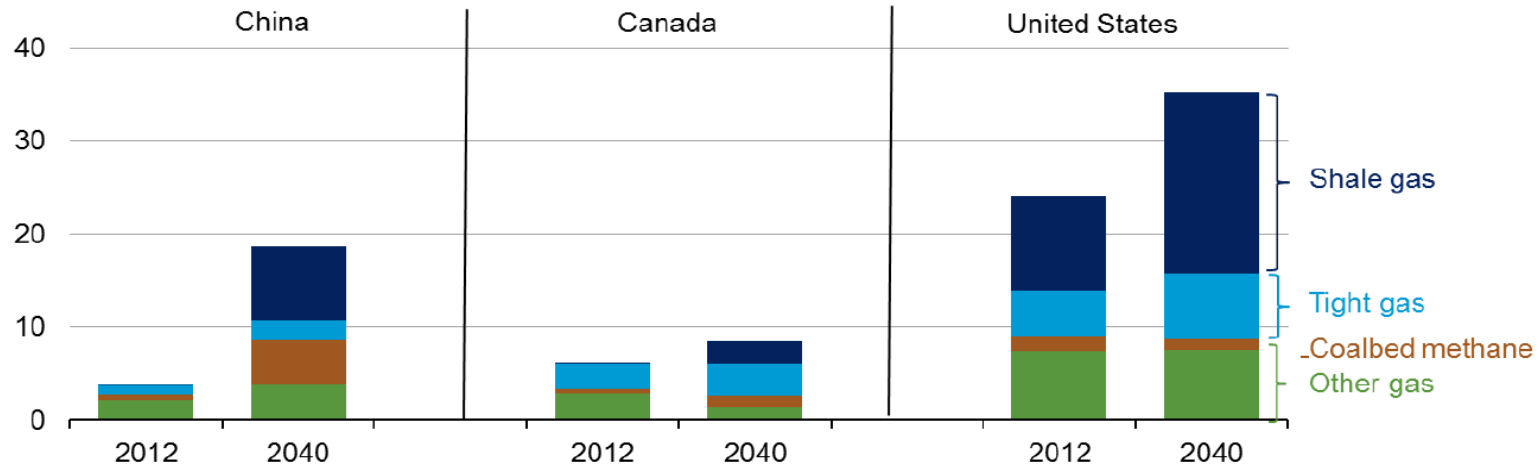
Natural Gas Production by Type

With a growing demand for natural gas, countries will rely more and more on non-conventional sources of gas, including shale gas, tight gas and coal bed methane.

Shale gas, tight gas, and coalbed methane will become increasingly important to gas supplies, not only for the U.S., but also China and Canada

natural gas production by type
trillion cubic feet



Note: Other natural gas includes natural gas produced from structural and stratigraphic traps (e.g. reservoirs), historically referred to as 'conventional' production.

Source: EIA, International Energy Outlook 2016

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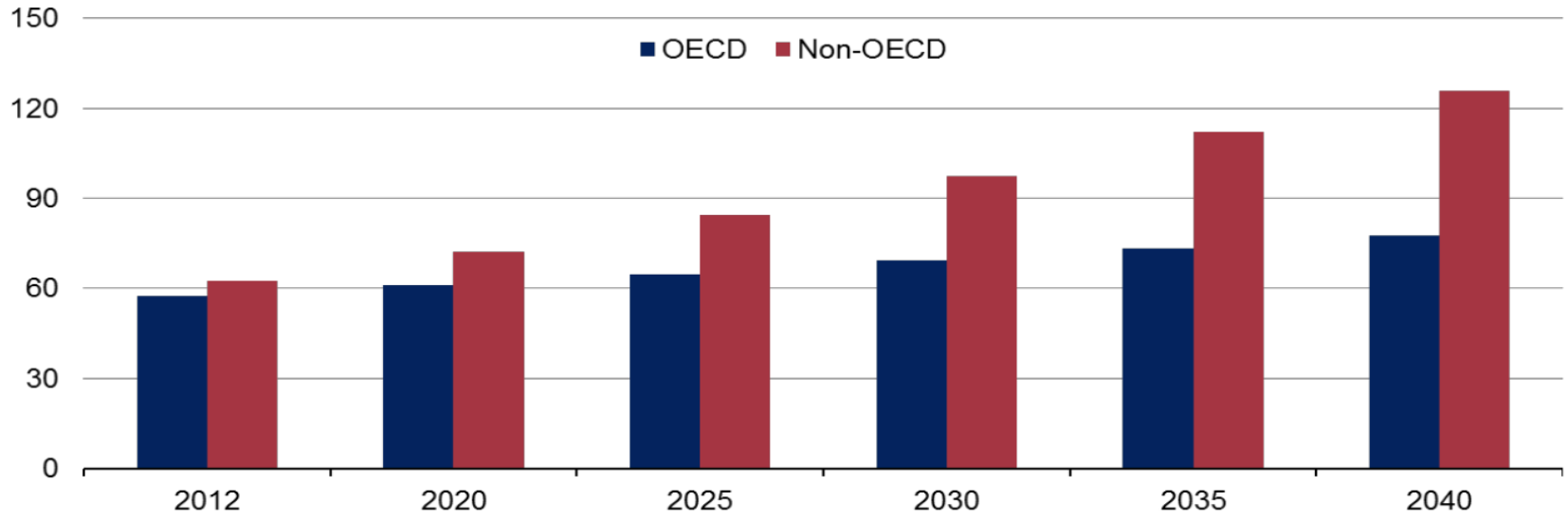
Developing Countries will have Greatest Growth in Consumption

Developing countries will account for the greatest growth in gas consumption. Since many of these do not have adequate transmission infrastructure for either gas or electricity, decentralized power generation will be favored over larger central generating facilities. The question then becomes: How much of this expanded gas consumption will be in gas engines as opposed to gas turbines or simple water and air heating units?

Non-OECD nations will account for 76% of the growth in natural gas consumption

world natural gas consumption
trillion cubic feet



Source: EIA, International Energy Outlook 2016

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Projected Number of New Stationary CI (Diesel) Engines per Year from 2011 through 2017

HP Range	2011	2012	2013	2014	2015	2016	2017
50-100	21,481	22,243	23,006	23,768	24,530	25,293	26,055
100-175	19,061	19,615	20,168	20,722	21,276	21,829	22,383
175-300	19,230	19,911	20,592	21,273	21,954	22,635	23,316
300-600	7,004	7,168	7,333	7,498	7,662	7,827	7,991
600-750	960	976	993	1,009	1,026	1,042	1,059
>750	4,781	4,908	5,034	5,160	5,287	5,413	5,539
Total	**72,516**	**74,820**	**77,125**	**79,429**	**81,734**	**84,038**	**86,343**

*The projected number of new stationary CI engines in this table represents non-emergency and emergency engines.

McILVAINE

Distributed Power

- Distributed power is power generated at or near the point of use. This includes technologies that supply both electric power and mechanical power, which provide torque to move liquids (such as oil) and objects (such as boats and trains). Distributed power technologies can be stationary (typical of electrical applications) or mobile (as in marine and locomotive applications). The potential output of a distributed power system can be measured in terms of its horsepower (hp) or electrical capacity (kilowatts or megawatts). Although there is no standard definition, distributed power systems are typically less than 100 megawatts.
-
- In 2014, GE published a white paper entitled "The Rise of Distributed Power." GE estimated that $150 billion was invested in distributed power technologies worldwide in 2012, including 142 GW of distributed power capacity as well as mechanical drive and propulsion applications. By 2020, GE estimates that annual distributed power capacity additions will grow to 200 GW, an average annual growth rate of 4.4 percent. During this period, the investment in distributed power technologies will rise from $150 billion to $206 billion.

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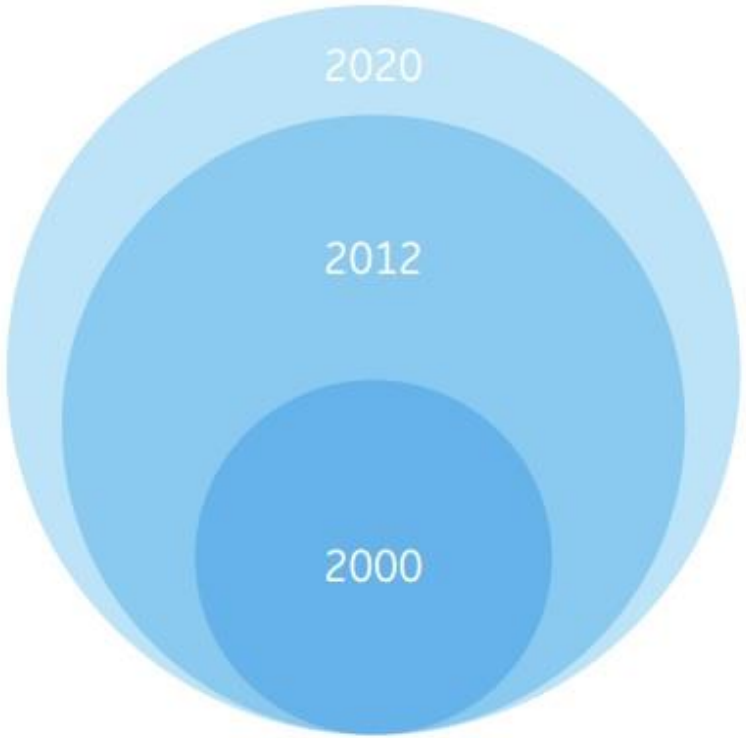
Distributed Power, cont.

Global distributed power installations and investment are on the rise. By 2020, $206 billion will be invested annually. Distributed power applications will account for 42 percent of global capacity additions.



2020
200 GW
$206 billion USD
42% Share of Capacity Additions

2012
142 GW
$150 billion USD
39% Share of Capacity Additions

2000
47 GW
$30 billion USD
21% Share of Capacity Additions

Source: General Electric, Diesel & Gas Turbine Worldwide, European Photovoltaic Industry Association.

McILVAINE

Potential Growth of CHP in the U.S.

- While CHP has been in use in the U.S. for more than 100 years, it remains an underutilized resource. CHP currently represents only eight percent of U.S. generating capacity, compared to 30 percent in countries such as Denmark, Finland and the Netherlands. The U.S. Department of Energy published an extensive study of the potential for combined heat and power (CHP) in March 2016, concluding that the CHP use in the U.S. is expected to grow as policy makers begin recognizing the benefits.
-
- Existing facilities with installed CHP tend to be concentrated at large industrial manufacturing facilities, such as chemicals, refining and paper. However, the DOE report concludes that a significant portion of the remaining technical potential for on-site CHP is located in commercial facilities.

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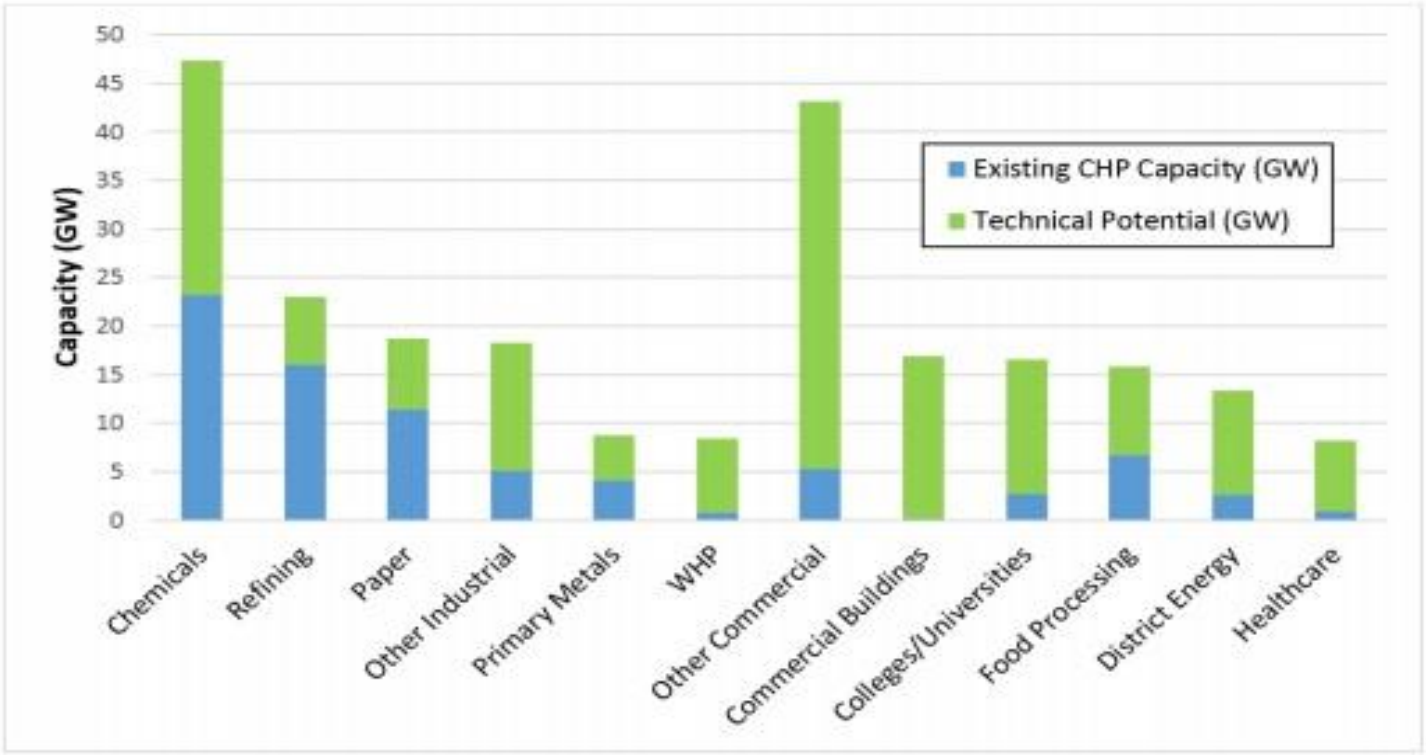
Existing CHP Compared to On-Site Technical Potential by Sector



U.S. DOE CHP Deployment Program, 2016.

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Total U.S. CHP Technical Potential Across All Facility Types

Across all CHP categories, DOE estimates that there is at least 240GW of technical potential at some 291,000 sites within the U.S.

Although reciprocating engines currently make up less than one percent of current CHP capacity in the U.S., the potential for growth is significant.

Business Type	50-500kW		0.5 - 1 MW		1-5 MW		5-20 MW		>20 MW		Total Sites	Total Capacity (MW)
	# Sites	Capacity (MW)	# Sites	Capacity (MW)	# Sites	Capacity (MW)	# Sites	Capacity (MW)	# Sites	Capacity (MW)		
On-site Industrial CHP	34,502	6,281	6,069	4,341	7,424	15,567	1,901	17,036	479	22,157	50,375	65,381
On-site Commercial CHP	185,625	20,068	37,939	18,100	15,535	20,284	1,084	9,452	174	8,026	240,358	75,930
On-site WHP CHP	332	73	132	95	341	868	204	2,003	96	4,585	1,105	7,624
Export Industrial CHP	na	0	na	7	na	3,929	na	11,535	na	65,578	na	81,048
Export District Energy CHP	0	0	0	0	5	18	8	75	51	10,567	64	10,660
Total	**220,459**	**26,422**	**44,140**	**22,543**	**23,305**	**40,666**	**3,197**	**40,101**	**800**	**110,913**	**291,902**	**240,644**

U.S. DOE CHP Deployment Program, 2016.

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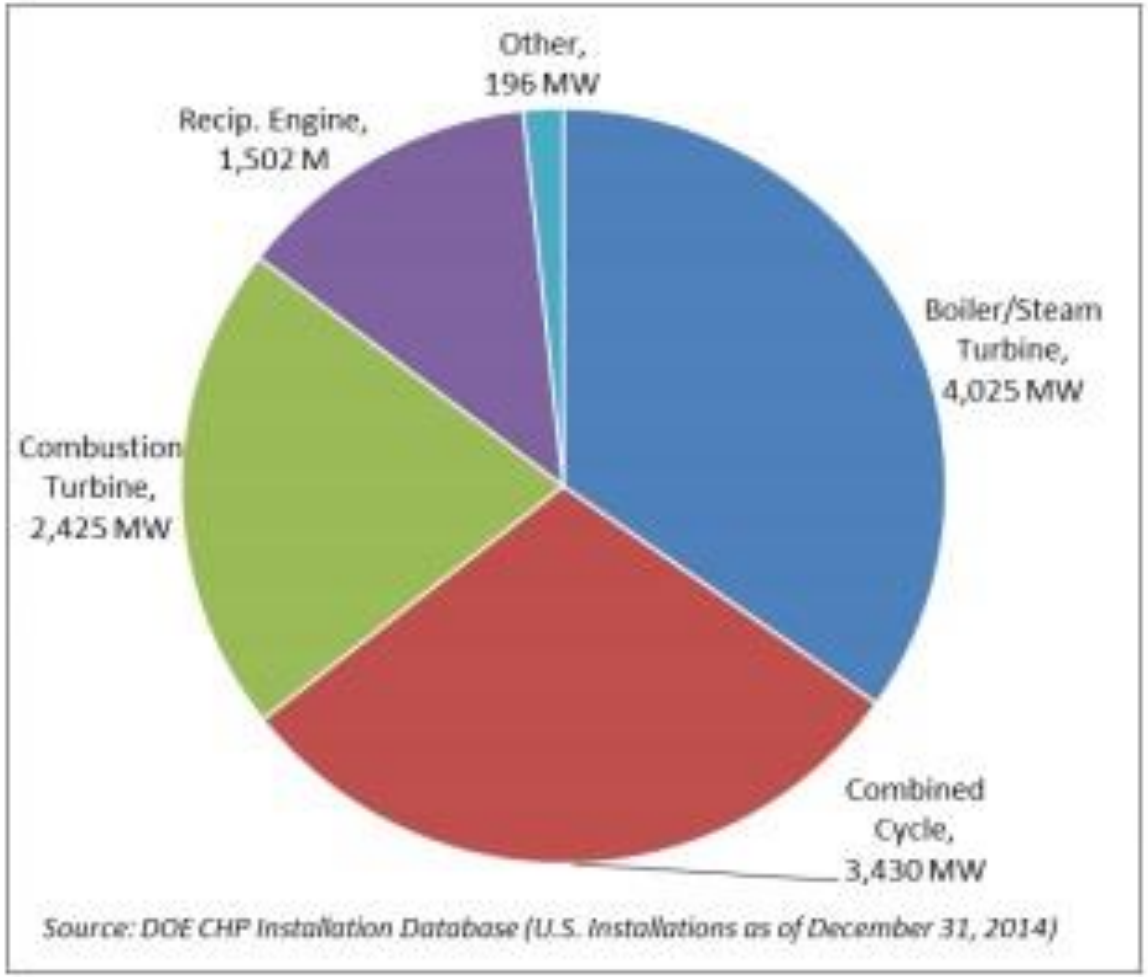
Existing Commercial CHP Capacity by Prime Mover



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Remote Monitoring of Compressor Station Engines with Rockwell PlantPAx

- CenterPoint Energy-Mississippi River Transmission (CNP-MRT) owns and operates 8,200 miles of transmission pipeline that carried 1.6 trillion cubic feet of gas throughout a nine-state region in one year. Delivering such large volumes of natural gas through pipelines requires adequate pressure, which is accomplished by reciprocating engine compressors typically every 40-100 miles. For CNP-MRT, each compressor station includes an average of four compressor engines, and at least one of the four engines will run at 80 percent 365 days of the year. These engines maintain a pressurized flow—up to 2,500 psi—to reduce gas volume up to 600 times and propel it through a pipeline.
- This process entails heavy reliance on data from resistance temperature detectors (RTDs) and thermocouple sensors to control the engine compressors. Unfortunately, CNP-MRT's legacy automation system provided little visibility for remote management of the equipment, so the company embarked on a pilot project to update its control architecture at one station that moves natural gas across a three-state region—Missouri, Arkansas and Illinois.
- For this pilot project at Horseshoe Lake station, CNP-MRT tapped Rockwell Automation's PlantPAx distributed control system (DCS) and its open-architecture platform to constantly monitor engine operational data, such as speed and load control visibility.

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Rockwell PlantPAx, cont.

- Via FactoryTalk Site Edition (FTSE) and FactoryTalk Machine Edition, CNP-MRT accessed more data on unit performance, emissions and even the safety of engines that pump and run on gas.
- The control system also determines which compressor units should start based on engine hours and the number of engines the system controls.
- Newly added insights into the process include a window on compression by incorporating performance metrics and the situational display of production information at engine, station and pipeline system levels. Other data points are reporting on real-time engine events, along with analysis tools and management dashboards that provide operators localized, role-based information for better decision-making on maintenance shifts.

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Condition monitoring, Dynamic Maintenance Planning and Condition Based Maintenance

Condition Monitoring (CM)

Remote monitoring of equipment parameters and operational data.

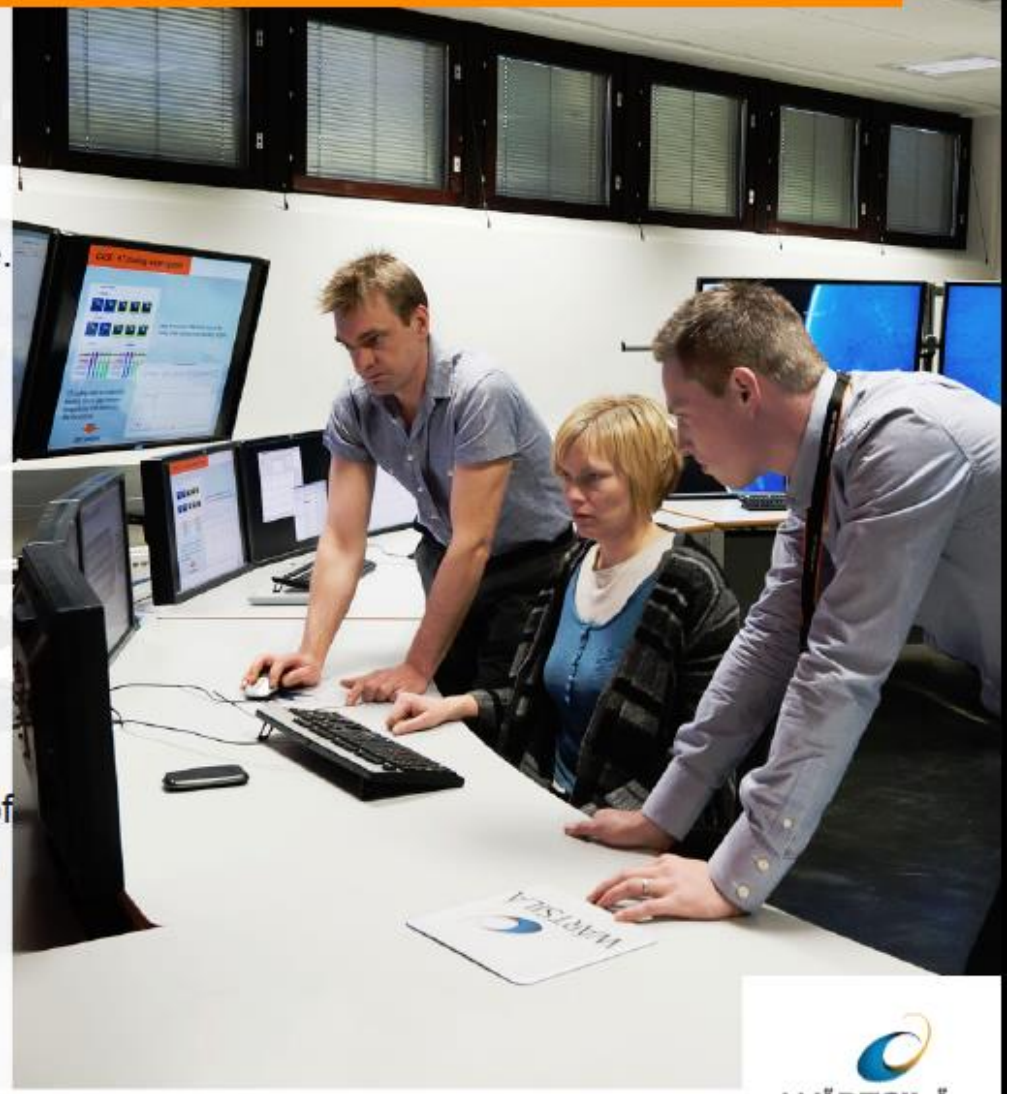
Supports operators in maintaining and optimising equipment original performance.

Dynamic Maintenance Planning (DMP)

Enables fine-tuning of operating parameters and adjustments of maintenance intervals for main components.

Condition Based Maintenance (CBM)

Optimises the availability, reliability and performance of installed equipment. Part of Wärtsilä's Dynamic Maintenance Planning concept.



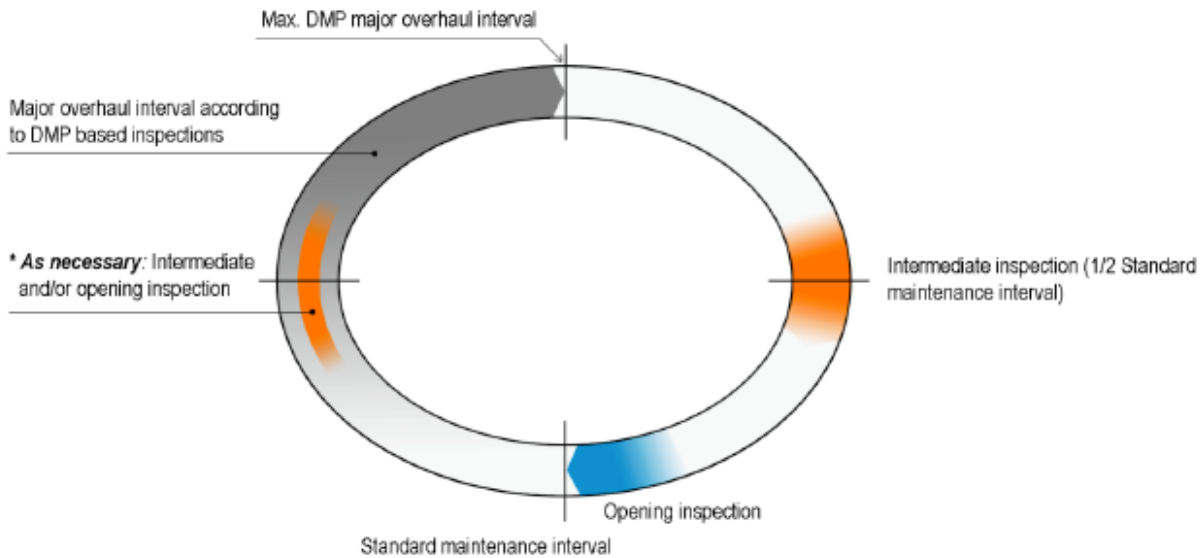
DMP Concept

DMP solution assist in meeting the technical, economical and environmental performance targets of an installation.

The DMP solution enables fine-tuning of operating parameters and adjustments of maintenance intervals for main components.

DMP consists of:

- Remote Condition Monitoring service
- Site audits and intermediate / opening inspections
- Maintenance planning service



* Depending on the operating conditions and results from previous inspection

DMP Concept

Remote condition monitoring

CBM collected data

Operating crew reporting

Fuel/ Lube oil analysis
Extended condition monitoring

Site audit and inspections

Execution of inspections

Report findings

Maintenance Planning

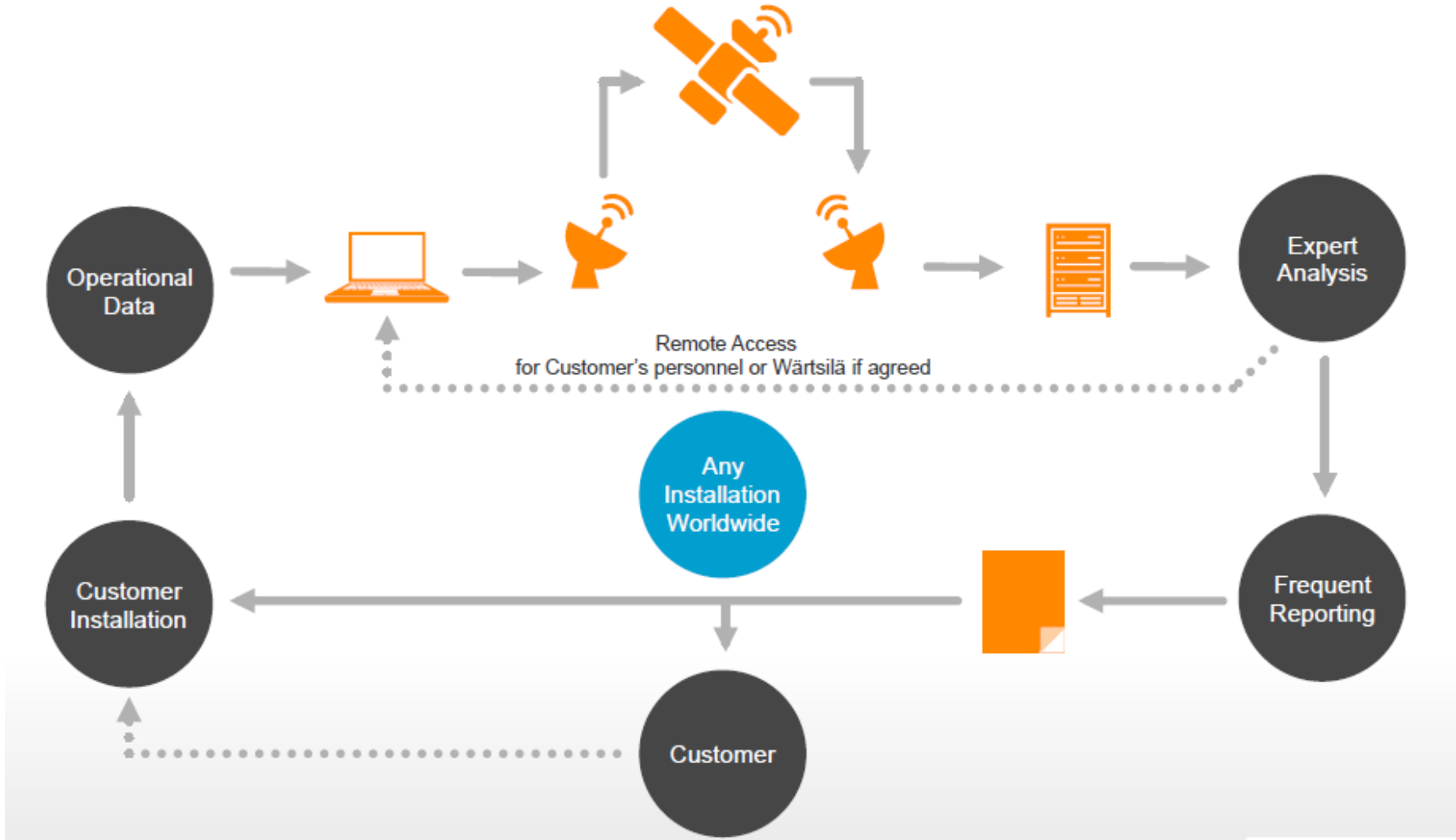
- CBM reports
- Measurements based on analysis update
- Work cards
- Spares scheduling
- Workforce scheduling
- Logistics and coordination report
- Recommendations actions needed

Online Report

Work orders

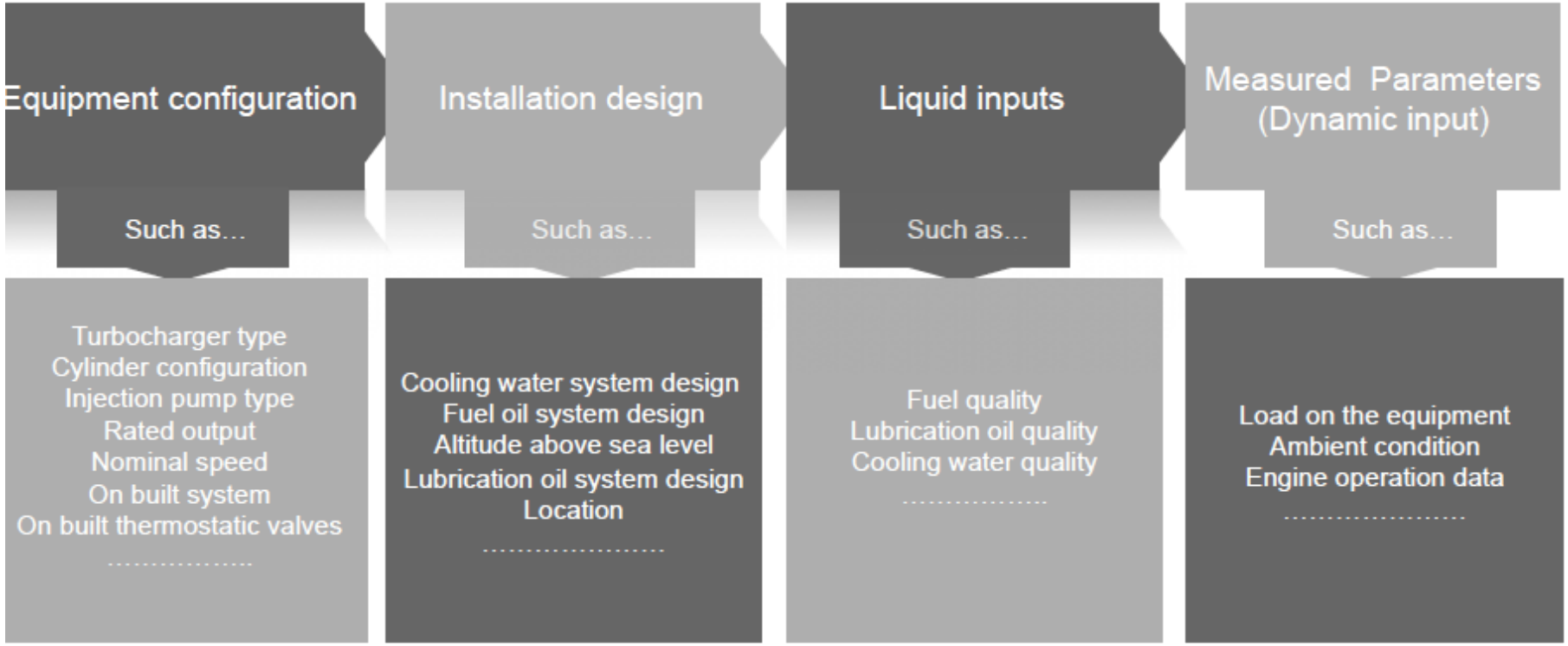
WÄRTSILÄ

CBM Way of working



How the engine health is determined?

The engine key operation data is continuously collected and combined with other relevant data. Comprehensive good quality condition evaluation is combination of high accuracy measurements, operation data and co-operation



Cummins CHP Systems provide up to 90% Energy Efficiency

- Running a greenhouse facility is an energy-intensive operation. Cummins helps growers establish independent power plants that deliver reliable electricity and thermal energy to fuel greenhouse operations. Our CHP systems provide up to a 90 percent energy efficiency and utilization, resulting in as much as a 30 percent reduction in energy costs. Any surplus power can potentially be sold back to the grid. And, because waste heat is captured, CHP can also fulfill the thermal heating requirements of the greenhouse.
- With a CHP system, greenhouse growers can capture two of today's most common waste products — exhaust heat and CO_2 — and convert them into tangible gains. CHP represents a true win-win scenario for greenhouse growers, allowing them to simultaneously increase yields while establishing environmentally responsible operations.

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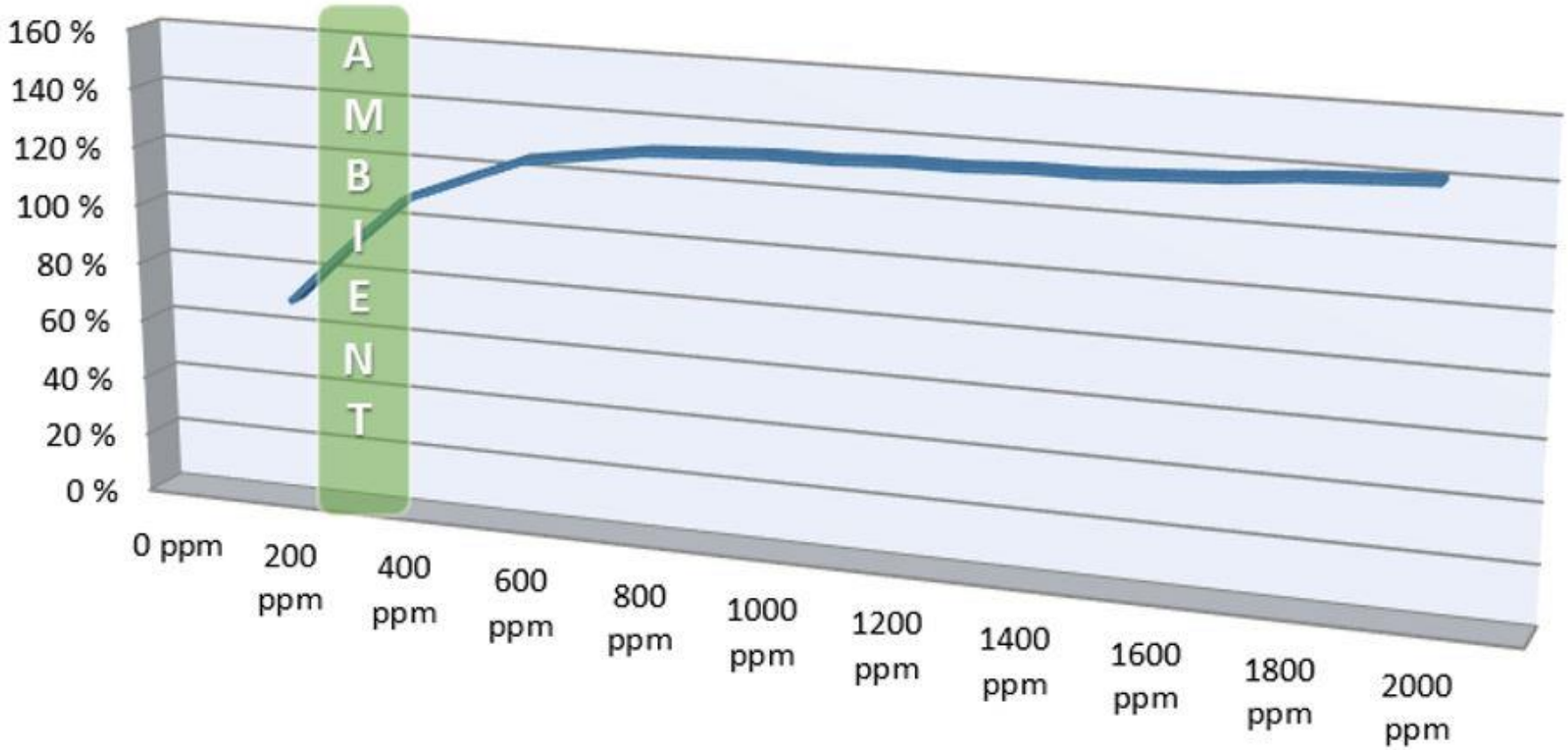
CO2 Cleaned and Returned to Greenhouse to Gain 30% Plant Growth (600 ppm)



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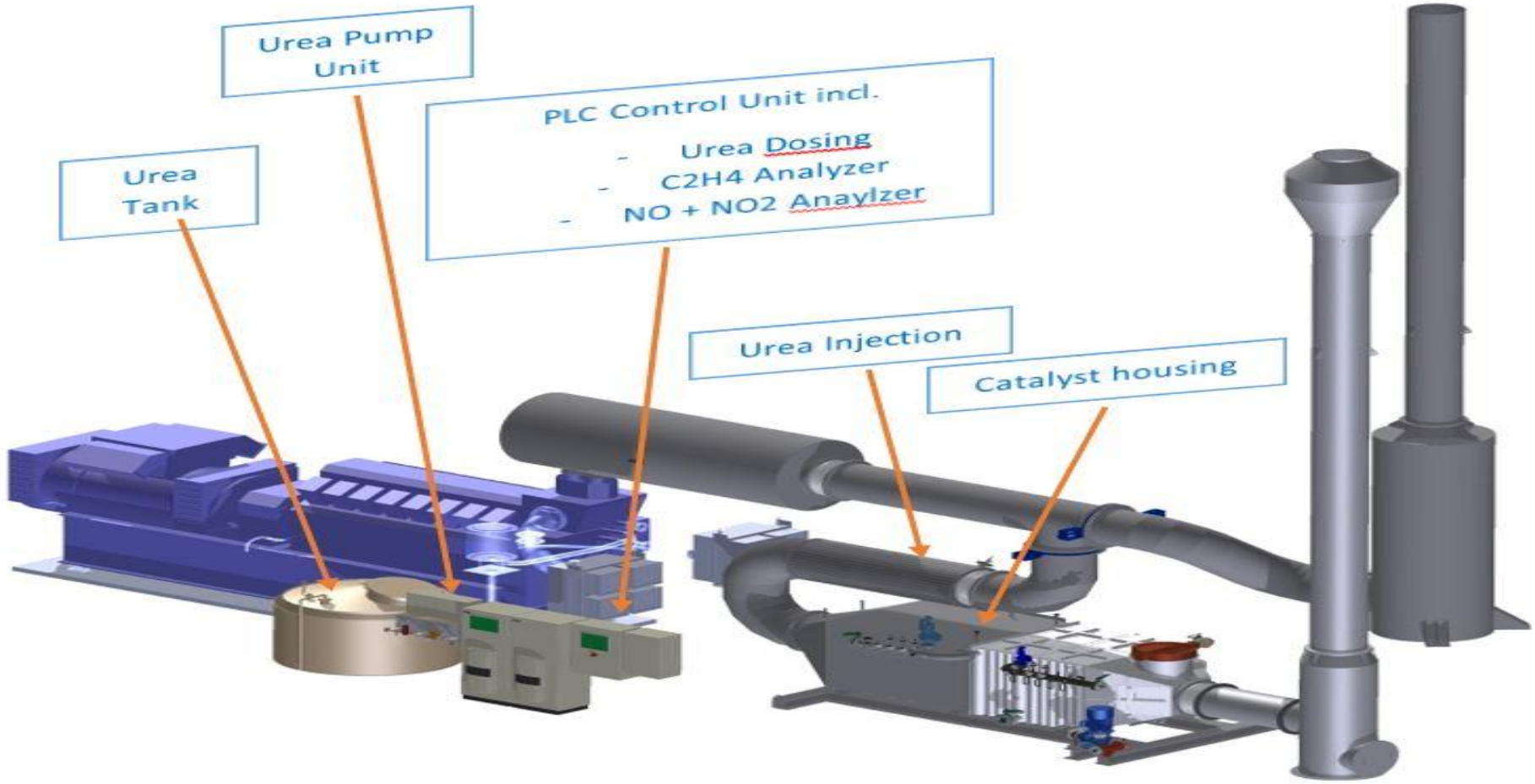
H&H SCR System Reduces NOx and delivers CO2 to the Greenhouse. System could be Remotely Monitored



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Clarke Energy provides Turnkey Engine Systems for CHP, Greenhouses, and Other Applications

- Clarke Energy provides the engineering, installation and maintenance of engine-based power plants. Their offering includes both gas and diesel-fueled technology. Clarke is the largest authorized distributor and service provider for GE's reciprocating engine business with a global turnover in excess of £230 million. Clarke Energy can either supply an individual generator, or deliver an EPC turn-key multi-engine power plant backed up by long-term service support. Clarke Energy is a specialist in high efficiency utilization of fuels and is an innovator in the field of combined heat and power (CHP) or cogeneration technology.
- Clarke Energy has multinational operations in Algeria, Australia, Bangladesh, Botswana, Cameroon, France, India, Ireland, Lesotho, Morocco, Mozambique, New Zealand, Nigeria, South Africa, Swaziland, Tanzania, Tunisia and the United Kingdom. Clarke Energy is committed to delivering the highest quality installation along with a reliable, localized service support network in all the territories in which it operates.

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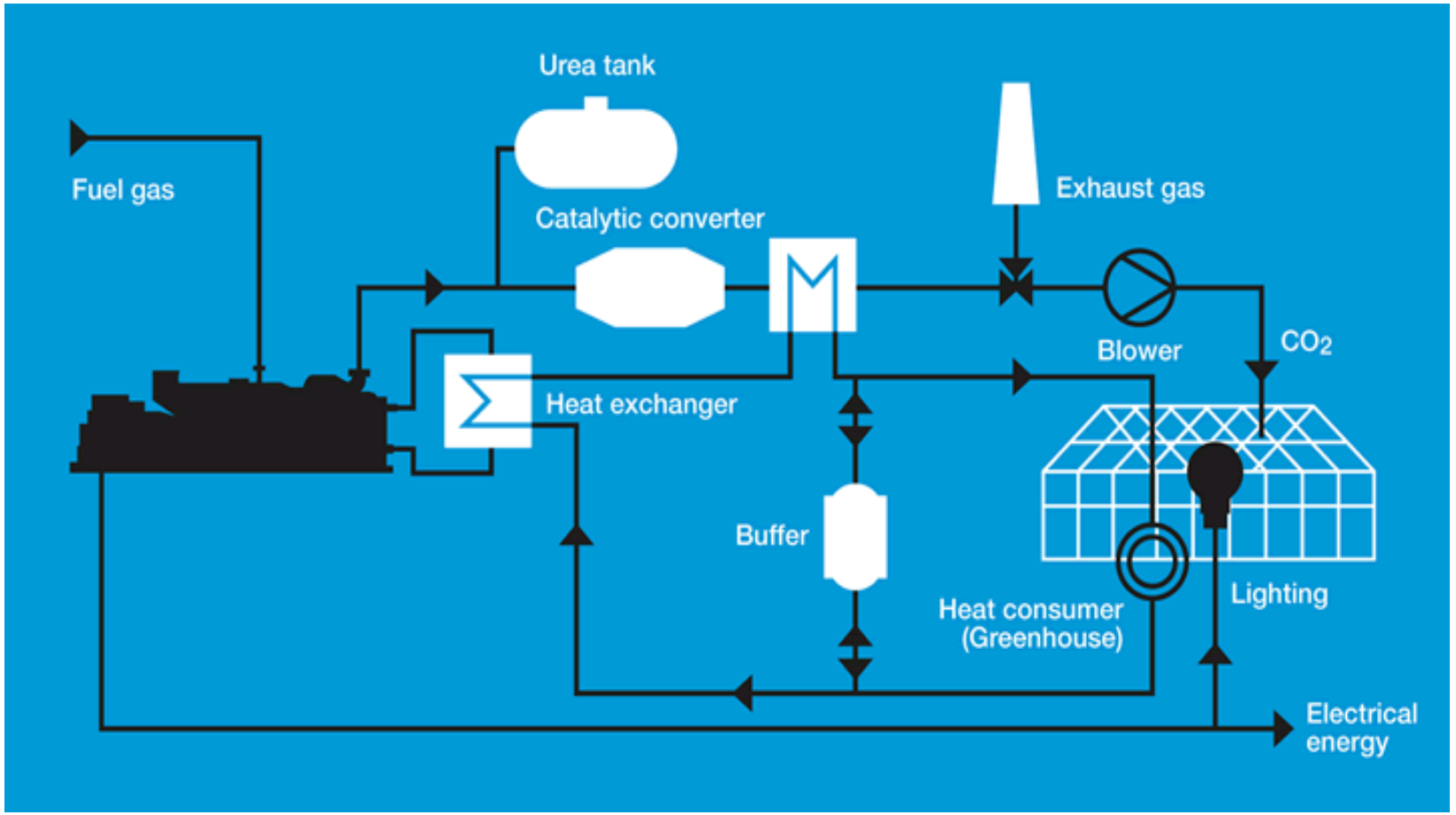
Clarke Energy Greenhouse System

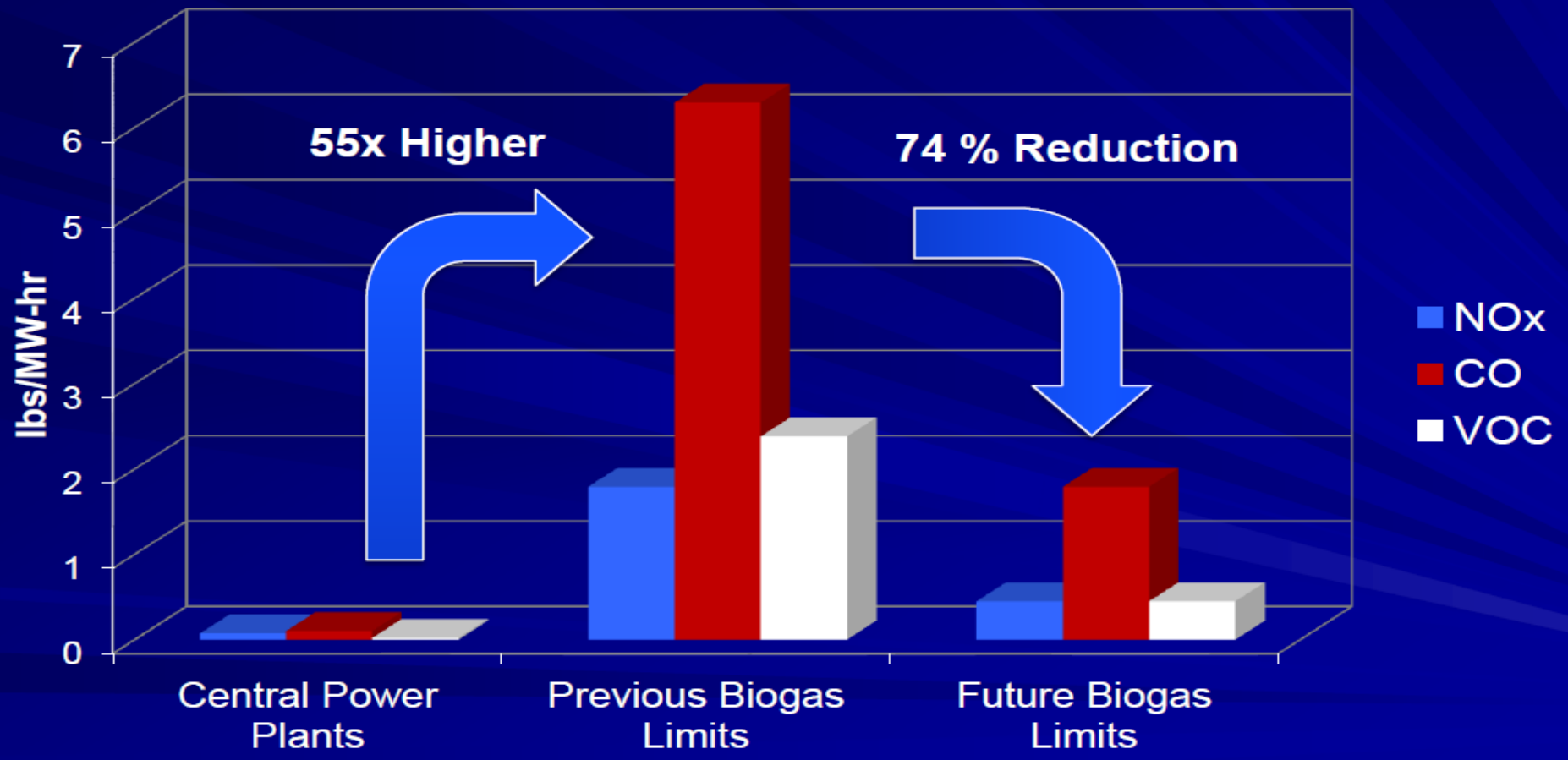


Biogas Engines

- Internal Combustion Engines (ICEs) fueled by digester gas or landfill gas (Biogas)
- Operated by many landfills and wastewater treatment plants to produce power

- Biogas is considered a renewable source of energy, **but**
- Power produced by Biogas engines is significantly dirtier than that of central power plants
- Rule 1110.2 limits Biogas engine emissions

Power by Biogas ICEs vs. Central Power Plants



*Previous Biogas CO value divided by 7