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## COVER STORY 20 CAN NATURAL GAS GENERATION SURVIVE?

California has the reputation of being on the leading edge of U.S. energy policy and renewable technology deployment. Yet in many ways, California follows the European example. It is in Europe where there is by far the most advocacy for emissions reduction to address climate change. It is in Europe where renewable penetration has reached the highest levels. And it is in Europe where targets have been set to eliminate natural gas from power generation within a decade. Several recent reports published by government bodies and consulting firms outline how this vision could potentially be executed. But how realistic is it? Drew Robb

Cover image: Power plant deploying the LMS100 aeroderivative gas turbine. Courtesy of GE



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The European PowerGen show shifted emphasis from fossil fuels onto renewables. From the opening keynote, renewable energy policy was the primary message. However, the Gas Track provided some balance with several speakers making it clear that Europe remains dependent on natural gas. The rapid rise of Liquefied Natural Gas terminals throughout Europe, in particular, appears to signal that natural gas generation will continue to play a major role in the continent's energy portfolio. Drew Robb

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#### 34 ENERGY STORAGE: WHY REINVENT THE WHEEL?

There are old-school turbomachinery approaches available that provide effective energy storage at scale. Pumped hydro storage and compressed air energy storage, for example, rely on basic mechanical principles. They are proven in the field at the size needed to support modern solar projects and wind farms. This article offers an overview of these technologies as well as some new twists on these familiar concepts.

Alex Nicolson

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There are various ways to assess safety as well as a variety of layers of protection available for turbomachinery. In most situations, safety is best achieved by developing an inherently safe design. If necessary, this may be combined with a protective system to address residual risks. *Amin Almasi* 

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## **RIP POWERGEN EUROPE**

fter two decades of attending PowerGen International in the U.S. each winter, I made my first visit to PowerGen EU. What a difference to the U.S. version. The European show was largely about transmission and renewable energy with a declining emphasis on traditional generation.

Let's track back a couple of years to understand the shift. Pennwell owned the PowerGen brand for decades. Clarion acquired Pennwell and combined PowerGen EU with its own European Utility Week show. Strolling through the exhibit floor, the Power-Gen booths were over to one side. They were outnumbered by those from utilities, renewable players, electricity component manufacturers, smart grid providers, digitalization vendors & software developers.

And then came the opening keynotes. Instead of rousing speeches from turbomachinery OEMs or utility executives, up came the head of the International Renewable Energy Agency. A host of speakers followed, promoting decarbonization, renewable energy and the elimination of natural gas generation from the grid by 2030. I've attended plenty of wind power and solar conferences in my time and this had a similar vibe.

Clarion took it a stage further by rebranding the show. The PowerGen EU and European Utility Week brands have been consigned to history. Enlit is the new title of the event. That brand is set to roll out across Europe, Asia and Australia — but not in the U.S., at least for now.

The plan is for Enlit to become, "the world's only complete energy event, bringing clarity to the global energy transition and defining the roles of all those involved in powering the next generation of the industry." This shift may mirror shifting political winds, stated government objectives and public opinion in some regions.

But there is one small problem. It leaves no European show with a traditional generation focus. Despite the tremendous headway made by renewables and their positive perception in the broad public, Europe remains dependant on coal, natural gas and nuclear for the bulk of its power. Advocacy to defund and close these power sources down may not be the wisest course.

I'm reminded of what happened in the U.S. after WWII. Cars were said to be the way of the future. Outmoded railways and city trams were to be eliminated. Freeway construction boomed.

Within a decade, the city, regional and national



rail and tram networks had been decimated. Yet today, cities are hurting badly for lack of much cheaper and more efficient tram and rail networks.

Projects are underway to bring fast rail transport to a wider area of the continent. Clearly, it was not an either-or proposition. There was a need for both rail and road transport. Yet the prevailing winds of progress demanded the rapid demise of rail. Billions in operational infrastructure and tracks were either ripped up or left to rust.

The zeal currently exhibited in Europe to eradicate the use of natural gas for power generation could be a similar case in point. An article in this issue delves into the numbers behind a series of studies that attempt to find a pathway to the removal of natural gas generation and the achievement of carbon neutrality in Europe. They lean heavily on unproven technologies. Each of the possible approaches discussed could eventually play a major role in future grid configurations. But the removal of natural gas from the power sector is unlikely to be attained in 2030, 2040 or even 2050.

In support of this, the continent currently has dozens of LNG import terminals and is building many more. In other words, huge sums continue to be invested in natural gas delivery infrastructure. It may be politically popular to condemn gas along with coal and nuclear. But natural gas isn't going anywhere even in Europe.

#### **Different U.S. flavor**

Meanwhile, the PowerGen International event in New Orleans in December, 2019 had a different flavor. Yes, there was plenty to say about the potential of hydrogen, the progress being made in energy storage and the growth of renewables.

But the North American show had a better balance between fossil and renewable sources. You can read reports from the European and North American shows inside. The issue also contains valuable material on turbomachinery-based energy storage, gearbox testing, an overview of the controls marketplace and our usual informative columns.

The next issue will provide a report from the Baker Hughes Annual Meeting in Florence, Italy. Expect to hear plenty about LNG and shale. By the time you read this, we will also be attending the Western Turbine Users Group in Long Beach, California. We hope to see you there. ■



cen loft

DREW ROBB Editor-in-Chief

## INDUSTRYNEWS

#### **New Elliott testing facility**

Elliott Group held a groundbreaking ceremony for a new test facility for its recently acquired product line of cryogenic pumps and expanders. The ability to test cryogenic pumps and expanders prior to shipping is a key element of the manufacturing process, and essential to Elliott's expansion plans.

Company officials and guests gathered at the former Jeannette Glass property at the end of 2019 for the ceremony, about a mile from the company's headquarters and main manufacturing campus in Jeannette, Pennsylvania. When complete, the test facility campus will include six buildings, with about 30,000 ft<sup>2</sup> under roof on the 13-acre site. Construction is expected to take about 18 months. Approximately 130 new jobs will be created when the facility is fully operational.

"We have built a new R&D center (commissioned in 2019) on our Jeannette headquarters campus, and we expect to develop new products and services that will expand our existing product lines," said Michael Lordi, CEO of Elliott Group.

"Big data, system integration, and the Internet of Things (IoT), as well as new technologies, such as additive manufactur-

#### **Ansaldo digest**

Edison is constructing a combined cycle power plant (CCPP) in Presenzano in the province of Caserta, Italy. The plant will have a capacity of about 760 MW with 63% efficiency and a reduction of more than 60% in nitrogen oxide (NOx) emissions compared to current combined cycle plants of the same size.

Water use is reduced, too. The plant will consist of an Ansaldo Energia GT36 gas turbine (GT), a recovery steam generator and a steam turbine (ST). Construction is expected to commence in the first part of 2020 and will last 30 months.

Ansaldo Energia will supply the main components of four AE94.3A GTs for China Datang Group for projects in Wanning, Hainan province, and Foshan, Guangdong in China. In addition, Ansaldo Energia will supply two AE64.3As to State Power Investment Co (SPIC) for the Jieyang site in Guangdong.

Ansaldo has signed a collaboration agreement with Equinor (formerly Statoil of Norway) to advance hydrogen combustion technology with full-scale, full-pres-

#### **Mechanical drive LNG boom**

The build out of natural gas pipelines around the world is behind Forecast International's prediction of a 16.7 % rise in sales of mechanical drive GTs delivered between 2019 and 2028, compared with the previous ten-year period. That adds up to \$23.95 billion over the next decade. Whether from new pipelines or upgrades to existing compressor stations, sales of 3,294 turbines are expected for the forecast period.

The international LNG trade is also expanding, according to Forecast International. Consumption of natural gas is expected to rise from more than 125 trillion cubic feet (Tcf) worldwide in 2016 to 156 Tcf in 2025. By that time, LNG will sure combustor validation tests. The main goals are the optimization for ultralow NOx emissions, operational flexibility and minimization of engine derating at high hydrogen content.

Compared to natural gas, the main challenge of hydrogen combustion is its increased reactivity, resulting in a decrease of engine performance for conventional premix combustion systems. The sequential combustion system of the Ansaldo Energia GT36 and GT26 GTs helps burn the full range of hydrogen in a low-NOx premix system. The GT36 H-class combustor can be operated with a volumetric hydrogen content in natural gas of up to 50%.

Ansaldo Energia, through Ansaldo Nucleare, and in association with Candu Energy, has been awarded a contract related to engineering services for performing condition assessments of systems, structures and components for the Cernavoda Unit 1 Candu nuclear reactor in Romania. This will extend its life for another 30 years. The facility produces 705.6 MW.

serve more than a quarter of worldwide demand for gas. This, in turn, will drive the procurement of further mechanical drive machines as gas needs to be transported by pipeline to LNG export terminals and from LNG import terminals to demand centers.

While smaller GTs will be used in some cases, Forecast International believes that more than half of all models sold for this purpose over the coming decade will be at least 7.5 MW. Aeroderivatives such as the GE LM2500/2500+ and competitive models from Siemens are likely to be in high demand. Similarly, Solar Turbines is doing well with plenty of orders to replace older and smaller Solar Centaur and Taurus GTs with larger and more modern units.



Rendering of the new Elliott test facility

ing and autonomous robots, are heralding a new industrial revolution that will translate into a steady stream of new manufacturing capabilities in the years to come."

#### **Digester turbine**

Eastern Ohio Regional Wastewater Authority (EORWA) has upgraded its Resource Recovery plant in Bellaire, OH. The retrofitted anaerobic digestion system is powered by a microturbine by FlexEnergy that converts gas from digesters into electricity.

It includes flexible membrane roofs, heat exchangers, feedstock receipt and mixing. This has enabled EORWA to generate more power from residual agricultural and municipal waste, manure, plant material, sewage and food waste. Anaerobic bacteria break down the water, releasing biogas to be used in the 333kW GT333S turbine while producing less than 10 ppm NOx.

#### **Tidal energy**

Atlantis Turbines and Engineering is operating the four-turbine Raz Blanchard tidal pilot array in Normandy, France. Capable of 1.5 MW, the project is connected to the grid via an undersea cable. Maintenance is performed on a boat by lifting the turbine out of the sea.

Orbital Marine, meanwhile, prefers a floating approach to tidal energy. The company has developed a device that sits on the water. Turbines connected to it capture energy from water turning the blades.

Subsea kites are being tested on the Faroe Islands in the North Sea by the local utility SEV. The island nation's three straits are considered a possible resource to provide baseload power. Known as Deep Green, the kite technology is being developed by Minestro AB. Recent estimates put the potential for tidal energy at 100 GW.

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### **INDUSTRYNEWS**



#### **Siemens digest**

Göteborg Energi of Sweden and Siemens signed a cooperation agreement to test GT technology that enables the operation of renewable fuels in the Rya combined heat and power (CHP) plant, which is currently powered by three Siemens SGT-800 GTs running on natural gas.

The aim is that by 2030 all district heating in Gothenburg, Sweden, will be produced by renewable or recovered energy sources. As a first step, one SGT-800 has been installed at the CHP plant for the validation of 3D printed burners. The goal is to run the Siemens SGT-600, -700 and -800 combustors fossil-free.

Siemens will equip Lalitpur Power Generation (LPG) with digital solutions for a power plant located in Lalitpur, Uttar Pradesh, India. The company will provide a thermal twin for the coal-fired plant, enabling improvements in performance.

It will also provide remote performance monitoring and diagnostics from the recently launched Siemens Mind-Sphere Application Center in Gurgaon, India. The thermal twin allows power plant operators to diagnose performance gaps for every asset in the cycle in real time and provides recommendations for improving efficiency.

Siemens delivered an SGT6-9000HL GT to Duke Energy's Lincoln Combustion Turbine Station near Denver, NC. It should begin operation in the first part of 2020. After passing prototype testing, it has now entered a four-year validation phase at the Duke facility. This simple-cycle

unit will be assessed by Siemens with a view to making any needed modifications to boost the efficiency of the 402 MW unit. It has an air-cooled, four-stage power turbine, hydraulic clearance optimization for higher efficiency (43%) at full load while facilitating immediate restart, a steel rotor with Hirth serrations, a central single-tie rod to lock discs and a can annular combustion system. Its ramp rate is 85 MW per minute and it only needs maintenance every 33,000 hours or 1,250 starts.

Siemens will supply Papierfabrik Palm of Germany with an SGT-800 GT and an SST-300 ST for a new CHP plant as well as switching and other electrical gear for paper production. It will also upgrade SGT-800s and SST-300s at other Palm sites to the latest power rating. Commissioning of the three power plants is planned for mid-2021. Palm also signed long-term service contracts.

Siemens will upgrade the Hiep Phuoc 1 steam power plant in Ho Chi Minh City, Vietnam to a CCPP, raising capacity from 780 MW to 1,200 MW. It will be fueled by liquefied natural gas (LNG) instead of oil. Three Siemens SGT5-4000F GTs, three generators, three heat recovery steam generators (HRSGs), related electrical equip-

engineering, procurement and construc-

tion (EPC) flexibility, simplifies plant lay-

out, reduces capital costs and shortens

ment and the SPPA-T3000 control system are the major components. Recommissioning of the CCPP is scheduled for 2022.

Siemens Gas and Power replaced the rotor of an SGT5-2000E GT at the Dunamenti Power Plant in Százhalombatta, Hungary (794 MW) and installed the SPPA-T3000 control system. Rotor exchange boosted output from 148 MW to 155 MW and increased efficiency by 0.8%.

Siemens has been selected to deliver the power generation equipment for two new peaking power plants for the stateowned utility company RUE Vitebskenergo in Belarus. The plants are expected to go into operation at the end of 2021. The open cycle gas turbine plants will operate in continuous availability mode and are designed to go from cold to full load in less than 15 minutes.

The plants are estimated to run about 700 hours per year. They will be used as a backup for future wind, solar and nuclear power plants, as well as for existing power plants. The company will provide five SGT-800 GTs, generators, gas receiving stations, booster compressors, high-, medium-, and low-voltage equipment and the PCS7 control system for the new 150 MW peaking power station at the Lukomlskaya plant and a 100 MW peaking power station at the Novopolotskaya plant.

Siemens and China's Harbin Electric signed an agreement with K-Electric to build a CCPP at the Bin Qasim Power Complex in Karachi, Pakistan. The project is expected to be completed in 24 months. Siemens will provide two SGT5-4000F GTs, STs, generators and condensers.

Compagnie Electrique de Bretagne (CEB) is developing a 446 MW CCPP in Brittany, France using Siemens turbomachinery and other equipment.

A new Sulzer facility in Indonesia is



#### L.A. Turbine and Waukesha

L.A. Turbine (LAT) commissioned its first ARES Active Magnetic Bearing (AMB) Turboexpander-Compressor within a Turbine ARES er with AMBs Magnetic Bearings that enables greater



#### **Sulzer center**

Sulzer has opened a new facility in Balikpapan, Indonesia. The service center serves customers in oil & gas, mining and power. It offers services for electric motors, compressors, pumps and STs.



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## **INDUSTRYNEWS**

#### Voith digest

Voith will retrofit a parallel shaft gear unit with Voith AeroMaXX technology at an air separation plant in China. The turbo gear unit from Voith is currently in service as part of an ST compressor driveline in northern China.

The contract includes retrofitting the existing housing and bearings to reduce the power loss of the gearbox by up to 30% as well as subsequent recommissioning of the gearbox. With the installation of AeroMaXX, the producer of technical gases will be able to increase energy savings at a plant that delivers oxygen to a nearby methanol plant.

Start of commissioning is expected for May 2020. AeroMaXX technology minimizes losses by separating lubrication and cooling, with no accessories needed due to its passive mechanical construction.

Additionally, Voith Hydro is a member of the Hydropower Extending Power System Flexibility (XFLEX HYDRO) project, with the goal of demonstrating how smart hydropower technologies can deliver a low-carbon, reliable and resilient power system.

The initiative shows how hydropower systems can help countries across the world to meet their renewable energy targets. The XFLEX HYDRO technologies to be tested are enhanced variableand fixed-speed turbine systems, smart controls and a battery-turbine hybrid, each of which will be demonstrated at hydropower plant sites across Europe. The project will conclude in 2023.



#### Sullair groundbreaking

Sullair has broken ground on an expansion project for its North American headquarters in Michigan City, Indiana. It includes the construction of an 80,000 ft<sup>2</sup> manufacturing building, a canopied storage building and an additional parking lot for employees. The plan also calls for improvements to portions of Sullair's existing 280,000 ft<sup>2</sup> manufacturing facility. Construction has begun.



#### **Capstone digest**

Capstone Turbine, in partnership with its UK distributor Pure World Energy, opened an International Organization for Standardization (ISO) turbine system test facility. It can accomplish turbine powerhead rebuild and balancing operations as well as recuperator remanufacturing. Capstone currently has 264 MW of microturbines under long-term contracts.

Capstone has secured a follow-on order for a C200 Signature Series microturbine with a 20-year factory protection plan from the National Science Founda-

#### **Dynamis CEO**

Dynamis Power Solutions, an affiliate of Evolution Well Services, recently named Matthew Crawford as Chief Executive Officer. Crawford joins the company after 13 years with General Electric holding various positions including Vice President of Sales.

#### John Crane facility

John Crane has opened a newly relocated service center in Mobile, AL. This equips the company with additional capabilities for addressing customer needs, such as aftermarket support, quick turnaround service and downtime cost reduction. In addition, it enables John Crane to support customers in Florida, Mississippi and Alabama in petrochemicals, oil and gas, and pulp and paper.

#### **3D printed turbine**

Together with H+E-Produktentwicklung in Germany, the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM has developed a true-to-scale GT that demonstrates the current potentials and limitations of powder bed-based additive technologies (3D printing).

The scale model of the Siemens SGT6-8000 H (1:25 scale) was manufactured with additive processes except for the shaft. Fraunhofer notes that many of the materials employed could not be processed in a commercial manner. tion (NSF) as part of a multi-phase modernization of the McMurdo research station in Antarctica.

The order was secured by Arctic Energy, Capstone's exclusive distributor in Alaska. The microturbine will be delivered in 2020, and is expected to be commissioned in February 2021.

E-Finity Distributed Generation, Capstone Turbine's distributor for the Mid-Atlantic, Southeastern U.S. and the Caribbean, has signed a service contract covering Capstone's largest CHP installation with 5 MW of Capstone microturbines. The Capstone Signature Series C1000's at this ceramic tile manufacturer were commissioned in late 2019.

Capstone Turbine helped complete upgrades to the International Remanufacturing Facility (IRF), located in Gosport, UK. This facility is a hub for Capstone Field Service Engineers (FSE) and is located close to the ports and shipyards in Portsmouth.

Dynamis provides GT packages that have an average mobilization/demobilization time of less than 14 hours for power from 2 MW to 30 MW. They can run directly off field gas, using natural gas that may otherwise be flared. The units can also run off of CNG, LNG or diesel.

The larger facility provides enough space for customer product training. Streamlined workflows will reduce lead times, improve quality and heighten support. In addition, the location offers new seal testing technologies, as well as seal repair with root cause analysis, and assembly and testing facilities for standard, engineered and metal bellows cartridge seals, and optional bonded stock for contractual repair needs.

The component assembly consists of 68 parts made of aluminum, steel and titanium. Through component optimization and the possibilities of Electron and Laser Beam Melting technologies, this replaced almost 3,000 individual parts in the original.

The turbine is fully functional. Housing components with stator stages were manufactured using Electron Beam Melting (EBM) of Ti-6A1-4V. The turbine stages and the other housing components were manufactured at H+E using Laser Beam Melting.

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### **INDUSTRYNEWS**



#### **Doosan digest**

Doosan Heavy Industries & Construction has signed an agreement with Korea Western Power Company (KOWEPO) to supply a gas turbine to the Gimpo Combined Heat & Power (CHP) Plant. The construction of the power plant is scheduled to commence in 2020 and will be completed by 2022.

After six years of smooth operation, a two-casing 135 MW condensation ST at the Kladno heating plant in Czech Repub-

#### **Turbomachinery research**

Researchers in the Penn State Department of Mechanical Engineering have been awarded a grant to support advancements in the performance and efficiency of GTs and turbine-based power cycles. The U.S. Department of Energy funded these projects through the University Turbine Systems Research program, which aims to develop nearzero emission turbine technologies.

Seven projects were selected, three of which are powered by Penn State research. Stephen Lynch, the Shuman Family Early Career Professor and asso-

#### **MHPS** digest

Mitsubishi Hitachi Power Systems (MHPS) shipped a J-Series Air Cooled (JAC) GT as part of a construction project for two CCPPs on the outskirts of Bangkok, Thailand. It is a joint venture between Gulf Energy Development of Thailand and Mitsui.

This is the first shipment of eight units ordered in February 2018 that will have a combined output of 5,300 MW. Commercial operation is scheduled to start in 2021. After startup, the plants will use natural gas as their main fuel source, with the electric power generated to be sold to the Electricity Generating Authority of Thailand (EGAT).

Suncor Energy has placed an order for two M501JAC GTs and two HRSGs from MHPS for a future cogeneration facility at the company's Oil Sands Base Plant facillic was opened for an overhaul for the first time. The unit operates at more than 30 bar steam pressure and at temperatures exceeding 535°C at full power.

It had to be shut down and cooled before the inspection so that it could be stripped of insulation, the steam pipes dismantled, screws in the split plane loosened and then opened, inspected, sandblasted where needed, and tested for further operation.

The most technically challenging step was repairing the turbine's parting plane. Doosan Škoda Power engineers used 3D scanning to make a model of the outer casing parting plane. This enabled technicians to address areas of deformation.

Most repairs were done at the Kladno heating plant. Only the rotor from the combined high- and medium-pressure section and the guided wheels from the low-pressure section were hauled to Doosan's Pilsen plant to replace sealing elements.

ciate professor of mechanical engineering, will spearhead an additive manufacturing project to enable transformative levels of performance for ceramic matrix composite turbine vanes that are subjected to some of the highest temperatures in the engine.

Lynch will collaborate with Michael Hickner, professor of materials science and engineering and chemical engineering at Penn State, as well as a team of researchers from the University of Wyoming. Further projects involve cooling effectiveness in turbine components and fuel injection hardware.

ity near Fort McMurray, Alberta. This will replace three aging coke-fired boilers and provide reliable steam generation required for Suncor's extraction and upgrading operations for bitumen recovery. The cogeneration units are expected to result in a reduction in atmospheric emissions.

Patria Investments, Shell and Mitsubishi MHPS signed a contract with Brazil's State-owned development bank (BNDES) to finance the gas-powered Marlim Azul Energia thermoelectric plant in Rio de Janeiro State. The joint venture will develop the plant and trade the energy generated. The 565 MW Marlim Azul plant is the first of Brazil's pre-salt, gas-powered energy projects to win an auction, offering one of the most competitive variable unit costs (VUCs) in gas-powered plants. The plant will come into operation in January 2023.

#### **GE** digest

GE will invest up to \$60 million over the next decade in its existing Global Repair Service Center in Singapore by adding a new HA Repair and Development Centre. It will begin repairing HA components in 2021 such as nozzles and blades.

GE Power said it has improved the operational efficiency and performance of ADNOC Refining's Ruwais General Utilities Plant with the implementation of its MXL2 upgrade solution on two GE 13E2 GTs.

The technology upgrade increased the total output by up to 23 MW using the same amount of fuel. It enhanced the availability of each turbine by an additional six days per year by extending the duration between GT maintenance intervals.

ADNOC Refining supplies petroleum products, including LPG, naphtha, gasoline, jet fuel, gas oil and base oils, fuel oil, petrochemical feedstock and propylene, in addition to specialty products, such as carbon black and anode coke. The Ruwais General Utilities Plant has an installed base of four GE 13E2 units that can generate up to 650 MW.

GE and African cement producer Dangote Cement signed an agreement to deploy GE's Asset Performance Management (APM) digital solution to reduce unplanned downtime and enhance performance at its two cement plants in Obajana and Ibese, Nigeria.

The project includes extending the current service agreement for an additional 50,000 operating hours for the seven GE LM6000PC aeroderivative GTs at the sites. APM monitors the performance of power generation assets to reduce downtime, avoid turbines damage and remotely predict and resolve issues. APM sensors will be installed on the seven aeroderivatives, as well as associated generators and gear boxes to predict and diagnose issues before they occur.

#### **Second-hand turbines**

Canadian power generator TransAlta has reached an agreement with Kineticor Holdings to purchase two 230 MW Siemens F class GTs and associated equipment. The Canadian company will be integrating the new GTs into the existing steam turbine at Sundance Unit 5, to transform it into an efficient combined-cycle unit. Once operational in 2023, it will generate 730 MW.





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## HOW TO ASSESS SAFETY AND PROTECTION LAYERS

BY AMIN ALMASI

here are various ways to assess safety as well as a variety of layers of protection available for turbomachinery. A safety issue with a 100 kW centrifugal water pump may have limited consequences. However, a safety incident with a 25 MW turbocompressor operated at 100 Barg for gas could lead to extensive damage.

In most situations, safety is best achieved by developing an inherently safe design. If necessary, this may be combined with a protective system to address residual risks.

Protective systems rely on different technologies including mechanical, hydraulic, pneumatic, electrical, electronic and programmable electronic. Nowadays, it is possible to achieve excellent safety and reliability levels for all types of turbomachinery.

Therefore, more protective systems and safety devices in the form of trips and alarms, emergency isolation valves, fire protection systems and gas detectors should be considered for critical turbomachinery.

Various levels of safety should be considered. The first layer depends on the materials and chemicals being used. It is best to stick to low-risk material where possible.

The second layer of safety is related to operating conditions. Take the case of a heater for a turbomachinery package where there may be the risk of fire or explosion. If the temperature goes above 150°C using a steam heater, an inherently safer configuration would be to use an electrical heater with temperature below 100°.

The third layer of safety addresses structural and mechanical details. It is the engineer's job to specify the parts, components and properties, such as strength, corrosion allowance, materials of construction and pressure ratings.

The fourth layer of safety is control. In the absence of good control, high pressures, high temperatures or other deviations may be experienced. With effective control in place, the control system will normally be able to cope with all transients, malfunctions and emergencies. It is rare that pressure, temperature or other parameters pass to the alarm stage.

The fifth layer of safety concerns passive safety devices. These are devices that do not rely on an actuation system, elec-

### Protective systems include mechanical, hydraulic, pneumatic, electrical, electronic and programmable electronic technologies.

tronics or motor. They include relief valves and bursting discs, for example.

The sixth layer of safety includes powered or active safety devices, such as suppression systems and safety shutdown systems. These instrumented systems should be carefully assessed as they contain many parts.

One component failure means the whole system has failed. Such systems should be used only when needed. In other words, the sixth layer of safety should be resorted to only when lower layers cannot offer sufficient protection.

Engineers should also be aware of the safety integrity level (SIL) system. It provides the relative level of risk-reduction provided by a safety function. In simple terms, SIL is a measurement of the performance required for a safety instrumented function.

If the preceding layers offer a good

degree of safety when compared to the targeted degree of risk reduction, the safety trip or safety action does not usually need to have a high SIL rating. A SIL assessment looks at the design as a whole to decide if there is a residual risk to be covered by the safety instrumented system.

#### Layer of protection analysis

A layer of protection analysis (LOPA) is a study of residual risk to assess requirements for safety-critical instrument loops. LOPA studies identify how often the initiating event occurs and the probability that everything that acts against it might fail simultaneously leading to an unwanted event.

There has been a tendency to rely on published data and calculations for such studies rather than knowledge derived directly from operators and experts. The knowledge and experience of those who know the specifics of the turbomachinery package under study are important. It is better to combine published data with expert data to avoid LOPA becoming a complex academic calculation.

Surge protection for a turbocompressor, for example, should be assured by an anti-surge system. This is a safety instrumented system that includes sensors and specially actuated (fast-acting) anti-surge valve(s). If one element fails, the entire anti-surge system fails. High integrity and reliability are needed for each element and for the entire system. A high SIL rating is required.



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equipment, condition monitoring and reliability.

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## COVERSTORY

# **CAN NATURAL GAS GENERATION SURVIVE?**

## EUROPE WILL BE THE CRUCIBLE FOR INNOVATIVE AND EXPERIMENTAL ALTERNATIVE TECHNOLOGIES

**BY DREW ROBB** 





alifornia has the reputation of being on the leading edge of U.S. energy policy and renewable technology deployment. Yet in many ways, California follows the European example.

It is in Europe where there is by far the most advocacy for emissions reduction to address climate change. It is in Europe where renewable penetration has reached the highest levels. And it is in Europe where targets have been set to eliminate natural gas from power generation within a decade.

The price tag for this, however, is not small. According to Francesco La Camera, Director-General of the International Renewable Energy Agency (IRENA), it will take \$110 trillion to meet Europe's 2050 decarbonization goals. That amount is the equivalent of investing 2% of global GDP per year.

Several recent reports published by government bodies and consulting firms outline how this vision could potentially be executed.

#### **World Energy Outlook**

The International Energy Agency's (IEA) *World Energy Outlook 2019* emphasizes achieving climate, energy access and air quality goals. It attempts to do this within the framework of reliability and affordability.

The report offers several scenarios: One based on how stated (current) policies will play out by 2040, another based on planned policies, such as eliminating coal generation or diesel vehicles by a certain date, and the sustainable development policies scenario — what the IEA believes needs to be done to reach targets set in the Paris Agreement and by other agencies.

The IEA considers the first two sce-

narios as grossly inadequate. The stated policies scenario, for example, results in a global rise in energy demand by 1% per year to 2040. Solar photovoltaic (PV) and wind will supply more than half of the growth, with natural gas accounting for another third. Oil demand will flatten in the 2030s, and coal use will decline. However, the rise in emissions slows but does not drop (Figures 1 & 2).

Under the planned policies scenario, the report perceives the U.S. energy sector to pose a problem: shale output from the U.S. will see the nation provide 85% of the increase in global oil production from now to 2030, as well as a 30% increase in gas. By 2025, the IEA predicts that total U.S. shale output of oil and gas will overtake all Russian oil and gas production. In Asia, too, natural gas demand is set to surge.

The sustainable development scenario, however, requires wind and solar PV to provide almost all the increase in electricity generation between now and 2040, i.e., little room for natural gas. As for coal, the study accepts usage will remain high in China, India and other



Figure 2: The last century has witnessed multiple transitions to and from different fuels and technologies. The challenge today is one of scale: global energy use is ten times higher than in 1919... and growing. Source: IEA

#### **Global energy demand in the Stated Policies Scenario**

Growth in gas demand and supply in selected Asian markets in the Stated Policies Scenario, 2018-2040



Figure 3: Developing economies in Asia account for half of global growth in gas demand, with industrial consumers taking the largest share. Source: IEA



Figure 4: The power mix is being re-shaped by the rise of renewables and natural gas. In 2040, renewables will account for nearly half of total electricty generation. Source: IEA

Emissions projections and outlook (based on EIA estimates)



Note: toe=tonnes of oil equivalent.

Figure 5: The power generation sector has a better record than industry, commercial, residential and transportation in reducing emissions over recent decades.

parts of Asia. Thus, carbon capture, utilization and storage (CCUS) and biomass co-firing equipment are part of the scenario for those regions along with plenty of coal plant retirements (Figure 3).

The IEA also predicts that under the stated policies scenario at least 120 GW of battery storage will exist by 2040. The

hope is that the decline in battery costs will be more rapid than expected or that technological improvements will facilitate an even greater amount of battery storage.

In essence, the report views natural gas as little more than a near-term bridging fuel temporarily replacing coal and oil. Yet the IEA recognizes the value of the existing gas pipeline network as a crucial mechanism to bring energy to consumers. The agency sees low-carbon hydrogen and biomethane (from organic wastes and residues) as the ultimate successors to natural gas. But for now, hydrogen remains too expensive to play a part.

"There is no single or simple solution to transforming global energy systems," said Dr Fatih Birol, the IEA's Executive Director. "Many technologies and fuels have a part to play across all sectors of the economy."

Looking across industry segments, the power generation sector is by far the most effective at reducing overall emissions. Progress in transportation, commercial, residential and industrial, however, has lagged (Figures 4 & 5).

#### Natural gas growth

Coal, natural gas and nuclear accounted for over 80% of total electricity generation in the U.S. in 2018, according to the IEA. But the share of renewable energy is increasing. Gas took first place at 34%, coal 29%, nuclear 19%, hydro 7%, wind 6% and solar 2%. The U.S. Department of Energy expects wind to surpass hydro generation in 2019 (Figure 1).

The U.S. is the top natural gas producer in the world. Natural gas accounted for 32% of total primary energy supply (TPES) in 2018, up from 24% in 2008. With 852.7 billion cubic meters (bcm) available in 2018, it is no surprise that the nation is now a net exporter of natural gas.

The share of natural gas in power generation rose from 21% in 2008 to 34% in 2018. Top gas-producing states by shares of total production were Texas (23.1%), Pennsylvania (19.7%), Oklahoma (8.5%), Louisiana (7.7%) and Ohio (6.3%).

Natural gas consumption in the U.S. is also on the rise: an 18% increase from 2007 to 2017.

Heat and power generation account for 37% of the total increase, followed by industry (23%), residential (16%), commercial (11%), energy (9%) and transport (3%).

Power generation and petrochemicals (ethane feedstock) have benefited markedly from low gas prices. According to the IEA current policies scenario, natural gas is expected to remain the dominant source in the U.S. for power generation up to 2050.

## COVERSTORY

US natural gas exports, 2000-18



Figure 6: The US became a net exporter of natural gas in 2017, with LNG exports reaching destinations in Asia. Source: IEA

Gas production in the U.S. is expected to reach 1,016 bcm by 2024, and 1,074 bcm by 2040. Prices are expected to remain low at least through 2024. This is in sharp contrast to the rest of the world. Prices in Europe and Asia are much higher – six times higher in Switzerland, for example.

U.S. gas exports reached 102 bcm in 2018. That is a 4X expansion in 10 years. Mexico took 52%, followed by Canada (23%), and then Asia Pacific. The volume of LNG has quadrupled since the opening of the Sabine Pass LNG terminal on the

Gulf Coast in 2016. But exports to Europe are expected to surge. The IEA predicts that the U.S. will lead LNG market supply growth until 2023 (Figures 6 & 7).

The U.S. natural gas system consists of more than 300,000 miles of transmission pipelines. That network delivered about 25 trillion cubic feet (708 bcm) of natural gas to 75 million customers in 2017. In addition, three large-scale LNG export terminals are now operating: Corpus Christi, Sabine Pass and Cove Point. More are on the way, including Golden Pass, Magnolia LNG, Delfin LNG, Lake Charles, Venture Global Calcasieu Pass, Driftwood and Port Arthur.

Based on IEA analysis, then, unless U.S. energy policy pivots, natural gas generation is likely to remain a central part of the power generation sector worldwide for many decades to come.

#### Capgemini World Energy Markets Observatory

Analyst firm Capgemini issued a report entitled the *World Energy Markets Observatory*, which predicts continuing demand and growth for gas. In 2025, it forecasts that the U.S. should account for more than half of worldwide oil and gas production growth (75% for oil, 40% for gas).

"No energy-related technical breakthroughs are expected by 2040, and nuclear fusion, if demonstrated, will not be at an industrial stage," said Colette Lewiner, Senior Advisor, Capgemini. "However, improvement of existing technologies will enable lower costs for renewables, electric batteries, electric vehicles, and small modular nuclear reactors."

She concludes that hydrogen for storage and mobility should be at the industrial stage by 2040. Digitalization, too, will bring productivity gains in all energy





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Natural gas prices in IEA member countries, 2018

Industrv



#### Figure 7

value chain segments. Smart grids will be deployed at scale with increased sensors, data collection, and data mining being used to improve forecasting and operations. Likewise, decentralized supply will increase. De-carbonization, decentralization and digitalization are on the rise. Some 23% of U.S. energy and utility companies, for example, have deployed intelligent automation initiatives.

Overall, Capgemini believes low prices for natural gas and renewables will mean they will continue to be the top U.S. sources for new capacity additions until 2050. Storage, for now, will continue to rely on government incentives and investment tax credits. That said, 760.3 MWh came onto the U.S. grid in 2018.

Europe, too, is heavily dependent on natural gas. It imports much of its supply, with Russia being the biggest source. But LNG imports are rising from places such as Algeria, Qatar and the U.S. Europe is keen to lessen its dependency on external sources of energy. It has set aggressive emissions reduction goals and is the most vocal continent for the elimination of natural gas.

California, too, has set forth ambi-



Figure 8: Potential (as used in "optimized gas" scenario)

tious goals: 60% renewables by 2030 and a zero-emissions economy by 2045. The Golden State hopes to achieve this by eliminating natural gas as an electricity resource while upgrading its local distribution and regional transmission systems. This includes expanding access to renewables via the western regional grid.

"California's renewables and emissions goals represent an extremely daunting challenge, and if we try to achieve them without a regional electricity market, we will regret it," said Carl Zichella, Director for Western Transmission, Natural Resources Defense Council.

California sits in contrast to the rest of the U.S. Total natural gas demand grew more than 40% over the past decade and rose by another 13% from 2017 to 2018, according to the American Gas Association.

At the same time, natural gas prices for retail customers adjusted for inflation were the lowest in decades. That is why Capgemini makes it clear that natural gasfired generation will remain the dominant fuel in the electricity power sector through 2050. Coal will not go away either, but its use will gradually decline.

#### Gas for climate change

Consulting firm Navigant issued a *Gas for Climate Report*, which sought to find the optimal role for gas in a net-carbonzero world. It assessed the cost of decarbonizing the EU energy system by 2050, as well as the role of renewable and low-carbon gas within the existing gas infrastructure.

In other words, the goal is to largely eliminate natural gas from Europe. Any gas remaining would either be low in carbon or would be fulfilled by gas produced from renewable sources, such as biomethane and green hydrogen (hydrogen produced by electrolysis powered by renewable energy). It also considered blue hydrogen: natural gas combined with CCUS and split into hydrogen and  $CO_2$  (Figure 8).

Navigant concluded that full decarbonization of the energy system would require a tenfold increase in renewable electricity production from wind and solar. This would have to be backed up by abundant dispatchable electricity production by either solid biomass or gas. The analysts concluded that replacing any type of gas with battery seasonal storage would be unrealistic even at strongly reduced costs.

In addition, the value of gas grids became clear ensuring the reliability and flexibility of the energy system. The belief is that these pipelines can be used to transport and distribute renewable

## **COVERSTORY**



#### Figure 9

methane and hydrogen instead of natural gas by scaling up production of biomethane, green hydrogen and power to methane.

The EU has high hopes for power to methane, or methanation — a technology by which synthetic methane can be produced based on hydrogenation of carbon dioxide. This can take place in a methanation reactor as an additional step to electrolysis with hydrogen produced from renewable electricity or as a coupled process in biogas plants using residual CO<sub>2</sub>.

Hydrogen and  $CO_2$  can be combined in a digestor where microorganisms would act as bio-catalysts. Synthetic natural gas can be then produced with a methane content of 96% to 99%.

All of these alternatives would need to be supplemented by blue hydrogen, said Navigant, until the cost of green hydrogen drops and enough wind and solar capacity exist to produce green hydrogen. But eventually, the plan is to eliminate blue hydrogen (and hence natural gas) (Figure 9).

There is a small problem. The EU currently imports more than 50% of its energy. If it is to phase out coal, nuclear and natural gas, where will the required energy be produced? Analysts at Navigant surmise that international trade in renewable energy will provide imports of solid biomass and green/blue hydrogen. A further idea is to transport blended methane and hydrogen through gas grids, while gradually creating dedicated hydrogen transport networks.

At the same time, the report expects light road transport (passenger cars, light commercial vehicles) and domestic shipping will be primarily electric by 2050.

Long-distance heavy transport is another matter. It requires fuels with high energy density. Similarly, direct use of electricity (from batteries) is less suitable for international shipping and aviation. In heavy road transport and international shipping, hydrogen and bio-LNG dominate in the optimized gas scenario while large quantities of biodiesel are used in the minimal gas scenario.

#### **Carbon capture of gas**

The bottom line on this and the other reports cited is that the elimination of natural gas from power generation in Europe seems unlikely in the foreseeable future. The projections for its removal depend too much on developing technologies that have yet to scale economically.

Meanwhile Europe is quietly beefing up its LNG import infrastructure. The billions being invested in LNG tend to contradict the sabre rattling about ending the use of natural gas on that continent.

What is likely to happen is that many of these alternative technologies will be fast-tracked toward maturity. That is good news in terms of lower emissions and greater energy efficiency. This movement will also bleed over to the U.S. in areas such as carbon capture of natural gas.

To help the U.S. do its part in reducing emissions from coal and natural gas, the Department of Energy (DOE) Office of Fossil Energy (FE) announced \$110 million in funding for research and development (R&D) projects for CCUS.

"CCUS technologies are vital to ensuring the United States can continue to safely use our vast fossil energy resources, and we are proud to be a global leader in this field," said former DOE secretary Rick Perry.

As well as reducing emissions, part of the purpose is to utilize the captured  $CO_2$  in enhanced oil recovery to maximize energy production. What is interesting about these grants is that they go beyond traditional CCUS for coal and branch into how to harness this technology for natural gas.

One project aims to retrofit a 2x2x1 natural gas-fired gas turbine (GT) combined cycle power plant (CCPP) with CCUS. Bechtel National will conduct the study at an existing Panda Energy Fund plant in Texas. The post-combustion capture plant is an amine-based conventional absorber-stripper scrubbing system with a solvent.

Another project concerns the design of Linde-BASF advanced post-combustion  $CO_2$  capture technology at a Southern Company natural gas-fired power plant. This will either be at Alabama Power Company's Plant Barry in Bucks, Alabama or Mississippi Power Company's Plant Daniel located in Moss Point, Mississippi.

An aqueous amine solvent-based post-combustion  $CO_2$  capture technology will be used at the chosen CCPP. Linde-BASF technology is based on a lean-rich solvent absorption/regeneration cycle for  $CO_2$  capture.

A different approach is to be taken by the University of Texas at Austin using the Piperazine Advanced Stripper (PZAS) process for CO<sub>2</sub> capture at the Mustang Station of Golden Spread Electric Cooperative (GSEC) in Denver City, Texas. This is a CO<sub>2</sub> scrubbing process with solvent regeneration for post-combustion carbon capture from natural gas flue gas. The project will provide insight on the benefits and economics of integrating CO<sub>2</sub> captured from a power station.





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## **SHOWREPORT**



# **POWERGEN EU**

### EUROPEAN SHOW SHIFTS EMPHASIS FROM FOSSIL FUELS TO RENEWABLES

DREW ROBB

owerGen EU has been a mainstay of the energy event circuit for decades. But a changing of the guard happened in Paris at the November 2019 show. The PowerGen brand was already partially submerged by being co-located with European Utility Week. Now both names have been replaced by a new event known as Enlit.

This appears to signal the show morphing into more of a renewable energy and transmission event. This may mirror cur-



rent EU policy direction and the energy procurement realities on the ground. But it leaves a hole for the traditional generation supply chain.

#### **Renewable emphasis**

From the opening keynote, renewable energy policy was the primary message.

"Europe is at the forefront of renewable energy goals, with a target of 32% renewables by 2030," said Francesco La Camera, Director General of the International



Renewable Energy Agency (IRENA). "The business case for renewables continues to strengthen."

Denmark, he added, has 50% of its power coming from renewables, and the UK, Germany, Portugal and Spain are all above 20%. He said that adding more renewables onto the grid is an important part of an overall trend: Electrification is becoming the central energy carrier.

Philippe Monloubou, CEO of French electricity distribution system operator (DSO) Enedis, laid out how his company is supporting this trend. It intends to complete the deployment of a smart grid, smart meters and end-to-end digitalization by 2022.

"The energy transition is an industrial reality," said Monloubou.

Siemens, too, is very much on board with the message. Cedrik Neike, CEO Smart Infrastructure & a member of the board at Siemens, was another in a long line of speakers promoting electrification, digitalization and renewable energy. But Neike noted some of the problems inherent in this transformation.

Francesco La Camera 24 *Turbomachinery International* • January/February 2020

Philippe Monloubou



#### **Cedrik Neike**

Back in 1990, he said, Germany had 1,000 power plants. Today, there are two million separate power producers (including home owners). The grid is not designed to deal with this. He said that a billion Euros a year of European wind power is wasted. It is produced in the north and cannot be gotten to areas where it is needed such as Bavaria. Thus, further decentralization and digitalization are required.

He also advocated that electric grids and building power systems converge.

"38% of global power is consumed in buildings and half of that is wasted," said Neike.

Siemens intends to be carbon neutral by 2030. Already, it has decentralized power production at its manufacturing plants and has put electric vehicles on the road as part of its fleet.

Livio Gallo, Head of Global Infrastructure & Networks at energy production & distribution company Enel, was bullish about the prospects for renewable power in Europe. He said the forecasts of the past have underestimated growth. "Renewable capacity is set to double again by 2030 driven by wind and solar," he said.

#### Finding grid balance

A panel followed the keynotes. Jose Torres, CEO of EDP Distribuicao of Portugal, Philippe Monloubou, CEO of Enedis, Thierry Trouve, CEO of GRTgaz, Olivier Grabette, Vice CEO of RTE and Chris Peeters, CEO of Elia Group argued about the balance between traditional and renewable generation sources.

"It is a real challenge to establish the infrastructure needed to bring bulk renewables to markets; many don't want that infrastructure nearby," said Peeters. "It is also difficult to implement digitalization to provide grid flexibility."

Trouve made it clear that balance was needed if power was to remain affordable. "Customers have to buy your power," he said. "We need gas for flexibility, storage and price containment."

But that doesn't mean that gas turbine (GT) fuels will remain as they are today. Thomas Thiemann, President of EU Turbines (European Association of gas and steam turbine manufacturers) said the immediate benefits of GTs include decarbonization, flexibility, grid stability and sector coupling (the convergence of gas, electric and heat grids).

"Decarbonization is already happening via the coal-to-gas switch," said Thiemann. "Now, we see our task as making turbines ready for renewable fuels."

He outlined the role GTs will play in carbon-neutral systems: GTs can be used to generate power and heat from green hydrogen (using excess renewable capacity to produce hydrogen via electrolysis); the existing gas network can be used for seasonal energy storage; and existing assets can be adapted to provide dispatchable energy using renewable fuels.

"Dispatchable power is extremely high value," said Thiemann. "Gas turbines



Left to right, Jose Torres, Philippe Monloubou, Thierry Trouve, Olivier Grabette and Chris Peeters

ensure there is enough grid in real time."

He believes hydrogen is too valuable to be burned in turbines, at least for the moment. However, all major European turbine manufacturers have agreed to deliver turbines that can burn 20% hydrogen by 2020 and 100% hydrogen by 2030.

"We are also building turbines that can be upgraded for green fuel," said Thiemann.



**Gergely Molnar** 

#### **Gas boom**

Conventional power did not completely disappear from the PowerGen EU/Enlit program. The Gas Track was kicked off by Domenico De Luca CEO of Axpo Solutions. He made it clear that the EU was going to be using natural gas for some time to come. LNG use in Europe is very much on the rise.

"Gas is needed to bridge the gap for many years to come," he said.

He introduced Gergely Molnar, a gas analyst from the International Energy Agency (IEA).

"2018 was a golden year for natural gas, with global demand growing by 4.6% and U.S. demand growing by 10%," he said.

Overall, natural gas was by far the fuel source that experienced the healthiest growth in 2018. According to the IEA, 45% of global demand growth was fulfilled by gas, followed by renewables at 24%, oil at 8% and coal at 7%.

Chinese demand for natural gas rose by 18% in 2018 to make it the biggest gas importer. This is being driven by a major shift from coal to gas to reduce smog and air pollution.

But overall demand may be slowing. Molnar said U.S. growth dropped to below 3% for the first half of 2019. IEA forecasts natural gas consumption to rise by 1.6% per year for the next several years. China will account for over 40% of the rise in global gas consumption through 2024.

Industry will account for more than 40% of global gas demand growth between now and 2024 mainly due to greater use of feedstock for petrochemicals, industrial

## **SHOWREPORT**



#### **Philippe Vie**

processes and fertilizers. But the power sector is expected to experience an increase of around 20%.

The U.S. and China will be responsible for almost half of the additional production, with the U.S dominating natural gas exports.

It is a very different picture in Europe. "We see little growth in natural gas demand in Europe despite the phase out of coal and nuclear power," said Molnar.

#### LNG expansion

Global LNG trade grew at an average of 10% per annum between 2016 and 2018 with Asia and Europe being the hottest areas. The U.S. is expected to be the largest LNG exporter through 2024 with China being the biggest buyer. Emerging Asia is also a major importer. Australian exports are expected to plateau while Qatar is preparing for a major expansion. Egypt, too, has begun exporting LNG.

"Europe absorbed 70% of additional LNG growth in 2019," said Molnar. "Coalto-gas switching in 2019 brought about 40 million tons of CO reduction."

He noted that investment decisions about new LNG projects faltered after 2013 but they picked up again in 2018 and 2019. Contracts, too, are getting larger, longer and more flexible. More than half the big deals that have been green-lighted are in the U.S., with others in Mozambique and Pacific Russia.

One side benefit of an expanding, more flexible and more geographically diverse LNG market is that the traditional premium price for Asian LNG is disappearing.

"We could be entering an era where gas prices are converging instead of there being a big price rise for LNG to Asia," said Molnar.

He concluded that natural gas demand will continue to grow in the medium-term, driven by emerging Asian economies and led by China. Although production increases are predicted in many regions, most of the additional exports will come from U.S. LNG and the Eurasian pipeline.

LNG trade remains the main driver of gas market globalization and a major source of incremental supply for Asia and Europe. This growth is supported by a rebound in investment, but additional capacity development will be necessary.

The LNG theme continued with Roxana Caliminte, Policy Advisor for Gas Infrastructure Europe. She made it clear that more LNG is coming to Europe. There are already 36 LNG terminals dotting the European coastline including floating terminals. Another six are under construction and 21 more are planned.

These LNG terminals help ensure the security of natural gas supply as Europe is no longer completely dependent on pipeline gas.

"Gas prices are going down, and more demand is coming so we need more LNG terminals," said Caliminte. "With Asian demand going down, and the phasing out of coal, LNG is coming to Europe."

The biggest importers are Spain, Turkey, France, Italy and UK in that order.

The primary suppliers are Russia, Qatar, U.S., Algeria and Nigeria. European terminals have learned to be flexible to react quickly to world prices. From these terminals, LNG is trucked or transported by train throughout the continent. Tanker loads have risen from 40,000 in 2013 to almost 60,000 in 2018.

She commented that growing LNG is a complement to renewables in reducing emissions. Long term, she believes that the LNG infrastructure could be used to convert renewable energy in liquids, such as ammonia and hydrogen that could be stored in existing LNG terminals.

#### **Renewable surge**

Phillippe Vie, Head of the Global Utilities Sector at the Capgemini consultancy, provided highlights from the annual *World Energy Markets Observatory*. He stated that the hard costs of photovoltaic (PV) solar are half of what they were in 2000.

Onshore wind costs decreased by 13% compared to the year before, with offshore wind costs dropping 1%. Lithium-ion battery costs, meanwhile, have dropped 8% to 35% every year since 2010. However, green hydrogen, said Vie, is too expensive. Its development depends on political will.

Vie cautioned the audience that levelized cost of electricity (LCOE) figures for renewables can be misleading as they do not consider transmission costs and intermittency.

"Today, a large grid composed of 100% renewables is unmanageable," he said. "But cost declines will continue to put pressure on fossil-fuel generation."

He covered the growth in EVs, with the number of car models available expected to double in Europe over the next two years. Norway already has EVs comprising 45% of new car sales. But a recharging bottleneck may impact expansion.

The oil market, meanwhile, is oversupplied. U.S. political pressure and sanctions on Venezuela and Iran are preventing oil from those regions from flowing onto the market. Without political tension, a price drop in oil is quite possible. Gas prices, too, are decreasing.

Despite the renewable push, coal extraction and coal-based electricity generation continue to rise. Asia Pacific accounted for 73% of coal production worldwide in 2018. Global consumption grew by 4% that year despite the steady phase-out of coal plants in Europe and North America.

"Europe and the U.S. are doing the best on CO<sub>2</sub> emission reductions," said Vie. "Asian Pacific and Indian emissions continue to grow."

Like Molnar, he said gas use will increase in the short- and medium-term in almost all regions except Europe. While hydrogen, fusion, battery storage and other technologies are touted as being the next innovation to transform the energy sector, Capgemini does not expect a major energy breakthrough to mature in the next decade or two.

Instead, many elements will contribute to incremental improvements: energy efficiency, renewable energy growth, storage technology, increasing the hydrogen mix



The closing panel discussed the role of natural gas in Europe's future

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in natural gas, digitalization, and more.

#### **Decarbonization limitations**

PowerGen EU ended with a panel of contrasting views. Jorgo Chatzimarkakis, Secretary General of Hydrogen Europe, expressed strong support for decarbonization.

"The entire gas grid will be decarbonized or transitioned to renewable gas," he said.

But he expressed concerns about physical limitations. Biogas and solar, for example, require a lot of land. And renewable transmission is curtailed by the design of the grid. His proposal is to use excess renewable energy to produce hydrogen and transmit it via pipelines.

"It is ten to twenty times cheaper to transport a molecule in the gas grid than an electron in the power grid," said Chatzimarkakis.

Edouard Sauvage, CEO of French gas distribution firm GRDF, offered an alternate view. His expectation is that natural gas has a bright future in Europe. It will be used in vehicles and blended with some hydrogen, but it will be very much in use in Europe for many decades to come.

Similarly, Pier Lorenzo Dell'Orco Chief Commercial Officer of Italgas, played devil's advocate with the vision that a transition away from natural gas will be completed over the next 10 years. He does not think it is possible in 30 years.

"Perhaps 60% electrification is possible by 2050, but there remains lots of space for natural gas," he said. "It remains the backbone of the energy system with pipelines giving two months of natural gas storage for Europe."



### Some gas turbines were on display but were not the focus of the show

Dell'Orco outlined the value of increased natural gas usage in bringing about a drastic reduction in emissions by displacing coal and oil in many sectors, not just power. He called for more investment in natural gas infrastructure, both to support current supply and to be able deliver a mix of different fuels in the future.

Hans Kreisel, Chairman of European energy distribution advocacy Geode, emphasized the value of the gas infrastructure in a greener future. He said fuels needed to be flexible and high density. Green gas will not solve the entire problem. Sector coupling is needed to greatly lower emissions.

Daniela Gentile, Executive Vice President of Product and Technology at Ansaldo Energia, stressed flexible solutions that included renewables and natural gas.

"Natural gas helps stabilize the grid to enable the deployment of more renewables," she said. "Fast-start GTs that can ramp up and down rapidly are required to compensate for intermittent generation sources."

Balance, she said, was required in policy and in implementation. There is no silver bullet for energy generation and emissions reduction. There must be harmony between demand, production, storage and energy distribution.

Giuseppe Viscardi, Senior Vice President for Regulatory Affairs, Gas and Power at Eni, also voiced a positive outlook for gas globally.

"IEA figures show gas consumption continuing to increase, driven by higher energy demand and the coal-to-gas switch," he said. "Long term, demand is going to rise almost everywhere except Europe and Japan."

That equates to a huge increase in consumption by 2040 (although Europe will see a slight decline by 2030). He called this a golden age for gas. Natural gas can help achieve decarbonization goals by displacing coal.

"While we wait for a zero-carbon breakthrough, gas is already helping countries to decarbonize and has become the preferred choice when paired with renewables," said Viscardi. "Gas remains in the future of Europe."



## **SHOWREPORT**



## POWERGEN INTERNATIONAL

### ENERGY STORAGE, HYDROGEN POWER, LUBRICATION AND CYCLING DOMINATE

**BY DREW ROBB** 

owerGen International remains the largest international event for the power industry. Held in New Orleans, LA in November 2019, one of the big changes from previous events was a focus on energy storage.

Battery technology is gobbling up market share that has traditionally been the province of gas turbine (GT) peakers. Batteries of 10 MW or more are now available. Analysts are predicting the likelihood of 10 GW battery farms by 2025. With costs declining below \$300 per kW/h, the peaking industry is in for some tough competition.

Ihaab Chaban, Commercial Development Director at GE Aero, noted the benefits of batteries, such as instant response, zero emissions, no need for

fuel, and short installation times. However, they struggle to operate reliably and do not offer the kind of ancillary services that GT's provide, such as grid inertia and synchronous condensing.

Mitsubishi Hitachi Power Systems (MHPS) has already entered the battery business. The company reports many orders for its lithium ion products. It has also launched a photovoltaic ((PV) solar company to develop PV projects. Known as Oriden, it is currently focused on the Northeastern U.S.

MHPS chose Powergen to release its plans for a smaller version of an existing GT to better fit market needs. By converting the steam-cooled 330 MW J-class turbine to air-cooling and adding the latest technologies for combustion and fuel efficiency, the 425 MW JAC (60 Hz) has been upgraded to 340 MW at 64% efficiency.

This may be part of an overall trend toward smaller GTs. For decades, "bigger is better," has been the operating rule as turbomachinery OEMs battled to release the largest machine at the highest efficiency. But medium-power GTs appear to be gaining momentum.

#### Lubrication

A partnership between GE and Exxon-Mobil was among the many other announcements at PowerGen. Mobil SHC 918 EE GT oil is tailored toward multi-shaft GTs, such as the GE 7HA,



GE 9HA, GE 6FA.01 and the GE 7FA.

Both companies are touting the value of this new lubricant, claiming improved reliability as well as a jump in turbine bearing efficiency of as much as 15% compared with traditional oils.

Not to be outdone, Shell Lubricants has released a gas-to-liquid (GTL) base oil aimed at lengthening GT life and minimizing the formation of varnish. The GTL base oil is produced by partially oxidizing natural gas to produce a syngas (a mix of carbon monoxide and hydrogen). A catalyst is used to convert the syngas into liquid hydrocarbons before cracking separates these into diesel, kerosene and lubricants.

#### Hydrogen push

Hydrogen power continued to generate attention at PowerGen. Ansaldo Energia is working with Dow Chemical to harness hydrogen remaining from Dow processes for power generation by mixing it with natural gas. Other approaches include electrolysis of water to produce hydrogen, powered by renewable energy. This is known as green hydrogen.

MAN Energy Solutions is another company investing in hydrogen. It has acquired a 40% share in H-Tec Systems, which specializes in electrolysis technology. H-Tec develops and produces stacks and electrolyzers for manufacturing hydrogen with electricity. Water electrolysis and other such techniques, they predict, will eventually lead to an affordable source of hydrogen on a large scale.

#### Cycling

Base loaded units run at or near full load for an extended period. They are warmed to their operating temperature slowly via restricted ramp rates. They come offline only for maintenance and otherwise run continuously.

Cycling units, on the other hand, experience varied loads, ramp up rapidly and experience frequent starts and stops. With far greater presence of renewables on the grid, cycling has become commonplace. But there are con-

sequences.

Daniel Azukas, Senior Management Consultant at Sargent & Lundy summarized the negative impact of cycling. Thickwalled components face increased thermal stresses. Rapid startup times are stressful for the steam turbine (ST) as it is typically the slowest part of the power generation system to warm up.

As a result, there is increased use of drains and vents, and more frequent condensate generation upon shutdown. If not cleared before the next start, this can be damaging.

To make a plant more capable of handling cycling, Aukas made several recommendations: • Maintain heat in the unit during shutdown

- Steam sparging
- Maintain a vacuum during shutdown
- Keep the ST warm

• Start the combustion turbine and ramp it up independently of the ST

• Ensure the drain system is adequate. Water chemistry upsets can affect fluid assisted corrosion (FAC) and ID corrosion. Appropriate water chemistry control should be instituted to deal with cycling demand, along with an FAC inspection program.

Cycling has a significant impact on the bottoming cycle, said Azukas. More output from an existing combustion turbine has consequence for the bottoming cycle. More exhaust gas flow, higher temperatures, a changing exhaust gas flow profile, more steam production, higher steam temperatures, and duct firing for supplemental fired units should be considered.

Additionally, the balance of plant would need to be able to handle higher heat loads and more steam condensing. Similarly, the auxiliary cooling system should be beefed up to handle increased heat load from equipment.



## **GEAR TOOTH CONTACT PATTERN**

## A REFINED METHOD BOOSTS THE QUALITY OF TOOTH CONTACT IN GEARBOXES

By Dietmar Sterns

t is important for gears to have the load distributed evenly over the face width during operation at rated conditions. If the load is distributed unevenly, contact pressure and bending stress increases locally, raising the risk of damage. To achieve an even load distribution, precision is needed in designing, manufacturing, assembly and installation of gear units. These elements are checked, tested and inspected at the gear vendor's shop.

Proper installation in the field is the final step in ensuring acceptability of gear tooth contact. It is vital to ensure that the casing does not get distorted during installation on the baseplate as this leads to bad tooth contact, uneven load distribution, local tooth overload and potential tooth failure.

Under ideal circumstances, gear shafts are parallel with the load uniformly distributed in the gear mesh when running at rated condition (Figure 1). However, the casing can be distorted when the anchor bolts are tightened. As a consequence, the gear shafts may not be parallel.

Assuming one corner of the casing is lifted upwards due to bad contact between casing and baseplate, the casing



Figure 1. Schematic of a gear set in a casing lower part

- b: gear face width in mm
- B: bearing span in mm
- CD: center distance in mm
- H: Casing height in mm
- L: distance between the reference bars (length of the casing) in mm
- W: Casing width in mm

would be twisted. Both rotors would be out of level, too. To determine tooth contact deviation, the difference between these angles must be calculated.

With this value known, the gear manufacturer can determine the influence on the load distribution and the allowable load for the gears. The gear manufacturer checks the tooth contact pattern in



 Figure 2. Checking the level of the gear casing

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the factory while the casing was not distorted. Achieving the same alignment on site makes sure the tooth contact pattern is equivalent to manufactured condition.

The lower casing part of the gear unit has two reference bars (Figure 2). These are precision cylinders with a diameter of 25 mm and a length of 160 mm positioned on the two sides of the gear unit parallel to the gear shaft axes. Each bar has a washer mounted on one end. A precision shaft spirit level has to be positioned on the bar, with the flat side pushed to contact with the washer.

#### Gear case leveling

Steps A to F in Figure 2 show how to proceed for the check of the gear casing leveling.

1. Use a wrench to remove the cover plates that protect the reference bars (2A). Screw the cover plates to the same spot on the casing, but rotated upside down (2B, C). Remove anti-corrosive agent and clean the reference bars.

2. Apply temporary tags on the casing and the cover plates indicating the location of the reference bar and orientation of the gear within the unit.

## **AUXILIARIES&COMPONENTS**

3. Place the shaft level on one reference bar and check the level (2D, E). Make sure the flat side of the shaft level is pushed to contact with the washer. Take a picture or make a sketch of the level. Make sure the tags are visible or that the sketch indicates the location and the orientation.

4. Place the shaft level on the other reference bar and check the level. Make sure the flat side of the shaft level is pushed to contact with the washer. Take a picture (2F) or make a sketch of the level. Ensure the tags are visible on the picture or the sketch contains information about location and orientation.

5. Compare the two readings. The difference between the two readings indicates the distortion of the gear casing, and a potential misalignment in tooth contact. That difference must be within the tolerance specified by the gear unit vendor.

Several conditions should be fulfilled when performing the check with the precision shaft level. The length of the shaft level must be at least 150 mm. The reference bars and spirit level must be clean. The spirit level must have the same orientation when placed on each of the two reference bars.

The gear unit manufacturer performs the same level check twice during manufacturing: once while casing is open and once when closed. The difference between the readings taken at the reference bars has to be within the specified tolerance. On site, it is enough to perform the check without opening the casing.

This method of casing leveling check can also be applied to other machinery components like motors, generators, pumps, compressors, turbines, extruders and base frames. If the component is large, more reference bars can be used.

#### **Case study**

A gear unit rated for 7,500 HP at an input speed of 1,800 rpm and an output speed of 11,808 rpm was delivered for a motor-compressor application with variable speed. Before the start of a string test at the compressor manufacturer, the gear casing was not properly aligned on the test stand. The deviation was 0.12 mm/m, exceeding the design limit of 0.02 mm/m specified in the gear unit manual. Accordingly, tooth contact was compromised.

The ability of the gear unit to handle part load conditions (23%) even with the internal misalignment revealed by the level check was a concern. The angular deviation between the two gear shafts (internal misalignment between the shafts) was calculated.

By taking that value and the reduced load of 23% of nominal torque into account, it was possible to demonstrate that the maximum local contact stress on the gear flanks as well as the maximum local bending stress in the teeth were still below the allowable stress numbers.

It was approved to run the string test at no load and part load with the gear unit as installed. The string test was performed successfully. After the test, the gears were visually inspected through the inspection hatch. It was confirmed that the gear flanks were still in perfect condition.



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analysis of high-speed gear units.

For more information, visit renk-ag.com or email Dietmar.sterns@renk.biz to obtain a complete paper on the topic or more details



## **TURBINES**

## **ENERGY STORAGE: WHY REINVENT THE WHEEL?**

BATTERY STORAGE SHOULD BE SUPPLEMENTED WITH PROVEN TECHNOLOGIES SUCH AS PUMPED HYDRO AND COMPRESSED AIR ENERGY STORAGE

espite rapid expansion, global electricity storage represents less than 2% of the world's electric power production capacity according to the Center for Climate and Energy Solutions. In response, subsidies, policy mandates and innovation are being leveraged to push storage technologies such as rechargeable batteries up to utility scale and economic viability.

Sodium sulfur, lithium ion and flow batteries are all the subject of intense research. Numerous startups have sprung up to bring the latest and greatest to the market. Additionally, there are initiatives around fuel cells, hydrogen power, superconducting magnetic energy storage and numerous other inventions that hope to unlock lowcost, large-scale storage.

But perhaps some of the answer lies in old-school turbomachinery approaches that rely on basic mechanical principles. Why reinvent the wheel when solutions are already available? Pumped hydro storage and compressed air energy storage are both proven in the field at the size needed to support the scale of modern solar projects and wind farms.

Taking a look at the capital costs for the various forms of energy, pumped hydro and compressed air came out well ahead of battery storage in the last Lazard study (Decem-

Storage Technology	Levelized Cost Range (\$/MWh)
Compressed Air	\$116 – \$140
Pumped Hydro	\$152 – \$198
Flow Battery (Vanadium)	\$314 – \$690
Flow Battery (Zinc-Bromine)	\$434 – \$549
Flow Battery (Other)	\$340 - \$630
Lithium-Ion Battery	\$267 – \$561
Sodium Battery	\$301 – \$784

ber 2016) that directly compared these traditional approaches with battery storage in terms of \$ per MWh.

Of course, battery storage prices have been declining steadily since that time. Lazard estimates that the rate of price decline ranges from 4% to 11% per year, depending on the battery technology. But there is bad news on that front. While prices have been dropping, the U.S. only experienced a 6% fall in battery prices in 2018 despite the market nearly doubling (350.5 MW of battery installations), according to energy consultancy Wood Mackenzie. 2019

777 MWh of storage deployed in U.S. in 2018, growing 80% from 2017

Q4 2018 surpassed previous MWh record by 50%



Credit: WoodMac

figures are being finalized but are likely to easily surpass the previous year.

Perhaps it's time to take another look at those golden oldies, pumped hydro and compressed air energy storage.

#### Pumped hydro

Pumped hydro storage (PHS) has been around since the tail end of the nineteenth century. Energy is typically stored by pumping water up a hill during low demand periods and storing it in a reservoir until it is needed during periods of high electricity demand or higher prices. Water is released to turn turbines that generate electricity in the same way power is generated in hydroelectric plants.

PHS can be constructed at a scale of hundreds of megawatts. The stored power can be released over a period of many hours. Despite all the headlines about battery and storage innovation, pumped hydro still accounts for about 90% of energy storage capacity in the U.S – 50 facilities adding up to 22 GW. Europe has about double that amount.

For example, Portugal has been adding PHS to handle the huge influx of renewables in recent decades. Two facilities take advantage of existing dams to store energy to address a growing problem – sudden shifts between abundant renewable resources and power demand.

The Frades I plant in the northwest of Portugal began in 2005 with an output of

## **TURBINES**



Pumped hydro storage is deployed widely across the world and can operate at utility scale

almost 200 MW. Its success led to the construction of Frades II utilizing two existing dams built for hydropower. Power is generated in a powerhouse built inside a cavern which holds two single-stage Francis pump-turbines, and two 420 MVA variable speed asynchronous motor-generators. Frades I and II now work in tandem to provide anywhere from 50 MW to 1,000 MW as required by the grid and the availability of renewables.

Voith Hydro and Siemens collaborated in the installation and commissioning of equipment. Voith supplied Frades 2 with both variable speed pump turbines (each with a rated output of 390 MW), two asynchronous motor generators (440 MVA each), the frequency converter and control systems as well as the hydraulic steel components. The company is currently introducing additional upgrades to extend the facility's power range through integration of hydraulic short circuit technology for variable speed machines. This should help to increase dispatchability while implementing synthetic inertia and frequency containment reserve. Voith believes these upgrades can make Frades 2 a showcase for the potential of PHS to help Europe achieve its renewable energy and emissions targets.

PHS won't work everywhere, however. Large reservoirs are required and not all regions possess them. But in places where hydroelectric facilities already exist, PHS is an option. Australia is reported to have more than 20,000 potential pumped hydro sites. A study by Australian National University (ANU) found that building only a dozen or



HP, IP and LP stand for high pressure, intermediate pressure and low pressure, respectively. The presence of the clutch means a Compressed Air Energy Storage (CAES) plant can easily switch between driving the compressor or generating power.

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so of those could help the nation transition to 100% renewables in less than two decades.

"No matter where you are in Australia, you will find a good pumped hydro site not very far away from where you, or your wind or your solar farm is located," said ANU engineering professor Andrew Blakers.

Another interesting take on PHS comes from Michigan Technological University. Research in Michigan's Upper Peninsula is considering abandoned metal mines as a possible home for pumped hydro. These mines tend to be flooded with groundwater, which could be pumped through turbines to generate power. A pilot project in the town of Negaunee, Michigan is ongoing. If this goes well, it opens the door to PHS across the American West which has hundreds of thousands of old mining sites.

#### **Compressed air**

Another alternative storage technology is Compressed Air Energy Storage (CAES). CAES uses low-cost electricity to inject air at high pressure into underground sites such as salt caverns, disused mines and oil fields and certain geological formations. When demand is high or renewables fall off the grid sharply, high-pressure air can be released and used to power natural gasfired turbines, using much less gas than in



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## **TURBINES**

a normal power plant.

Where CAES exists, it is a resounding success. However, lack of funding has inhibited its deployment. There are currently only two major examples in the field. Both utilize a single shaft design consisting of a compressor/expander, a clutch and a motor-generator.

The original CAES facility is in Huntorf, Germany. The 320 MW E.ON Kraftwerke plant was built in 1978. Its two salt caverns have a capacity of 310,000 m<sup>3</sup>. Its 60 MW compressor can fill the repositories in about eight hours, while the 290 MW turbine operates for two to three hours at an air mass flow rate of 417 kg/sec. Intercoolers on the compressor reduce energy requirements for compression.

The success of Huntorf gave rise to a similar plant being commissioned in the U.S. in 1991. The McIntosh plant in Alabama comprises three Dresser-Rand (now Siemens) compression trains and a huge salt cavern. Its compressor can produce about 54 MW and its expander is rated at 114 MW.

It takes about 40 hours to compress the chambers. Once done, the generator can operate at full capacity for 25 hours or so. The unit can perform emergency starts in nine minutes. The plant runs year round. It provides peaking power when needed and otherwise helps control the grid in fall and spring, or provides backup power. The facility responds based on market conditions. Fuel costs, electricity prices and grid conditions determine how it operates. The German and U.S. CAES plants both use a single powertrain, with self-synchronizing clutches manufactured by SSS Clutch. The engagement or disengagement of these clutches controls whether the motor/ generator is used to drive the compressor or generate grid power.

Since McIntosh, a series of additional U.S. CAES facilities have been proposed. The most recent is the 324 MW Bethel Energy Center in Anderson County, Texas. With a potential storage capacity of around 16,000 MWh, it will provide full power within 10 minutes from a cold start. Its purpose is to offer fast-response ancillary services to help balance renewable energy production, and storage of up to 48 hours to support the growing solar and wind fleet in Texas. It can provide the same volume of ancillary services as 2,000 MW of combined cycle gas turbines with only 112 MW of associated energy production. The project is fully permitted and construction-ready but awaits funding.

There are many suitable storage locations for CAES throughout much of the world. According to the EPRI, about 85% of the U.S. has geologic sites that could work for CAES. Northern Europe, too, has plenty of potential sites, some of which are already used for natural gas storage.

#### **CryoBattery**

A modern update to traditional approaches to storage comes in the form of CryoBattery from Highview Power. Its cryogenic

> system uses liquid air as the storage medium to support power generation, provide stabilization services to transmission grids and distribution networks, and act as a source of backup power. These systems are clean – air in, and nothing but air out with standard plant configurations of 50 MW/500 MWh that can be scaled up.

> When air comes in, it is compressed to form a liquid, refrigerated and stored in tanks (as opposed to requiring underground caverns). When needed, the liquid air is expanded into gas using a turboexpander and clutch arrangement to generate power. This technology is best suited for long-duration applications.

> Highview Power has announced CryoBattery projects in Spain, the Middle East and South Africa. The company is also working on a number of projects in the

UK (North Yorkshire) and in the U.S. (Kansas). For example, Highview is working with TSK, a Spanish engineering, procurement and construction (EPC) company, to co-develop gigawatt-hour scale cryogenic energy storage system.

"This partnership will help Highview Power accelerate momentum for our cryogenic energy storage systems in global markets," said Javier Cavada, CEO of Highview Power. "It is ideal for applications like renewable energy shifting, enabling wind and solar for baseload generation, and hybridizing cryogenic storage plants with traditional thermal generation systems."

Highview Power earlier built two cryogenic plants for the UK grid. One in Slough, Greater London has a capacity of 2.5 MWh. The other in Bury, Greater Manchester has a capacity of 15 MWh. Now the company is modularizing its technology for broader usage. It has partnered with Citec of Finland to streamline engineering and design to be able to deploy CryoBattery systems more efficiently and cost-effectively. The design includes a turboexpander attached to a clutch.

#### **Conventional funding**

A lot of money is being spent on battery storage R&D and incentives. This is certainly needed to push the technology forward. But perhaps some of those funds could be allocated to pumped hydro and CAES. The Australian government, for example, has approved close to \$10 million for a startup named Hydrostor that has developed a new wrinkle on CAES. It aims to build a 5 MW demonstration plant in South Australia that takes surplus grid electricity and uses it to pump air into a cavern partially filled with water. Like the Upper Michigan Peninsula PHS pilot, it seeks to take advantage of a discontinued mine. Hydrostor claims to have 15 more sites in its development pipeline.

The large-scale deployment of CAES and PHS and other systems could offer the support wind and solar need to dominate the grid. Instead of dumping overcapacity at times when wind or solar generation exceed demand or transmission capacity, that power could be harnessed to store energy for use when demand is higher.



Alex Nicolson is a writer and energy consultant based in Southern California. He has a Masters Degree in Mechanical Engineering from Glasgow University.

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## **ROTOFLOW TURBOEXPANDERS**



Darren Prosser, Global Business Manager for Aftermarket at Rotoflow, discusses his company and the products and services it offers in turbomachinery

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This access to operational data enables Rotoflow to incorporate feedback and knowledge into our machinery design. Air Products has designed turbomachinery for over 75 years. We acquired the Rotoflow turboexpander business in 2018. They have been integrated into a single portfolio.

## What turboexpanders do you offer?

Rotoflow's high-pressure compressor-loaded turboexpanders (companders) provide refrigeration for the most efficient air separation and liquefaction facilities in the world. Our companders offer efficiency and reliability in a compact, simple-to-operate-and-maintain package. Features include single-stage, high power-density expansion ratios up to 19:1, up to 15 MW refrigeration, and isentropic efficiencies up to 92%.

### What about generator-loaded expanders?

Rotoflow's generator-loaded turboexpanders (direct-drive, integral gear, external gear and multi-stage) provide refrigeration and economic power recovery in air separation and liquefaction facilities. Used for gas service and dense fluid applications, they offer efficient designs for power recovery on new or existing processes. Features of integrally geared types include an expander impeller mounted directly to the gearbox pinion to eliminate the need for high-speed coupling and an extra set of high-speed bearings. Direct drive and external gear approaches simplify installation and offer flexibility.

#### How about your energy-dissipative expanders?

Available in three types (oil-loaded, blower-loaded, and resistor-loaded), Rotoflow's energy-dissipative turboexpanders provide refrigeration options for efficient hydrocarbon, air separation, and liquefaction operations. They are often used in cryogenic gas separation facilities. Features include efficiency (87%) and a range of sizes. They have millions of successful hours of operation in Air Products plants.

### Rotoflow's energydissipative turboexpanders provide refrigeration options for efficient hydrocarbon, air separation, and liquefaction operations.

#### What do you offer in reciprocating cryogenic pumps?

Primarily handling liquid oxygen, argon and nitrogen, Rotoflow's reciprocating cryogenic pumps reduce cryogenic tank losses and deliver increased refrigeration.

#### What services do you provide?

Rotoflow's service technicians have experience with a wide range of rotating and reciprocating equipment and are able to service and repair all brands of expanders, in addition to Rotoflow equipment.

Aftermarket service and support is available 24/7/365. We are a full-service

OEM with a complete offering including service in the field, spare parts inventory, shop and field repairs, upgrades and rerates, performance and reliability assessments, remote monitoring and training.

## Is there an expander model you'd like to highlight?

Recently we have seen a lot of opportunity for our expander-compressor product line designed for the hydrocarbon market. They offer a broad, standard set of features, while still allowing customization. With development activities, we have achieved a 15-25% reduction in delivery time for some models.

## What markets do you primarily serve?

Rotoflow primarily serves the industrial gas, hydrocarbon, and energy recovery markets, as well as other markets where precision and reliability are key. The industrial gas market includes the use of oxygen, nitrogen, hydrogen, helium and carbon monoxide. We are experienced in the separation, compression, and processing of these gases and other gaseous compounds, backed by the industrial gas expertise of Air Products.

Rotoflow is a pioneer in turboexpander technology in natural gas applications. In 1958, Dr. Judson S. Swearingen, founder of the original Rotoflow Corporation, initiated the program for building and operating the world's first hydrocarbon turboexpander. Today, Rotoflow designs and manufactures specialized turboexpanders used in processes that remove heavy hydrocarbons from natural gas and transform gaseous natural gas into LNG.

Rotoflow turboexpanders can also be used to recover energy. Applications include converting industrial or geothermal waste heat, as well as excess process or pipeline pressure into either electricity or supplemental compression.

#### What about new products?

Our focus continues to be further optimizing efficiency and performance across all product lines. We're working on designs that are a result of customer discussions. In some cases, we collaborate with a customer's technology team to optimize our equipment and their process in parallel, with equipment options that enable innovative process cycle solutions.

## Ride the Wave of New Technology!



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## **CORPORATEPROFILES**



## **Atlas Copco Gas and Process Solutions**

Great ideas transform industries. At Atlas Copco Gas and Process, we help customers prepare for tomorrow by designing, building and servicing turbomachinery for the industrial gases, power generation and hydrocarbon industries. Our passionate people are dedicated to helping customers handle today's pressures while creating a sustainable future.

Solutions include:

- Process centrifugal compressors
- Process and energy recovery expanders
- Process screw compressors
- Aftermarket solutions and upgrades

We are a division of the Compressor Technique business area, headquartered in Cologne, Germany, with additional production centers in the United States, China and India.

Find out how Atlas Copco Gas and Process can help you handle the pressure at atlascopco-gap.com



## A Powerful Synergy

As a turbomachinery company with world-leading operating expertise, Rotoflow, an Air Products Business, draws on decades of experience and operational know-how to design, build, and support mission-critical turbomachinery for the hydrocarbon, LNG, petrochemical, and industrial gas markets. Rotoflow is transforming the turbomachinery industry with unprecedented performance, reliability, and value. Customers across the globe can reach their unique technology and performance targets more efficiently and reliably than ever before.

ROTOFL

Rotoflow is one of the only OEMs both manufacturing and operating turbomachinery, providing total solutions – simple or complex. With its global services team, Rotoflow offers complete support for all types of turbomachinery equipment and systems.

Whether you need new equipment, field service, parts, repairs, upgrades, or rerates, let Rotoflow help you keep your operation running at its best.

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### HydroGT Provides the Ultimate Protection for your Gas Turbine

AAF's HydroGT has been specifically designed to provide the ultimate protection for your gas turbine, ensuring reliable performance and power output in the most demanding of operating environments. By maintaining engine cleanliness HydroGT helps remove unplanned maintenance shutdowns and downtime.

The HydroGT high efficiency filter delivers class-leading protection for your gas turbine, EPA efficiency grades significantly reduce compressor fouling and the need for offline water washing, resulting in increased machine availability and reduced operational costs.

HydroGT's large media coverage ensures a high dust-holding capacity, resulting in a longer filter life. The product is water repellent with vertical pleats to maximize drainage and enhance engine protection. AAF's proprietary media repels water, oil, hydrocarbons and salt, making it one of the most versatile barrier filters on the market today. Efficient drainage of the filter ensures performance is maintained and the gas turbine remains protected, even during moist and humid conditions.

The robust filter frame and protection screen prevent distortion of the media pack over the life of the filter, delivering stable filter performance and low differential pressure. Compared to many competitors' filters this solid and durable design offers a step change in performance and can easily be installed in competitor filter systems without any modifications.

For the very maximum protection specify HydroGT V450+, this deeper filter has an extended media area for even longer operational filter life.



Experience more. Together.



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## TURN TO US FOR YOUR ROTATING EQUIPMENT SOLUTIONS

Our organization is engineered to deliver value. We work in partnership with our customers to fully understand their needs, and provide customized solutions.

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Find out how we can maximize the return on investment for your rotating equipment at www.ethosenergygroup.com





Mitsubishi Heavy Industries Compressor International Corporation (MCO-I) combines highly efficient turbomachinery meticulously manufactured in Japan with over 100 years of experience with fast, fine-tuned local services in the Gulf Coast region. The Pearland Works 26-acre campus, located just south of Houston, TX, is the first facility in the Americas dedicated to the packaging, service and storage of Mitsubishi and other OEM's turbomachinery backed by local sales, engineering and operation experts. Our after-sales service team offers an extensive portfolio of proactive and reactive service solutions for mechanical drive steam turbines and centrifugal compressor of all makes and models. We work around the clock to complete emergency repairs fast and efficiently to mitigate risk. For more routine maintenance, our outage management expertise and critical path scheduling keep projects moving quickly from shutdown to start up. Planned or unexpected, our teams mobilize to your sight to provide a variety of customized services designed to mitigate your risk, improve performance, and reduce outage time frames.

**EthosEnergy** 

## CUSTOM BEARING SOLUTIONS

Marine Engines & Systems Power Plants Turbomachinery MAN PrimeServ

MAN Energy Solutions enables its customers to achieve sustainable value creation in the transition towards a carbon neutral future. Addressing tomorrow's challenges within the marine, energy and industrial sectors, we improve efficiency and performance at a systemic level. Leading the way in advanced engineering for more than 250 years, we provide a unique portfolio of technologies. Headquartered in Germany, MAN Energy Solutions employs some 14,000 people at over 120 sites globally. Our after-sales brand, MAN PrimeServ, offers a vast network of service centres to our

Waukesha Bearings<sup>®</sup> is a global leader in the design and manufacture of engineered hydrodynamic bearings, active magnetic bearing systems and brush seals for high-performing turbomachinery.

Our engineering expertise has earned us a strong reputation for achieving lasting performance. Our comprehensive range of oiland process-lubricated bearings are engineered for low power consumption, low bearing temperatures and the highest reliability. Our magnetic bearing systems address the requirements of rotating equipment from 50 kW to 80 MW and have achieved 99.9% availability.

Through ongoing research and development, Waukesha Bearings continues to expand bearing capabilities and improve performance.

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## **CORPORATEPROFILES**



#### RENTECH BOILER SYSTEMS CONTINUES TO LEAD THE IN-DUSTRY IN PRODUCING NEW, INNOVATIVE BOILER DESIGNS

Our boiler manufacturing experience and passion for customer service has made a significant difference to our customers, who include the largest independent power producers, refining, petrochemical, and industrial companies in North America. At RENTECH, we aren't resting on our reputation – we are continually building one!

#### HRSGS FOR SMALL- AND MEDIUM-SIZED GAS TURBINES

We specialize in, and are the largest supplier of, HRSGs for today's high-efficiency gas turbines that operate in the 3-40 MW size range. Our expertise in high-fired applications incorporates full optimization of the duct-burner performance while utilizing Catalytic Oxidation and SCR for control of emissions from the entire system.

#### MARKET LEADER IN LARGE FIRED PACKAGED BOILERS

Our Packaged Boiler design has been specified time and again for critical industrial processes, turbine warm-up and auxiliary boiler applications because of its rugged design and proven reliability. 100% Membrane Wall construction eliminates the need for refractory and enables quick start-up to achieve full steam capacity of the boiler in a fraction of the time that it takes with older designs.

#### INTEGRATED SOLUTIONS FOR ACHIEVING LOWER EMISSIONS

Our approach to achieving lower emissions starts with optimization of the boiler design. Coupled with RENTECH's knowledge of low emissions burner and catalytic reduction technologies, we are capable of supplying a system that fully complies with all performance criteria and is backed by a single-source guarantee.



ILERS FOR PEOPLE WHO KNOW AND CARE

## **ADINDEX**

### What if you could get a like new high performance coupling for less?

Kop-Flex High Performance couplings are engineered to API 671 guidelines for each application and designed for the life of the connected rotating equipment. However, couplings subjected to stresses during operation beyond their design criteria can result in a shortened service life. Since safety, performance and reliability are priorities for turbomachinery in the Oil & Gas Industry, it is important to inspect high performance couplings during scheduled turnarounds. Not doing so could result in unplanned downtime costing tens of thousands of dollars. At Kop-Flex® recertification facilities worldwide, we have the equipment and expertise to recertify your worn high performance couplings to "like new" for 50-60% of the cost of a new one. In two to six weeks, Kop-Flex engineers and field specialists work with you to understand your application, make recommendations to improve life, create inspection reports and provide a specific recertification proposal. The coupling recertification process is completed with a full hardware replacement and an original factory warranty.

For information about how we can help recertify your high performance coupling to like new, call 800-626-2120 or visit us at regalbeloit.com/turbomachinery.



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#### Waste energy recovery

AMSEnergy energy recovery systems use heat-pipe technology that acts as a heat exchanger and a way to collect, convey and redistribute thermal heat energy within a system.

Advancements in the production and efficiency of heat-pipe heat exchangers offer the opportunity to recoup more thermal energy.

Thermosyphon heat pipes from AMSEnergy are hermetically sealed evacuated tubes normally containing a working fluid in both liquid and vapor phase. When the evaporating end of the tube is heated, the working fluid absorbs the latent heat of vaporization.

Hot vapor flows to the colder end of the tube where it condenses and gives up the latent heat to the receiving thermal energy stream. The condensed liquid flows back to the hot end of the tube where the cycle repeats. Considerable quantities of heat can be transported with a small temperature differential from one end of the heat pipe to the other.

Each heat pipe can be filled with a variety of working fluids to maximize the heat transfer potential according to the application. The selection of the correct pipe material and the proper working fluid is said to allow the heat pipe to transfer up to 1,000 times more thermal energy than a normal copper pipe of the same dimensional mass typically found in a standard heat exchanger design.

As part of an evaluation process, companies should take critical measurements within the production process to identify the amount of energy that can be captured from the heat in the waste-energy stream.



The available heat, coupled with its mass flow capacity, determines the amount of energy that can be captured and returned to the facility or application for re-use by the same or a completely different process which could be on or offsite, e.g., district heating or power generation.

#### Amsenergy.com

#### **Condition monitoring**

Alta Solutions has developed a condition monitoring system that is said to interface with any existing machinery protection system, including Bently, Vibrometer, SKF, Shinkawa, and so on. The AS-6000 Condition Monitoring System records data, integrates into various IT infrastructures and communicates with the control room while meeting or exceeding cybersecurity requirements.

It is a modular monitoring system for capturing dynamic data from existing protection systems, control systems or directly from machine-mounted sensors. Its compact chassis has a 10-slot backplane and configurable input modules. The modules can be installed or removed as needed depending on the application size and requirements. Machinery sensors connect directly to the modules, which acquire and process real-time waveform data. The AS-6000 with the AS-6030 SM+AP option records machinery events for analysis as well as long-term trend data for preventative maintenance.

Alta Solutions analysis software (AS-250 SpectralMon) can also be used to evaluate and interpret the data. Up to 64 channels can be configured to interface with many types of sensors including, accelerometers, pressure transducers, velocity transducers and displacement probes. The AS-250 SpectralMon software acquires and processes the same data as AS-410 software. The difference is in the user interface, which is frequently configured to provide numerical data values and alarm logs rather than analysis plots.

The AS-250's alarming logic allows the Alta system to determine when to capture essential machinery and process data needed for machinery diagnostics and troubleshooting. Operators are informed of machine condition so action can be taken if required, using machinery vibration data synchronized with plant process data.

#### altasol.com

#### MAN augmented reality

MAN Energy Solutions is testing its newly developed augmented reality (AR) application. Known as PrimeServ Eye-Tech, it is being used in more than 20 applications for service orders and in cooperation with a pilot customer for turbomachinery maintenance and repair.

The remote support tool enables mobile video conferences to be set up via data glasses. In this way, the technical specialists in the MAN Remote Operation centers can take the customer's perspective without having to be on site themselves.

PrimeServ EyeTech combines a safety helmet with a camera, micro screen, microphone and headphones. The camera mounted on the helmet enables the MAN expert to see on screen what the technician sees on site and to guide the technician visually and acoustically through



Man PrimeServ EyeTech for remote support of maintenance actions

maintenance processes. Additional information is provided to the customer via a helmet display.

ManES.com

#### Alstom, Siemens bolting

Prime Turbine Parts (PTP) provides certified bolting for all Alstom gas turbines (GTs) and Siemens V machines. Coupling bolt sets, rod bolts, body-bound studs, double-ended studs, valve spindles and stems, weighed bolting sets, coupling bolts and through bolt sets are available for:

- Alstom GT11N2
- GT11N
- GT24B
- GT26
- Siemens V84 or V64

All bolting supplied is equivalent to the OEM and all material certifications are available when requested at time of order.

primeturbineparts.com

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AAF International

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New lubricants
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Petro-Canada Lubricants, a Holly-Frontier business, has launched its new automatic lubricator, Grease-N-Go in two sizes (125ml and 250ml) and for seven grease products across the Petro-Canada Lubricants Purity FG, Precision and Peerless product lines.

The automatic lubricators ensure optimum protection of equipment operating in the food manufacturing, general manufacturing, construction, petrochemical and heavy-duty industries.

These automatic lubricators can be used for lubrication points in difficult-to-reach areas, such as tight corners, spaces near rotating equipment or areas subject to high or cold temperatures. Once installed, the automatic lubricator can be left in situ to deliver grease for a chosen lubrication period.

#### lubricants.petro-canada.com



#### Joining tools

Monaghan Tooling Group had introduced Mechanical Joining Tools (MJT) to join tubing to flanges and fittings. This is said to create secure, leak-proof joints that withstand up to 20,000 pounds of hydrostatic pressure.

These joints are said to be superior to welded, brazed or crimped joints. Rolling to a torque ensures consistent results, regardless of tolerance and variations of the tube OD, wall thickness and component ID. Rolling to a consistent diameter guarantees a consistent ID of the tube, which makes it possible to round up the ID of the tube.

Almost any annealed or ductile product can be mechanically joined, including mild steel, stainless steel, aluminum, titanium, Inconel and more. This approach works well for applications where joints loosen due to temperature changes, altitude changes, and vibration, and where high pressure is present.

#### MonaghanTooling.com



Monaghan has introduced Mechanical Joining Tools

#### ExxonMobil/GE oil

ExxonMobil and GE collaborated to develop Mobil SHC 918 EE, a GT oil that is said to improve turbine bearing efficiency by up to 15% compared to conventional ISO VG 32 turbine oils. Designed for use in multi-shaft 7HA, 9HA, 6FA.01 and 7FA GE turbines, it is designed to help power plant operators reduce production costs and lower carbon dioxide emissions.

GE developed a test rig to simulate turbine bearing surface speeds under varying load conditions to select the optimum turbine oil to provide energy efficiency benefits. Mobil SHC 918 EE was successfully tested in GE's test stand for 7HA and 9HA GTs. Performance was monitored by 4,000 sensors through a battery of testing conditions, including critical speed startups under a variety of operating conditions. GE field-tested the turbine oil in 6FA & 7FA turbines for over two years.

Mobiloil.com

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## **MYTH: YOU CAN ALWAYS LEARN SOMETHING FROM FAILURE**

ark Twain once said, "Good judgement is the result of experience; and experience the result of bad judgement." That wise saying is something that turbomachinery engineers and machinery manufacturers should take to heart, especially when it comes to equipment failures.

In most cases, a conservative approach to preventing future failures by avoiding past mistakes is wholly appropriate. Unfortunately, this philosophy can lead to long-term innovation stagnation and risk avoidance. The result can be less than optimal designs.

Rainer and I both work for companies (Solar Turbines and Elliott Group, respectively) that have decades of turbomachinery design experience. Both companies have built tens of thousands of machines for clients all over the world. They have track records of reliable machinery with low failure rates. But Murphy's Law will always hold: Machinery problems can and will happen.

When failures do happen, a root cause analysis (RCA) is performed. An RCA helps to identify the cause of failure. However, in some cases, the RCA misidentifies the underlying reason for a failure.

The complexity of turbomachinery, after all, means that failures can occur in many possible ways. Some are completely unexpected. They may be unexplainable with the forensics and analysis methods available at the time.

RCA methods typically include material, structural, vibration, and other engineering reviews. The technologies and techniques available have drastically improved over the last 30 years. Although not every failure cause can be identified 100% accurately, human nature drives us toward a desire to reach a final analysis conclusion.

Out of an over-abundance of caution, almost all of these failures resulted in an engineering design rule, restriction or operating limitation to avoid future failures. Over the years thousands of rules and design limitations have become common engineering practices. Many of these practices have been codified in API, ISO, and ASME standards or other industry norms and customer specifications. Over the decades, these standards, norms, and specifications have drastically limited the possibility of creative engineering.

### Failures must not always lead to limiting design restrictions. They should incentivize innovative and novel design solutions.

#### Not all the same

Not all failures are the same. Those that pose a safety risk should be handled differently than those requiring repairs or related to inability to achieve performance. There are obviously grey areas. There are likely to be discussions about which category a failure belongs to. But such questions can usually be clarified using the following simple questions:

• When does a machinery failure pose a risk to the health, environment and well-being of the operators or public?

• Is the failure catastrophic or did it result in repairable equipment damage?

• When is it more of an operational nuisance rather than a true failure?

• Is the failure truly related to the operability of the machine or is it primarily an annoying performance issue?

Over time, collective machinery experience has resulted in design practices that could be considered overly restrictive. Examples include vibration and dynamic limits, control and instrumentation requirements, prescribed materials and coatings for key components, utilities and utility connections, structural load limits, and inspection and inspection access points, many of which are considered unimpeachable in the cannon of machinery engineering.

Rather than accepting them, they should be subject to re-evaluation and technically assessed to make sure they are appropriate and applicable, especially when considering novel technology options and creative solutions.

When a failure occurs, therefore, we should not only ask how we can avoid the failure, but how can we creatively modify, redesign or even reinvent a system to avoid future failures. Not every failure is avoidable and not every failure should result in a design or operation restriction.

A single data point does not make a trend. Yes, costly failures should be avoided, and safety and the environment are always paramount. Failures must not always lead to limiting design restrictions. They should incentivize innovative and novel design solutions.



Klaus Brun is the Director of R&D at Elliott Group. He is also the past Chair of the Board of Directors of the ASME International Gas Turbine Institute and the IGTI Oil & Gas applications committee.



Rainer Kurz is the Manager for Systems Analysis at Solar Turbines Incorporated in San Diego, CA. He is an ASME Fellow since 2003 and the past chair of the IGTI Oil and Gas Applications Committee.

Any views or opinions presented in this article are solely those of the authors and do not necessarily represent those of Solar Turbines Incorporated, Elliott Group, or any of their affiliates.

## Handle the Pressure

Tight budgets. Shrinking timelines. Growing expectations. They challenge us to transform industrial ideas into solutions that help you thrive under pressure. Depend on Atlas Copco Gas and Process to design, build and service turbomachinery for the industrial gases, power generation and hydrocarbon industries.



27 MW Mixed-refrigerant Compres

PROCESS AND ENERGY RECOVERY EXPANDERS



Expander Compressor for NGL recovery



**PROCESS SCREW** 

COMPRESSORS

Gas Screw Compressor

+ AFTERMARKET SOLUTIONS AND UPGRADES

### What sets us apart



#### Reliability & availability

**8,000+ reference machines** running in process gas applications worldwide.



**10–15% efficiency increase,** thanks to advanced technologies perfectly matched to your process needs.



#### Custom aero, standard package

CAPEX and OPEX savings with our standardized solutions that offer optimized aerodynamics and pre-engineered package components.

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## Process Industry = solutions expertise

Sustainable ideas for energy efficiency Improving energy efficiency reduces your environmental footprint and energy costs while raising output and profits. With our expertise and innovative ideas, we can implement resource-efficient, low-impact technologies and services for large industrial plants and small, single-site operations.