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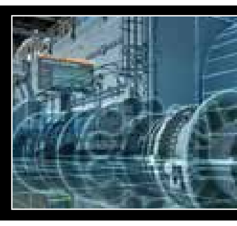
Special Project Supplement

HYFLEXPOWER aims to demonstrate a world first for hydrogen.

Mirror to the future

GE Digital's Colin Parris explains the benefits of digital twins and offers a glimpse of what's to come. *Page 14*



Final Word

Don't get lost down a rabbit hole in pursuit of net zero, warns Junior Isles. *Page 16*

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Calls for changes to ETS as Europe raises Paris ambition

European Commissioner Ursula von der Leyen pushing for stronger emissions target

Changes are needed to Europe's emissions trading scheme if it is to fulfil its new target for carbon emissions. **Junior Isles**

There has been a growing number of calls for the European Commission to upgrade it Emissions Trading Scheme (ETS) following the announcement of the bloc's proposal to increase its climate commitment and reduce carbon dioxide emissions by at least 55 per cent by 2030 relative to 1990 levels. This is the level necessary to put the EU on a path to climate neutrality by 2050.

A new report by the European Court of Auditors (ECA) called for the Commission to update its procedure for targeting free allowances to reflect the Paris Agreement and recent developments. It noted that free allowances still make up over 40 per cent of all available allowances under the EU's 'cap and trade' ETS, and that these free allowances, distributed to industry, aviation and, in some Member States, the electricity sector, were not well targeted.

The EU's ETS uses free allowances to discourage EU businesses from transferring activity to non-EU countries with lower environmental standards, as this would reduce investment in the EU and increase global emissions. This is known as carbon leakage.

The industrial and aviation sectors benefit from free allowances, unlike most operators in the power sector, as it is considered that they can pass on carbon costs directly to the consumer. However, in the eight Member States with a GDP per capita below 60 per cent of the EU average, the power sector received free allowances to enable modernisation to take place. According to the ECA, this has significantly reduced the speed of decarbonisation in the power sector.

"Free allowances should be targeted at those industrial sectors least able to pass on carbon costs to consumers," said Samo Jereb, the ECA Member leading the audit. "However, this is not the case. Sectors representing over 90 per cent of industrial emissions are equally considered at risk of carbon leakage and benefit from continuous high rates of free allowances. Unless the allocation of free allowances is better targeted, the EU will not reap the full benefits the ETS could have on decarbonisation and public finances."

The auditors acknowledge, however, that the Commission has tightened rules affecting the power sector for 2021-2030.

There were also calls to extend the ETS to heating. EGEC Geothermal said it is absolutely crucial the European Commission recognises the importance of decarbonising heating and make this a priority area for action.

The heating and cooling sector represents 51 per cent of final energy consumption in Europe and approximately 27 per cent of EU carbon emissions.

EGEC Geothermal noted that 80 per

Continued on Page 2

Trump administration continues pushback on Democrat clean energy stance

Trump administration has finalised its weakening of an Obama-era rule aimed at reducing polluted wastewater from coal burning power plants that has contaminated streams, lakes and underground aquifers.

Utilities are expected to save $140 million annually under the changes, which Environmental Protection Agency (EPA) Administrator Andrew Wheeler said in a statement would protect industry jobs in part by using a phased-in approach to reducing pollution.

But environmentalists and a former EPA officials warned the move will harm public health and result in hundreds of thousands of pounds of pollutants annually contaminating water bodies.

The new rule introduced at the end of August largely exempts coal plants that will retire or switch to burning natural gas by 2028.

It is the latest in a string of regulatory rollbacks for coal power under US President Donald Trump – actions that have failed to turn around the industry's decline amid competition from cheap natural gas and renewable energy.

The Democrats' clean energy vision has come under fire since Trump took office in 2016 and has become a point of political debate with the California forest fires that have caused blackouts in the Democrat-run state.

The American Energy Alliance said California was a preview of what Democratic presidential candidate Joe Biden's plan would do to the rest of country, stating that the blackout stemmed from a "severe heatwave and without the wind blowing and the sun shining".

"Residents are asked to conserve electricity to keep the power on – something most other states do not have to endure," the Alliance noted. "This should be a warning to America about the risks of Biden's Clean Energy Standard that would require 62 per cent of our electricity which is now produced from natural gas and coal to come from non-carbon sources, which would primarily be wind and solar power."

Renewables currently generate about 15 per cent of America's power. Biden has specifically pledged to eliminate carbon emissions from the power grid by 2035.

"The whole thing is a kind of fairytale that assumes you can run the electric grid on fairy dust," said Myron Ebell, Director of Competitive Enterprise Institute's Center for Energy and Environment. "What the Green New Deal and the Biden Energy Plan have not figured out is where the electricity is going to come from when the wind isn't blowing and the sun has been down for a day."

Meanwhile, Wyoming's governor is promoting a Trump administration study that says capturing carbon dioxide emitted by coal fired power plants would be an economical way to curtail pollution. PacifiCorp, the utility that owns the plants and wants to shift away from the fossil fuel in favour of wind and solar energy, has questioned the findings.

The study released in late August says adding carbon capture at the four plants would reduce carbon dioxide emissions 37 per cent, cost electricity customers 10 per cent less and produce up to five times more jobs compared with PacifiCorp's plans to shift to clean energy.

PacifiCorp took issue with the study, saying it ignored "everything associated with how a utility's costs flow into rates" and made a range of assumptions.

"As PacifiCorp continues to examine the study's assumptions and calculations to properly evaluate its conclusions, we're finding many of those conclusions are simply wrong," David Eskelsen, a spokesman for PacifiCorp subsidiary Rocky Mountain Power, said in a statement.

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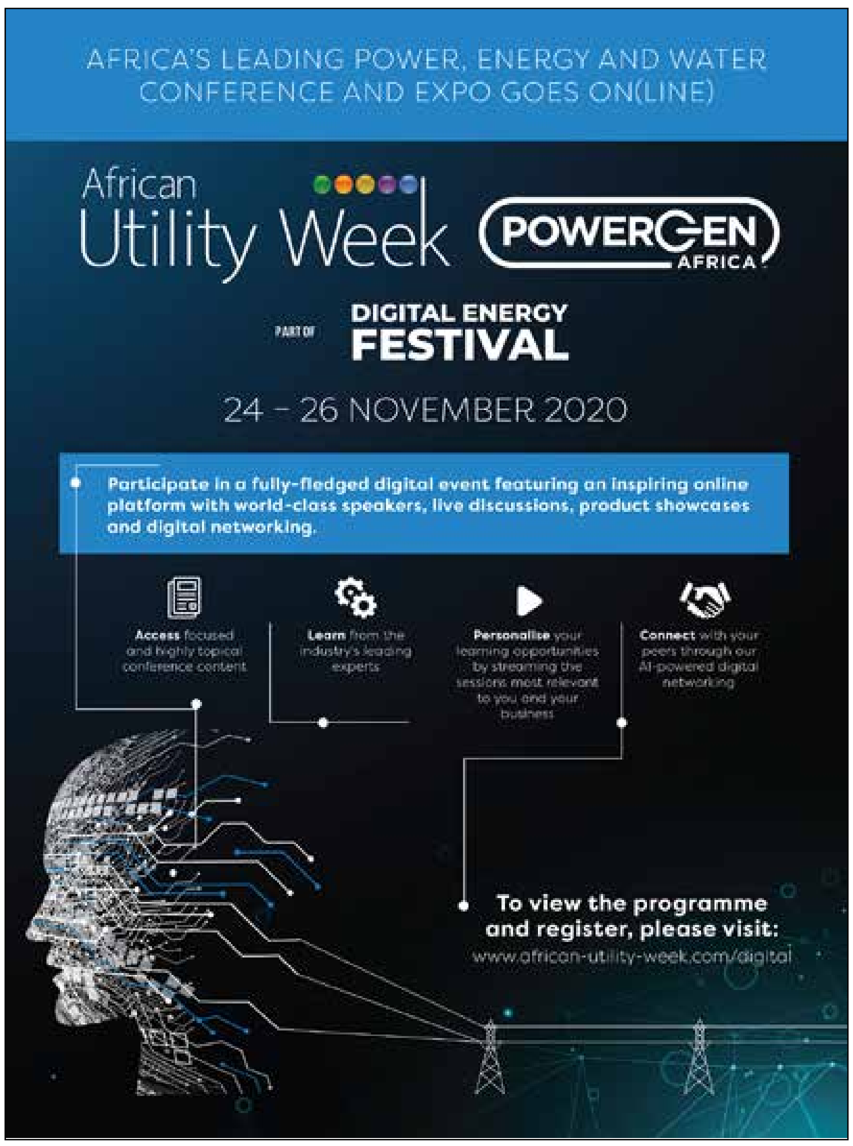
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US tensions impact China power sector

■ Government reduces gas fired power tariffs ■ US reactors no longer in favour

Syed Ali

Tension between the US and China is having an indirect impact on China's power sector.

Last month Wood Mackenzie reported that gas power plants are struggling to stay afloat as they face mounting pressure from lower tariffs and the ongoing trade war.

The Chinese government has been reducing regulated gas fired power tariffs by 16 per cent to 28 per cent in key provincial markets since June 2020. This is driven by political goals of reducing end-user power prices and improving manufacturing competitiveness in the wake of trade tensions with the US. Power tariffs for industries in China have fallen 25 per cent in the last three years.

Gas fired power tariffs at some higher-utilised gas plants (>3500 hours per year) have even been lowered to a level similar to the much cheaper coal fired power. This 'coal parity' initiative has a huge impact on the economics of the current gas fleet and investment decisions for new units.

Wood Mackenzie principal consultant Frank Yu said: "The new regulations will cause at least a 5 to 6 percentage point decline in the already poor margins of gas power plants. Delivered fuel costs at most gas power plants have only declined by 10 per cent to 13 per cent, while revenues have been cut by 16 per cent to 28 per cent due to the new regulations. Most projects are now loss-making or barely breaking even."

Despite strong demand growth for clean power, government policies have been moving to limit gas power development and support energy security goals.

By 2025, around 8 billion m^3 or 17 per cent of gas demand for power generation in four coastal markets could be at risk due to fewer new builds and lower utilisation hours as a result of poor economics. Wood Mackenzie estimates around 7 GW out of 17 GW of gas fired power projects scheduled for commissioning between 2022 and 2025, to be at risk of delays or cancellations. These projects are located in the coastal provinces of Zhejiang, Jiangsu, Shanghai, and Guangdong.

Worries over energy security and increasing geopolitical uncertainties, has also seen the country switch from US nuclear power technology to a domestically developed alternative, according to a recent report in the *South China Morning Post*.

The AP1000 technology, designed by America's Westinghouse Electric Company, was once the basis of China's third-generation nuclear power, but now the country has more third-generation reactors based on its own Hualong One technology under construction or approved, than it does AP1000 reactors.

Meanwhile, four units approved last year and another four nuclear reactors approved on September 2 – in Hainan and Zhejiang province – will also use Hualong One technology.

Wang Yingsu, Secretary General of the nuclear power branch of the China Electric Power Promotion Council said that technology localisation, development of indigenous nuclear power technology, and the capability of constructing and operating nuclear power plants independently had always been China's goal since it began its nuclear power journey more than 50 years ago.

"More power plants will choose Hualong One in the future because it's China's independently developed technology and it's as good as AP1000," Wang commented. However, he added: "AP1000 is Westinghouse's technology and we might be controlled by them if we want to build the reactors, sell and export to other countries."

When the US sanctioned China General Nuclear Power Group (CGN) and three of its subsidiaries in 2019 over accusations of stealing US technology for military use, CGN said the impact on the company was "controllable".

Xu Kan, assistant general manager of Qinshan Nuclear Power Plant, a subsidiary of China National Nuclear Corporation (CNNC), said last year that CNNC began investigating the possible impact of geopolitical factors on its 21 reactors in 2018.

Japan prepares offshore wind blueprint

Japan is set to draft new rules and create a support framework in a drive to construct offshore wind projects at 30 locations by the end of the next decade.

Under the plans, three or four projects would be built per year with a total generation capacity of 1 GW, from the fiscal year beginning in April 2021 until 2030-2031. By the end of the decade, a total of 10 GW of potential generation sites are expected to be identified for further development, according to data and analytics company GlobalData.

Japan's offshore wind sector is already proving attractive to investors. In September Equinor, Jera and J-Power announced a partnership to enter a joint bid agreement prior to Japan's upcoming Round 1 offshore wind auction.

The three companies will jointly evaluate and work towards submitting a joint bid in the Round 1 auction once the Japanese government officially opens what will be country's first offshore wind auction.

The Japanese government has dedicated Yurihonjo and Noshiro, two areas offshore the northern Japanese prefecture of Akita, as promotional zones for offshore wind, each representing an area for bottom-fixed offshore wind farms of approximately 400 MW and 700 MW, respectively.

The upcoming auction is anticipated to start within the next months, with bid submission taking place six months after the auction opens. Once the auction is closed, the results are expected to be announced towards the end of 2021. Potential wind farms would then tentatively be operative post 2025.

Also in September, Spanish energy company Iberdrola reached an agreement with Macquarie's Green Investment Group (GIG) for the acquisition of 100 per cent of Japanese developer Acacia Renewables. Acacia Renewables currently has two offshore wind farms in development, with a combined power of 1.2 GW, which could be operational by 2028.

It also has four other projects in its pipeline, with a total generating capacity of 2.1 GW. Three of the six projects will use floating foundations. Iberdrola will hold an equal share in the six projects alongside GIG, and the partners will develop the portfolio.

The acquisition of this local renewable developer gives Iberdrola the opportunity to position itself in the Japanese offshore wind sector, which is at an early stage of development.

Installed offshore wind capacity in Japan is currently around 70 MW, but the forecasts indicate that the market will reach 10 GW of installed capacity in 2030, and up to 37 GW in 2050.

Special Project Supplement

Flexing the power of hydrogen

Smurfit Kappa PRF's site in Saillat-sur-Vienne, France where the HYFLEXPOWER project will be built

In May this year, Siemens Energy together with its consortium partners announced a project that will see a dry low emissions gas turbine burn up to 100 per cent hydrogen produced from renewable energy. Known as HYFLEXPOWER, the project will be the first to achieve this at an actual industrial site. **Junior Isles**

The potential of hydrogen as an energy vector – capable of decarbonising heat, industry, power and transport – has long been recognised. But it is only during the last couple of years, with the plummeting cost of electricity from wind and solar, that developments have really escalated.

Using renewable electricity to decarbonise energy across all sectors has huge environmental and business benefits. And with the first significant projects now taking shape, this so-called 'sector coupling' – bringing renewable energy from the power sector into the other sectors to thereby decarbonise the entire energy system – is finally set to play a crucial part in the energy transition.

It is an area that Siemens Energy believes has enormous potential and over the last few years has therefore been ramping up investment in power-to-X (P2X) technologies that enable sector coupling.

In May this year, the company unveiled a significant venture known as HYFLEXPOWER, a project that will play a key role in decarbonising its fleet of gas turbines. Siemens Energy notes that although the power sector has decarbonised significantly by switching from coal to gas and using renewables, there has not been the same level of focus on using hydrogen to cut carbon dioxide (CO_2) in the power industry compared to other sectors.

Eva Verena Klapdor, Head of Gas Turbine Technology at Siemens Energy, commented: "There has been a lot of discussion on how hydrogen could reduce emissions in the industrial and transport sectors, but not so much on how to it could reduce carbon emissions in the power sector itself, i.e. power-to-X-to-power."

She added: "Batteries are fine for short-term storage of excess renewable energy but if you want to move to a future where you decarbonise the energy system completely, then you have to look at systems where you can store energy for more than a couple of days. Hydrogen is really an optimal solution, whereby you could use it to store renewable energy and then convert it back to electricity at a later date through a gas turbine in a combined cycle plant or combined heat and power plant.

"We have a vision that needs to be demonstrated. You can do lots of calculations and modelling of the economic viability of such a solution but… ultimately you have to go and demonstrate it."

The HYFLEXPOWER project will see a consortium made up of Engie Solutions, Siemens Energy, Centrax, Arttic, German Aerospace Center (DLR) and four European universities implement a project funded by the European Commission under the Horizon 2020 Framework Program for Research and Innovation (Grant Agreement 884229).

The project, which is being hailed as the world's very first industrial-scale power-to-X-to-power demonstrator with an advanced hydrogen turbine, will be launched at Smurfit Kappa PRF's site in Saillat-sur-Vienne, France. Here Engie Solutions operates a combined heat and power (CHP) facility, which produces 12 MWe of electricity and 20 MWth of heat as steam for Smurfit Kappa's recycled paper manufacturing process.

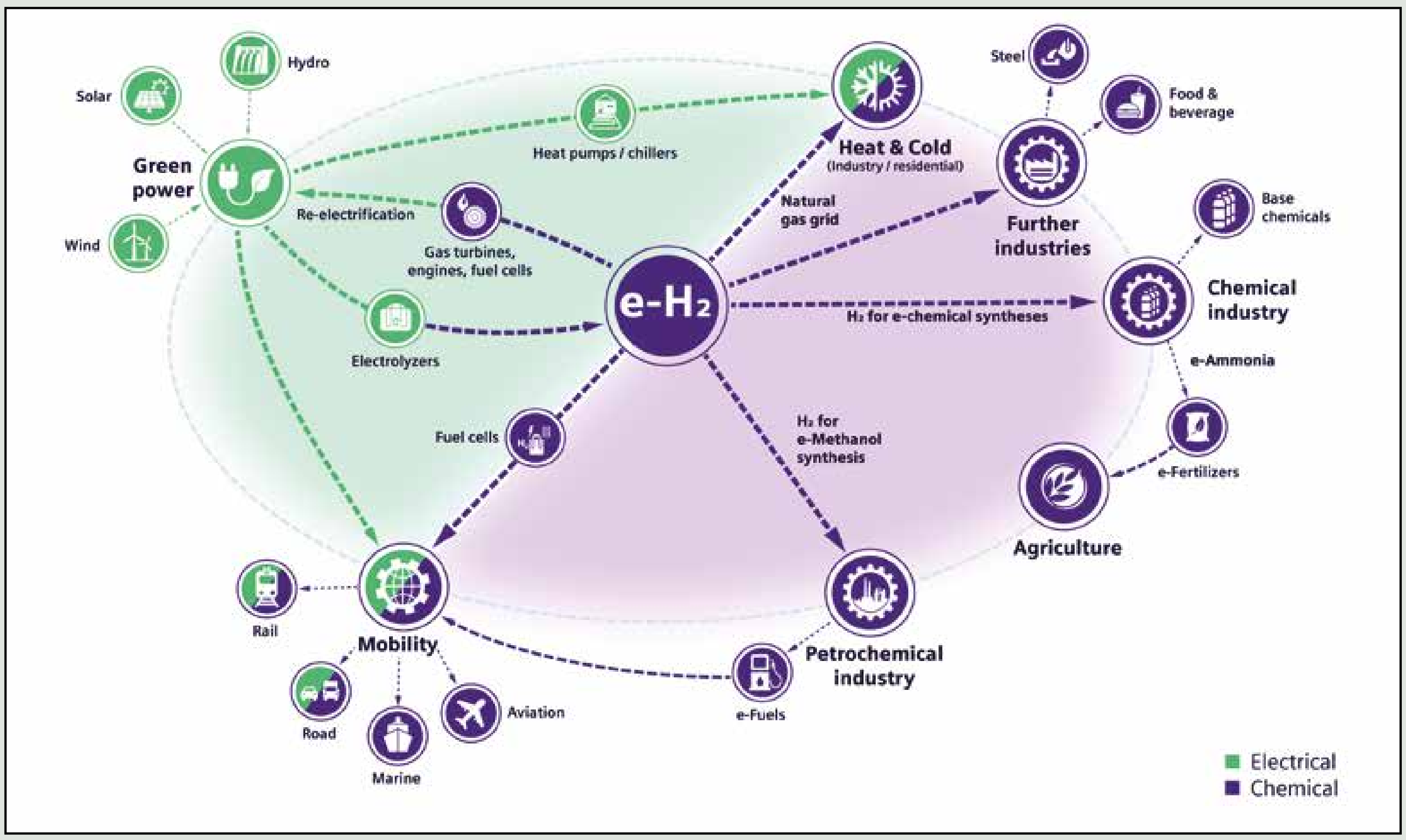
The aim of the HYFLEXPOWER project is to prove that hydrogen can be produced and stored from renewable electricity and then mixed, up to 100 per cent by volume, with the natural gas currently used at the CHP plant. This means it will be a completely dispatchable CHP unit, even if insufficient hydrogen is available.

Blending natural gas and hydrogen can substantially lower carbon emissions. The EU is closing coal fired plants and has made renewables a central pillar of achieving carbon neutrality by 2050 but in the long term it will also have to remove carbon from its gas fired plant. Displacement of natural gas fuel with hydrogen is a viable means of enabling carbon neutral power plant operation as hydrogen combustion produces no CO_2.

Notably, when operating on 100 per cent green hydrogen the SGT-400 in baseload operation at the Smurfit Kappa site would save up to 65 000 tons of CO_2 per year.

Hydrogen fuel blending not only lowers CO_2 emissions, it also ensures that the gas turbines can participate in electricity storage and re-electrification. Hydrogen can serve as a chemical storage vehicle by being produced through electrolysis of water during times of excess renewable energy generation, and then used to fuel gas turbines or sold to other industries

Ertan Yilmaz, Strategy Manager for Gas Turbine Technology at Siemens Energy, and coordinator for the HYFLEXPOWER project commented: "The project is not only a world first



Sector coupling: using renewable electricity to decarbonise energy across all sectors has huge environmental and business benefits

Klapdor: Hydrogen is an optimal solution to store renewable energy and then convert it back to electricity at a later date

but will demonstrate the importance of hydrogen as a long-term energy storage technology for a grid that has a high renewables penetration."

HYFLEXPOWER is an important advance on another project that Siemens Energy is working on for chemical company Braskem in Brazil, where two SGT-600 DLE (dry low emissions) gas turbines are scheduled to begin commercial operation on hydrogen in early 2021. Here, hydrogen will be produced from an industrial process as opposed to coming from renewables. Delivery tests conducted in 2019 proved the turbines for that plant can run on a mixture of up to 60 per cent hydrogen by volume, while maintaining NOx emissions of 25 ppm. According to Siemens Energy, the burners are designed for reliable operation on 80 per cent hydrogen.

For hydrogen mixtures the relationship between CO_2 reduction and hydrogen content is non-linear because the hydrogen molecule has 2.5 times the energy content of methane by mass, but one-third on a volumetric basis. Carbon dioxide emissions scale by hydrogen mass content in the fuel, while typically hydrogen and natural gas mixtures are defined on a volumetric basis.

Explaining the significance, Klapdor said: "If you look at the CO_2 reduction with 100 per cent hydrogen versus 60 per cent hydrogen, you can achieve more than double the amount."

It is clear that even with smaller amounts of hydrogen in the fuel it is still possible to make significant emission reductions. For example, adding only 10 per cent volume hydrogen in the fuel will reduce CO_2 emissions by 2.7 per cent, which would result in a reduction of 1.26 million metric tons of CO_2 for a reference 600 MW combined cycle power plant that runs for 6000 hours a year at an average 60 per cent efficiency

This is why the concept to be demonstrated at HYFLEXPOWER is so important. As Yilmaz noted: "HYFLEXPOWER will be the first time that we will be creating hydrogen using renewables and storing it long-term; then supplying it back to the gas turbine at the right time so it can generate power for the grid and heat for the process. It will be the first time that this will be done with no CO_2 emissions."

The HYFLEXPOWER project essentially kicked off just over two years ago when Siemens began to lay out its technology roadmaps for its gas turbines and other technologies related to decarbonisation and the role of hydrogen. Siemens' vision to cut carbon emission from gas fired power generation was one shared by Engie.

Yilmaz commented: "We wanted to work with an industrial partner and at the same time partner with government. We found out that Engie, which also had significant interest in decarbonisation and CO_2 reduction, could offer potential sites. We were also aware that there was a government opportunity under the European Commission's Horizon 2020 programme. Following discussions, we engaged Centrax and began really intensifying our efforts and developing the proposal about a year ago."

Under the project, an existing Siemens SGT-400 industrial gas turbine will be upgraded to convert stored hydrogen into electricity and thermal energy. According to Siemens Energy it will be the first time an industrial scale power-to-hydrogen-to power project will be demonstrated in a real world application. The total budget for the project is €15.2 million, of which €10.5 million will be covered by the Horizon 2020 grant. The remainder will be provided by the industry partners, who will be responsible for the overall project implementation.

Engie Solutions will build the hydrogen production and storage facility, including the natural gas/hydrogen mixing station prior to the turbine; Siemens Energy will supply the electrolyser for hydrogen production and develop the hydrogen gas turbine; and Centrax will upgrade the package for hydrogen operation and install the new turbine.

The universities will support the project's implementation with their research know-how. "Our university partners will play a vital role in understanding the detailed physics as well as the social impact of the programme," said Klapdor. "The Athens university is currently doing an economic analysis and assessing the social impacts. The Stuttgart university is studying the flame behaviour to support the combustion system development."

Following the kick-off meeting in May, the consortium is progressing with the designs. The first important milestone will be at the end of 2021 when the hydrogen production and storage facility, including the electrolyser, will be installed. The following year will see the upgrade and installation of the gas turbine, and during that summer the demonstration of what Siemens Energy calls the "advanced plant concept".

Yilmaz said: "This will be the initial demonstration of the entire plant – the electrolyser for generating the hydrogen and the equipment for storing the hydrogen and supplying it back to the gas turbine. It will be done in phases. Each time we will learn more about operating with higher percentages of hydrogen."

Initially, Siemens Energy says that the hydrogen content will be higher than the 10 per cent the unit is already capable of handling. The end goal is to demonstrate the advanced energy plant concept sometime in the summer-autumn of 2023 for 100 per cent hydrogen.

In the meantime, Siemens Energy will continue to adapt its turbine combustor, while Centrax will make the necessary upgrades to the turbine package.

Siemens Energy also aims to demonstrate the gas turbine can operate on pure hydrogen in DLE mode. In DLE combustion systems, fuel and air are mixed prior to admission to the combustion zone in order to precisely control flame temperature. This in turn allows the control of the rates of chemical processes that produce emissions such as nitrogen oxides (NOx). The relative proportions of fuel and air is one of the driving factors for NOx but also for flame stability. Hydrogen's higher reactivity poses specific challenges for the mixing technology in DLE systems. According to Siemens Energy, this has never been demonstrated when burning 100 per cent hydrogen at an industrial site.

Hydrogen differs from hydrocarbon fuels by its combustion characteristics, which pose unique challenges for gas turbine combustion systems designed primarily for natural gas fuels. A key challenge is the fast burning nature of hydrogen compared to natural gas.

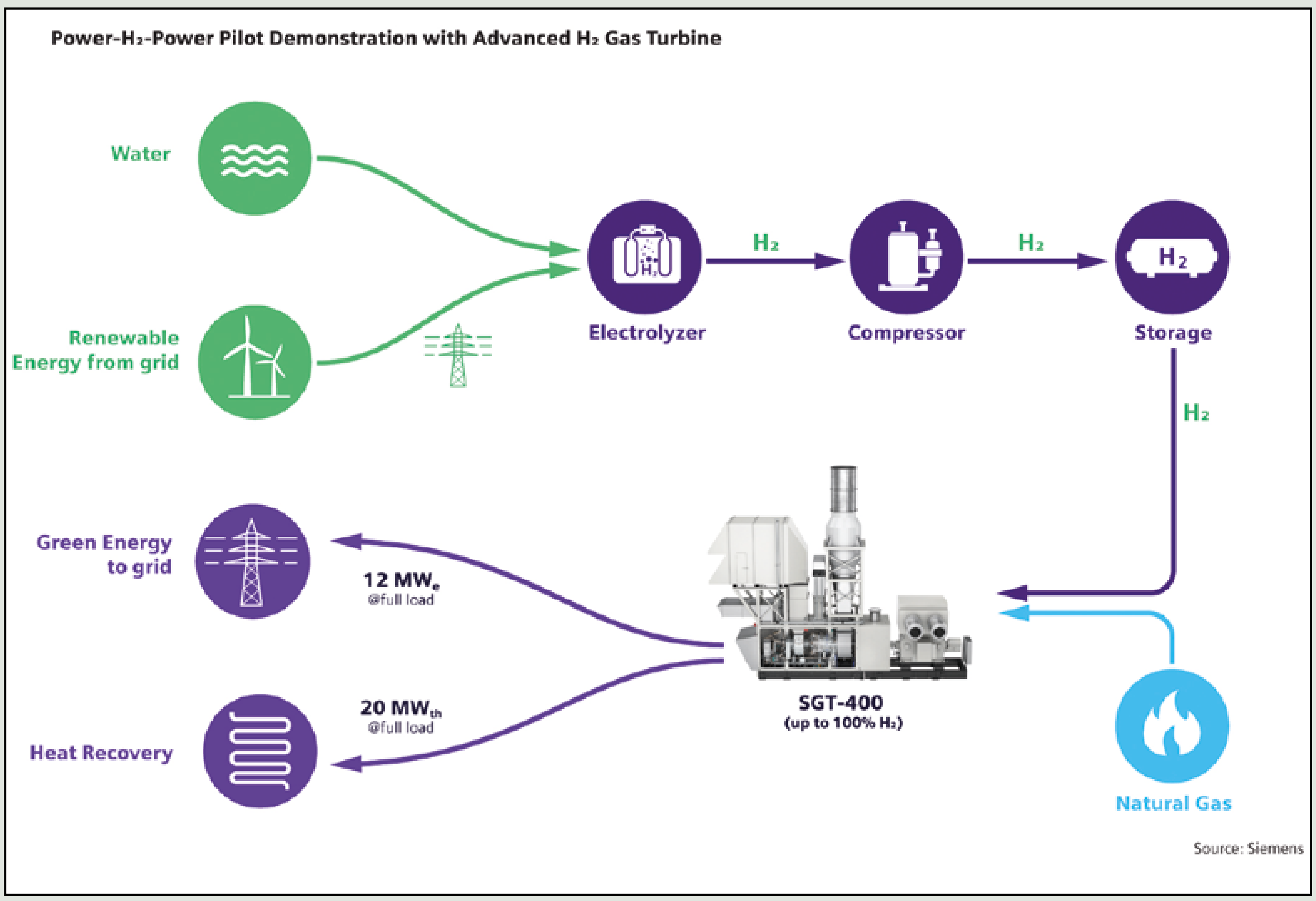
Klapdor explained: "The real challenge is having a combustion system that can run on various mixtures hydrogen and natural gas – from 0-100 per cent hydrogen. The tricky part is to stabilise the flame in the right part of the burner. With the burner design and the guidance of the airflow, you have to counteract the burning velocity of the hydrogen fuel/natural gas mixture. So it has to be designed in such a way as to create a stable, controlled stream inside the combustion chamber."

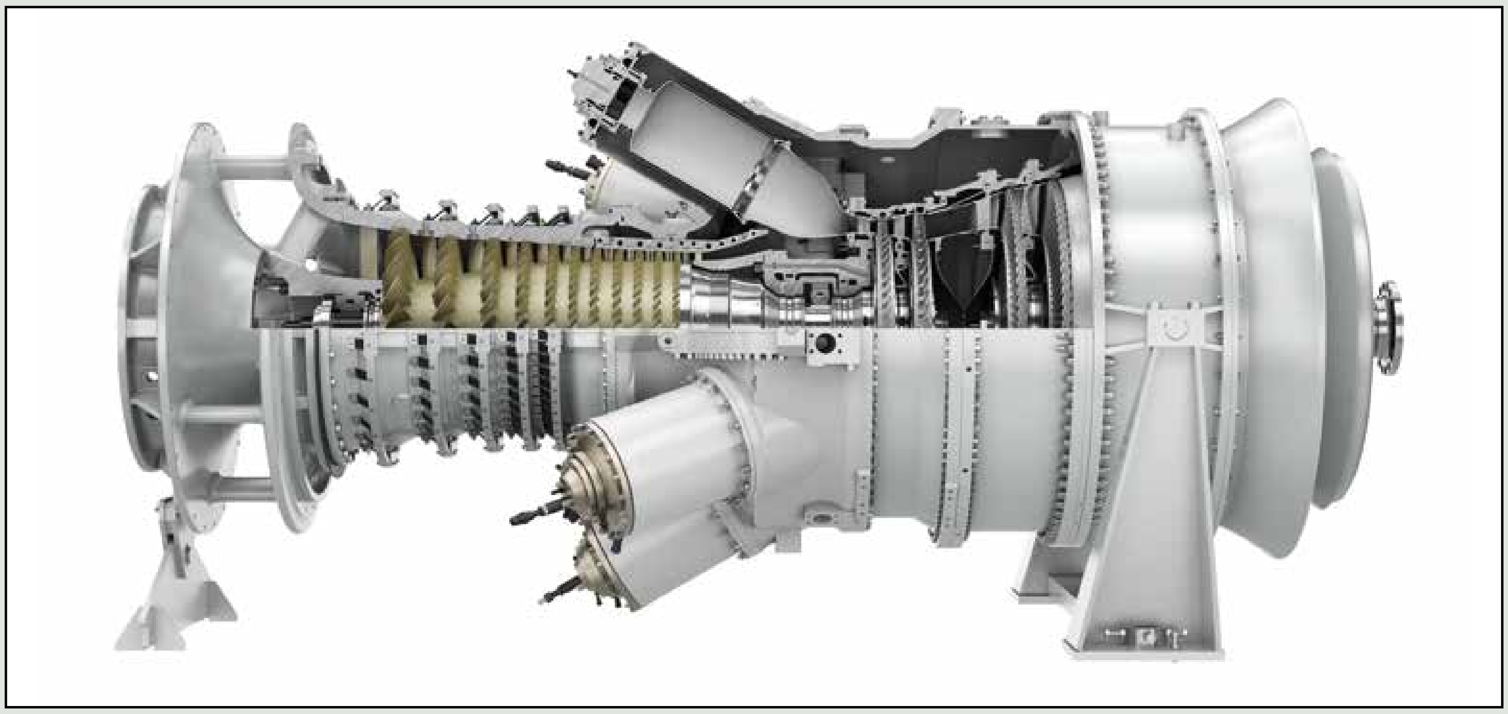
Yilmaz added: "When you premix the fuel, as the amount of hydrogen increases you increase the chance of combustion upstream – in an area that is not designed to withstand high temperatures."

With regards to the turbine package, the piping and materials used will have to be altered according to the site. If the materials at the site cannot accommodate 100 per cent hydrogen, they will have to be upgraded. The pipe diameters may also need to be adjusted.

Another key area is the explosion safety systems. For an existing installation, the fire protection system and enclosure ventilation have to be

Schematic of the EU-funded HYFLEXPOWER project





SGT-400 industrial gas turbine: Siemens Energy also aims to demonstrate the gas turbine can operate on pure hydrogen in dry low emissions mode

configured for hydrogen. "There are stricter rules around safety standards for high hydrogen content, since the explosion risk is higher than for natural gas," said Klapdor.

Hydrogen for the gas turbine package will be generated by an electrolyser based on the Siemens Energy Silyzer portfolio. It is a PEM (proton exchange membrane) type electrolyser, with high operational flexibility. This makes it ideally suited to produce energy generated from volatile wind and solar power. Notable features of PEM electrolysers are: high efficiency at high power density; high product gas quality, even at partial load; low maintenance and reliable operation; and no chemicals or impurities.

Siemens Energy has been using its PEM technology to produce hydrogen from water since 2011, with the introduction of its Silyzer 100. This was a lab-scale unit of 0.1 MW. Since 2015, Siemens Energy has (with its Silyzer 200) a MW-sized electrolyser in operation. On average the company has been scaling its electrolyser portfolio by a factor of 10 every four to five years and in 2018 launched the double-digit megawatt-class Silyzer 300. This is already being used in the world's largest power-to-gas project in a steel plant .

The trend towards higher capacity units is well under way. In a presentation on its hydrogen strategy, Siemens Energy said the next generation of electrolysers is already under development. These will be in the 100 MW range and could be available by 2023. Looking further ahead, it believes that 1000 MW units could be a reality around the end of the decade.

This scaling is important if green hydrogen is to compete with so-called grey hydrogen. The hydrogen market currently stands at around 80 million t/year, the vast majority of which is grey hydrogen produced by steam methane reforming of fossil fuels. Green hydrogen currently only represents 5 per cent of the market – about 3.5 million t and less than 300 MW. But according to the International Energy Agency, this is predicted to reach nearly 3 GW in three years, driven by ambitions for net-zero carbon emissions by 2050.

To achieve this will require a big push by policies and market design, as well as an acceleration of renewables deployment and continued scale-up of electrolyser capacity.

Siemens Energy's latest product, the Silyzer 300, represents the current state-of-the-art in terms of size for PEM technology. The electrolyser system that is currently being marketed uses a standardised, modular and pre-fabricated system concept based on so called half- and full-array (24 modules) configurations. Silyzer 300 is equipped with a fully automated water management system (water treatment and refinement loop), leveraging natural water circulation. Operation with a natural circulation of the process water means that there are no pumps, actuated valves,

Yilmaz says other customers and partners are interested in the application

or other moving parts required in the electrolyser core. This leads to high reliability and availability and reduced maintenance requirements.

The full array configuration has a power rating of 17.5 MW and is scalable to 100 MW and more.

Siemens Energy estimates that roughly 1 t/h of hydrogen would be needed to operate the HYFLEXPOWER project's SGT-400 on 100 per cent hydrogen. This is a significant amount, requiring a sizeable amount of renewable electricity – the bulk of which will come from nearby wind farms owned by Engie.

Klapdor notes, however, that the energy content of this quantity of hydrogen is in principle the same as for natural gas. She said: "People always say, that's a lot of hydrogen and talk about how much renewable electricity is needed, but we need to be cognizant that the amount of natural gas used coming out of the ground is taken for granted. We will be just substituting the natural gas with hydrogen containing the same energy content. However, it's good for people to think about it because it highlights the required investment in renewables to meet decarbonisation goals."

HYFLEXPOWER is a four-year project, and the plan is to complete all the data analysis and socio-economic assessments by April 2024. This will signal the finalisation of the demonstration.

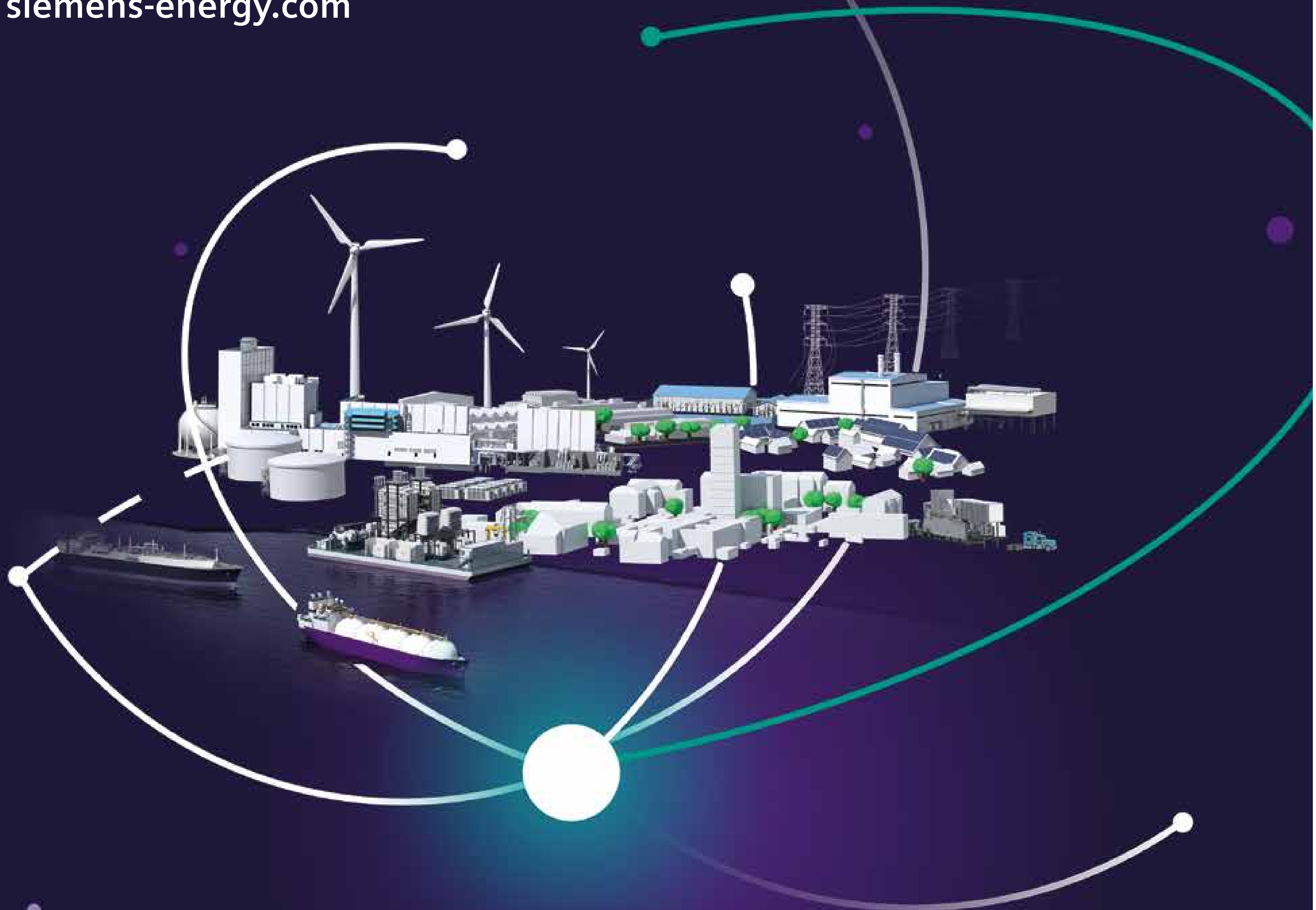
It will be a key milestone in Siemens Energy's goal to make its entire turbine range capable of burning 100 per cent hydrogen. All of Siemens Energy's gas turbines can already operate on hydrogen fuel, with the specific capability of a unit depending on the gas turbine model and the type of combustion system.

While some of its small and medium DLE gas turbines can burn up to 60 per cent hydrogen, the current limit for its large machines is 30 per cent. The company's technology roadmap is to have its dry low emissions units capable of running on 100 per cent hydrogen by 2030 to meet customer demand for their gas turbine portfolio.

Demonstrating 100 per cent hydrogen capability at the HYFLEXPOWER project will be an important step in realising that goal. Further, the project's outcome will no doubt give potential users a realistic view on the technology's suitability in meeting their future decarbonisation goals. Certainly the project has attracted significant global interest.

Yilmaz concluded: "We have other customers and partners interested in this application and we are looking to apply what we learn from this installation to other countries and in different scenarios. The goal is to build on this momentum and really penetrate the combined heat and power market."

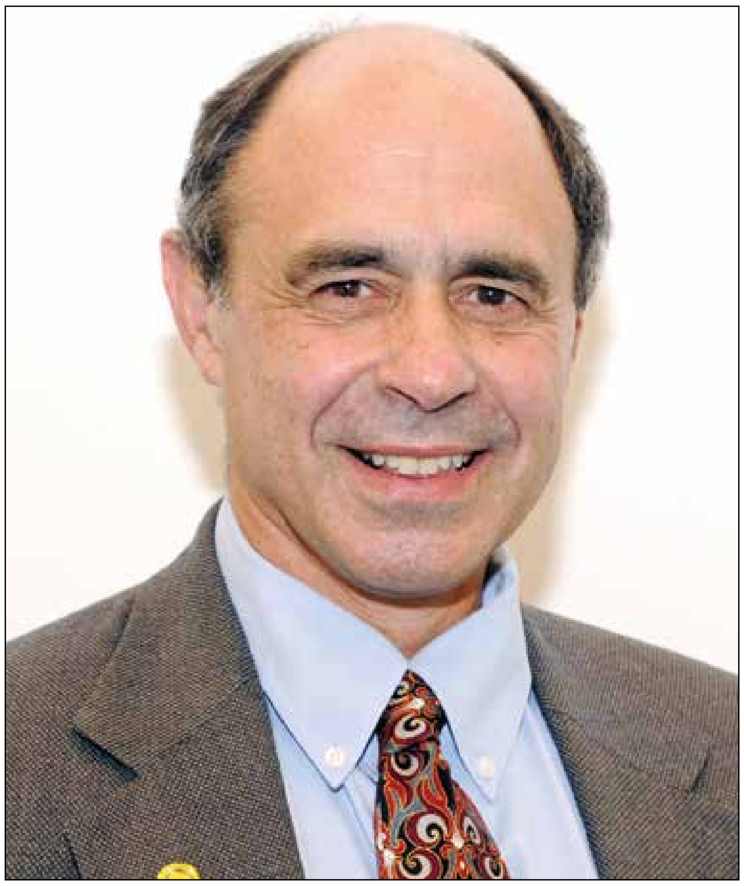
Siemens Energy's Silyzer 300 full-array (17.5 MW) can produce hydrogen for a gas turbine package



A random walk through the energy transition

A number of oil and gas majors are now grappling with making a significant shift into renewables. Aspen Technology's **Ron Beck** discusses the technologies that will help in what will be a difficult transition for them to make.

Beck: As is being applied for LNG capital assets, wind farms have already begun successfully adopting prescriptive maintenance solutions



Several oil and gas majors have made clear their plans to shift strategic focus. Just recently BP, for example, in the face of a massive fall in oil prices, said it will invest tens of billions of dollars over the next decade to meet its target of becoming one of the world's largest renewable power generators and achieve net-zero in its operations by 2050.

But the energy transition will be complicated for these companies to navigate. There are many factors at play that make this more complex than it may appear. So how to rise above the crowd in these next few years? Technology is proving to be a valuable tool in navigating and thriving during the energy transition and will help companies be leaders.

Global energy demand will continue to rise, according to most predictions. There are two factors driving these forecasts: population and standards of living. The Energy Information Administration (EIA) forecasts global energy demand to grow by almost 50 per cent between 2020 and 2050. This will continue to drive the need for energy – the question is which energy sources? And therefore the "energy transition" required as the sustainability movement drives the globe towards "greener" energy sources.

The challenge, of course, is the formidable reality of global energy mathematics. The numbers are so high, that no matter what the rate of adoption of renewable energy sources, hydrocarbons will remain a crucial element of the world energy picture for decades.

So how can technology help adapt hydrocarbon use to achieve better sustainability results? Let's look at a few levers the industry has and the key role technology will play.

Natural gas is emerging as an important future energy source, often seen as a 'bridge fuel' to reduce carbon. To make natural gas transportable, though, requires the energy-intensive and complicated liquefaction (LNG) process. Technology is playing a key role in improving the costs and reliability of natural gas supply. Digital twin models and advanced control have already proven to be crucial in the reduction of energy use during LNG processing.

Much more use of technology will be necessary here, as the producers, driven by both economic reality and sustainability needs, are embracing these proven approaches beyond the initial successful adopters of these tools. Each implementation of this technology further advances the 'green-ness' of natural gas.

Huge capital has been tied up in these projects, and so utilisation rates of these capital-intensive LNG plants is crucial. There, the prescriptive maintenance technology, which embeds machine learning and advanced AI analytics in solutions which alert operators to conditions that create risk of degradation of the high-capital compressors and cold boxes, are now beginning to have an important impact. The confidence of owners and developers in this technology will enable several large development projects to proceed quickly.

For highly complex and demanding assets, such as LNG plants, the self-optimising plant, a future vision for industry in which data and AI contribute to make these investments self-learning, self-adapting, and self-sustaining, will be important.

To achieve the aggressive targets of global players, who are pledging to reach "zero carbon" operations by dates ranging from 2030 to 2050, increasing the pace of developing renewable power assets is viewed as crucial. These technologies, though, are still relatively new in terms of the maturity curve. Utility scale wind and solar arrays are just now beginning to reach the operational phase where maintenance and uptime become concerns.

Again, as is being applied for LNG capital assets, wind farms have already begun successfully adopting prescriptive maintenance solutions, which provide asset health alerts to maximise the availability and utilisation of these large assets, which have not yet established a long-term reliability and maintainability record. This advanced digitalisation technology will be crucial in monitoring the health of equipment which is inherently installed remotely, under environmental stresses, and requires maximum uptime to be reliable in the energy mix.

An interesting analysis compiled by global political thinker Peter Zeihan, looks at the distribution of land across the globe that is suited for utility-scale renewable electricity production. Interestingly, Zeihan shows that roughly half of the world's population is located in Eastern and Southeastern Asia, which has low potential for solar and wind farms. Perhaps as a consequence of that, Southeast Asia has pursued a path of exploitation of palm oil plantations as a potential source of bio-energy and bio-chemicals. The balance of that ledger, however, is not clear, as clearing of rainforest in favour of palm oil farms, is arguably a net negative on the sustainability scale.

Bioenergy conversion approaches, including bioethanol, biodiesel, waste-to-energy pyrolysis, algae conversion, and biochemicals, have gained acceptance at least partially through the benefit of subsidies and government policy. Process modeling technology continues to be crucial, although not widely enough used, in improving the performance of these processes. These processes are hamstrung by the high energy consumption of currently accepted technology.

In order to contribute effectively to sustainability and energy transition, advanced modeling and optimisation is needed to achieve fundamental improvement. Dr. Eric Dunlop, a specialist in large-scale biochemical engineering projects and the algae business, has pioneered these approaches in some groundbreaking work on algae-to-fuels.

New startups continue to innovate with novel new technologies to improve bio-energy conversion, and the new generation of hybrid modeling, which combine AI analytics with rigorous process modeling (such as AspenTech's innovative AI model builder), will be playing a big role here in improving the technical pace of innovation and commercialisation opportunities.

Reducing energy use is another key area. Energy is consumed inefficiently in the conversion of hydrocarbons, synthesis of chemicals and the supply chain. Technology will play a key role in helping the industry navigate a drive towards carbon neutrality. In addition to improving energy efficiency, optimisation technologies can contribute to increasing the production efficiency of oil and chemical operations. Both digital twin monitoring systems and dynamic optimisation solutions can together save 5-15 per cent energy use, reducing carbon emissions a proportional amount.

Another great technology weapon is utility supply optimisation. As power plants looks to minimise carbon emissions, the choices between oil, gas, biofuels, and renewables can be made on a sophisticated basis. The choices can be made minute-by-minute, or at any longer interval. The technology can model the interplay between multiple plants, and multiple utility sources, for example choosing between a wind energy source, natural gas-based electricity, or diesel combustion at the plant, taking into account dollar cost, carbon costs, and reliability.

So what is the future path for oil and gas majors? Firstly, predicting peak oil demand is the forecaster's elusive gold star. Will it be 2025, 2030, 2040 or later?

This will depend on factors including global economic growth (only really forecasted to grow significantly in Asia), energy conservation (or "intensity") in different regions, a shift to electric power over combustion and others. The IEA in its most recent report has forecast peak oil demand will take place in the 2030s.

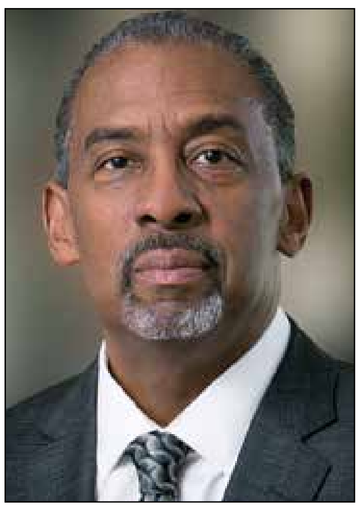
Corporations globally have acknowledged the onset of the energy transition. Some have chosen to reflect this through their investments and their actions. An IHS Markit analysis shows that Total, Shell, BP and Equinor have made at least 66 acquisitions in the past several years to diversify their energy portfolios. Others have chosen to focus on innovation in use of capital and on operational excellence to build a resilient market position.

As the industry navigates the energy transition, technology will be a key partner as organisations and their executives make strategic moves to improve their agility and competitive positions into the future. Those companies who adopt some or all of the technology opportunities mentioned will be bound to have an advantage.

Ron Beck is Marketing Strategy Director at Aspen Technology.

A mirror to the future

Digital twins are an exciting technology with incredible potential. **Junior Isles** catches up with GE Digital's Colin Parris for his take on some of the benefits they bring and a glimpse of what's to come.



Parris: we are now moving into combining the physics and AI to give us deeper and deeper insights into what's happening

Digitalisation has opened up all kinds of possibilities in the power sector. Yet there is one area of digitalisation that can make a profound difference – the concept of the digital twin, a mirror of the physical world.

The digital twin is most commonly defined as a software representation of a physical asset, system or process designed to detect, prevent, predict and optimise through real-time analytics to deliver business value. The technology has been around for some time but with the Internet and progress in technologies such as artificial intelligence (AI) and machine learning, digital twins are entering a new phase, bringing new possibilities to owners and operators of power assets.

Colin Parris, Senior Vice President and Chief Technology Officer, GE Digital, has seen the technology grow from its infancy to become an important tool in GE Digital's arsenal to better serve its customers' efforts to improve the operation and value of their assets – whether in power generation or transmission and distribution.

He said: "The digital twin actually came out of aviation and in particular the military, perhaps a decade or more ago. The Navy was looking at how to understand the readiness of an aircraft sitting on one of its carriers. It's not like a plane at an airport; if you don't plan for parts or service, the aircraft doesn't fly and the mission is compromised.

"So the notion was: can I have a digital model that can tell me the state of readiness of an aircraft…? GE then began thinking about how it could do something like that, initially for its Aviation business. And because we also have turbines running everywhere for the electricity and energy sectors – where typically we had to give suppliers six or seven months lead-time before the parts were needed – it made sense to have digital twins."

GE Digital then began to investigate what else a twin might be able to do. "Because we have engines that are in the air, engines that are producing electricity or engines that are pumping oil out of the ground, we began to see a pattern of what customers wanted to do.

"First, they want an early warning of a problem; with a jet engine you need an early warning about failure. In the energy sector, you want to be warned about any anomalies – it's much better to fix a bearing or blade early rather than to get to a point where there is damage that can cause an engine to be out for six months. The second is continuous predictions on the remaining life of a part, to understand what parts I need in my inventory for when it has to be replaced. And the third thing is optimisation: optimising a turbine for highest energy delivery and lowest fuel cost."

GE Digital then moved to see how this could be expanded across an electricity network, looking at all the components on the grid to optimise the maximum amount of generation for the lowest cost. This was then extended to processes, such as smelting in order to consume the least amount of electricity and least amount and materials.

The digital twins that are increasingly being adopted today are not like the static models of the past that were used to perhaps predict the behaviour of a network at a given moment in time. Today's digital twins are what Parris calls "living, learning models" that take in a steady stream of data to continuously update their models.

He said: "While there is widespread use of things we call twins, which just give insights from data coming in, we are now moving into combining the physics and AI to give us deeper and deeper insights into what's happening. There are twins in generation, transmission and distribution and there are especially new twins for what is going with distributed energy resources. People are wondering how to model all of the electric vehicles and battery sources that are coming on line – with all the volatility it creates, you need twins and analytics to help you."

GE Digital is focused on how digital twins can help its customers across three core areas: assets, networks and processes.

Addressing the power generation sector, the company's Asset Performance Management (APM) software solution creates digital twins based on operational/fleet data of: components such as pumps or compressors; critical assets, like turbines; or systems of assets such as an entire power station. This type of digital twin is an increasingly common tool for operators of large equipment to optimise their maintenance schedules and to predict and avoid unplanned downtime.

For transmission and distribution, its Advanced Distribution Management Solution (ADMS) and Geographic Information System (GIS) use operational data from across the network to create network digital twins that can create virtual models. These allow grid operators to better manage and optimise networks, for example, in the face of increasingly extreme weather, aging infrastructure, and the growing use of renewables on the grid. Such twins essentially provide a connected view of the end-to-end network of assets, based on real operational data.

Operators and owners can implement these digital twins in several ways: either they can purchase the relevant tools from GE Digital and build it themselves; or buy a twin from GE Digital's catalogue of twins and input their own data. "We have over 300 pre-built digital twins of components in our APM systems, so they can feed their data into the twin, which then learns about their system," said Parris. The third way, he notes, is for GE Digital to take the customer's data and build the twin.

One of the biggest challenges that companies often face, however, is to first collect the necessary data, and this to some degree is determining the prevalence of the technology in the various parts of the power sector.

Looking forward, Parris highlights a few key areas of advancement in digital twins and ways in which GE Digital is working to accelerate their use.

Although digital twins can bring value and deliver savings through early warning, prediction and optimisation, he noted that operators are often not comfortable with basing their strategies on twins to, for example, predict the lifetime of a $20 million sensor in a turbine.

"Getting people to adopt it is the hardest thing. So about three years ago we created something called Humble AI, which takes into account the zone of competency for a particular [digital] model; so you use the model inside the zone of competency, and when outside that zone you use a different model or human and feed that data back in so the AI system gets smarter. That's why it's humble; it knows what it doesn't know and it wants to learn."

The technology has already been developed for gas turbines and wind turbines and Parris notes that it is giving operators greater comfort in terms of reducing risk.

Another area that Parris says GE Digital is currently focusing on is how to put this "all into a process that people like". The company is therefore combining digital with Lean methodology.

He explained: "Lean takes any process you have and says: 'tell me what you are trying to solve.' In power, you might be trying to reduce the cost of maintenance or increase how much power you deliver at a certain fuel level. So there's a process behind it. Lean will call for a value map of the process, whereby all the data will be pooled from the experts. Lean is about pulling the data, and that same data is what a data scientist needs... to create a model for embedding in the process.

"Engineers like this combination of digital and Lean because they all know Lean, and now they can see Lean inside of digital. Lean helps focus on the amount of money you will save, or whatever it is you want to change, while digital does the digital transformation inside the process. This is allowing the technology to gain more traction in the industry."

So what is the future of the technology itself? Parris offered a glimpse of a few research projects he has been working on with investment from organisations such as the US Defense Advanced Research Projects Agency (DARPA) and the Intelligence Advanced Research Projects Activity (IARPA).

Over the last three years they have been investing money with GE Digital in an area called 'Emerging Languages'. About five years ago, GE Digital began exploring the idea of assets that could talk to each other and solve problems.

Parris explained: "What if one wind turbine could show another turbine its sensor readings, ask if it has seen these readings before and then ask: 'what was the problem?' And that turbine could respond, saying for example, I have seen these readings before and it was a bearing problem. And what if then, that asset could communicate with us and tell us what it thinks the problem is? This would be tremendously helpful. It would allow us to identify problems very early on."

GE began developing a language between the turbines and has been experimenting for the last year, with "some interesting results".

Parris said: "It can communicate simple things like: there was a storm, damage to a blade, this sensor reading looks wrong and I think it's this. It's at an early stage but what begins to get me excited is the speed at which they communicate, and the things that they say is interesting.

"If you think about the next 4-5 years of this and get to a point where machines are diagnosing themselves, although humans will still be involved, it will all be a lot faster."

It's an exciting future. On a wider scale machines talking to each other in such a way offers an incredible opportunity in the fight against climate change.

Parris concluded: "It's especially relevant to me because of the decarbonisation problem. If you ever get to a point where these assets are going to have to work together to reduce carbon in the atmosphere, you want them working together in the most optimal way."

Junior Isles

Chasing the white rabbit

It's easy to get lost down the rabbit hole of focusing on renewables and new clean energy systems as we strive to reduce carbon emissions and halt climate change. Almost every online conference or webinar (and there have been way too many since the lockdowns have prevented physical gatherings) has in some way focused on renewables. Whether it's increasing the use of wind and solar, or energy storage to optimise the use of intermittent generation, or smart grids to accommodate fluctuating generation, or the decarbonisation of industry and transport through greater electrification using renewable sources – it almost always comes back to renewables.

Clearly the reasoning is born of necessity. In its recently published 'Energy Transition Outlook' (ETO), DNV GL stated that despite a fall in carbon dioxide emissions this year due to the pandemic, "we will still blow past the carbon budget for a 1.5°C future in 2028". It said the 2°C carbon budget would be exhausted by 2051.

It notes that the transition is happening at a fast pace, predicting that "within a generation", renewables and fossil fuels will have roughly an equal share of the energy mix compared to an approximately 20-80 split today. According to the company's projections, solar capacity will expand by 20 times and wind 10-fold by 2050 as costs plunge. Yet it will not be enough.

Policy levers are needed to stimulate other technologies that are vital to reduce energy use and emissions. DNV GL says that carbon capture and storage (CCS), for example, is a vital component in decarbonising natural gas, including the production of blue hydrogen, but notes that a lack of policy coordination means that by 2050 CCS will only capture 11 per cent of carbon emissions, despite the technology first appearing in the 1970s.

Launching the ETO 2020, Remi Eriksen, Group President and CEO of DNV GL, said: "We can't empty the airliners twice, so we need all hands on deck to find practical solutions to the climate crisis – now. The rapid rise of solar PV, wind and battery technologies in recent years gives me hope that humanity has solutions at hand. However the so-called hard to abate sectors need strong policy incentive to move the needle on decarbonisation. Decarbonised natural gas, including hydrogen, will play a key role in the transition to the energy future humanity wants and needs."

Similar observations were made by the International Energy Agency in its recent Energy Technologies Perspective (ETP) 2020 – the first core ETP report for three years following a revamp of the series.

The report analyses more than 800 different technology options to assess what would need to happen to reach net zero emissions by 2070. The blistering pace of technological transformation that would be necessary for the world to reach net zero emissions by 2050 is explored in the report's 'Faster Innovation Case'. It finds that to meet the huge increase in demand for electricity, additions of renewable power capacity every year through 2050 would need to average around four times the current annual record, which was achieved in 2019.

The report stresses that energy innovation will be crucial but sees "reason for optimism", despite the disruption and uncertainty caused by the pandemic. Dr Fatih Birol, the IEA's Executive Director stated: "Investment in clean energy start-ups by venture capital funds and companies rose to a new record in 2019. And governments and businesses are finally putting serious resources into the clean energy potential of hydrogen, which this report makes clear will be critical for reaching net zero emissions."

But his most important takeaway from the report is the major challenge of how to tackle emissions from the vast amount of existing energy-related infrastructure around the world.

"Personally, the most important blind spot in the climate change debate today is the overwhelming focus on what we are going to build – the new power plants, new factories, new cars – and that they should be clean and sustainable," said Dr Birol. "Yes they should be, and we should focus on them but there's a big issue: we have built power plants, steel and cement factories for years and years and they will be with us for several decades to come. Without addressing emissions from the world's existing infrastructure, we will have no chance whatsoever of meeting our energy and climate goals."

According to the IEA, if no action is taken, today's existing infrastructure will emit about 750 Gt of CO_2 over the next five decades. The bulk of cumulative emissions from existing infrastructure is expected to come from the power (55 per cent) and heavy industry (26 per cent) sectors, reflecting their large shares of emissions today and the long lifetimes of the assets, e.g. power stations and manufacturing facilities.

Timur Gül, the IEA's Head of Technology Policy and director of the report, said there would be no chance of fully decarbonising the energy sector by 2050 unless "we find a way to address emissions from these existing assets".

How each country tackles the problem will depend on its individual circumstances and the age of the different facilities. Some may opt for retrofitting or modernisation, and some may go for early retirement. In Asia for example, 80 per cent of existing coal fired generating capacity was built in the last 20 years – retiring these early will be hard to justify economically.

The existing coal plant fleet, along with emissions from industry are particularly tough nuts to crack. Green hydrogen is attracting increasing interest as a way of decarbonising industry and transport (alongside electric vehicles). CCS and CCUS (carbon capture utilisation and storage) has been promoted for some time as a way to address the existing coal, and to a lesser extent gas, power generation fleet but the economics still do not stack up. There could be a case for industrial settings and there has been some progress here, but the uptake of CCS/CCUS in the power sector has been woeful.

Gül commented: "Progress with CCS technology has been somewhat behind expectation over the last decade but it is a technology that we will ultimately need in certain applications such as cement [production]; to produce synthetic fuels; and to remove CO_2 emissions from the atmosphere."

According to Dr Birol, of the 800 technology options covered by the report, CCUS, hydrogen, batteries and bioenergy, "appear to be the frontrunners today" and are "the game-changing technologies that are ready for the big time". But with regards to CCUS, he also concedes that although "the technology has been with us for a long time, we have still not seen a major breakthrough yet".

Still, he maintains it is a necessity. "In my view, we don't have many options to have a bridge between our huge fossil fuel assets and our climate goals."

That may be so but the economics will have to change and this can only come with a big policy push to drive the price of carbon.

In the meantime, the world will likely continue to focus on how it can increasingly utilise renewable energy sources, which are becoming cheaper and cheaper. Renewables in power generation and greater electrification of industry and transport can do much in navigating the road to net zero but it is difficult to see how they can get us there alone, and by 2050.

Like Alice in Wonderland, we will have to go further down the rabbit hole – pursuing maximum use of renewables going forward without losing sight of the technologies that are needed for the fossil fuel and industrial installations of today. It is a complex journey but let us hope that chasing zero emissions is not as chaotic as chasing Alice's white rabbit.

Cartoon: jemsoar.com