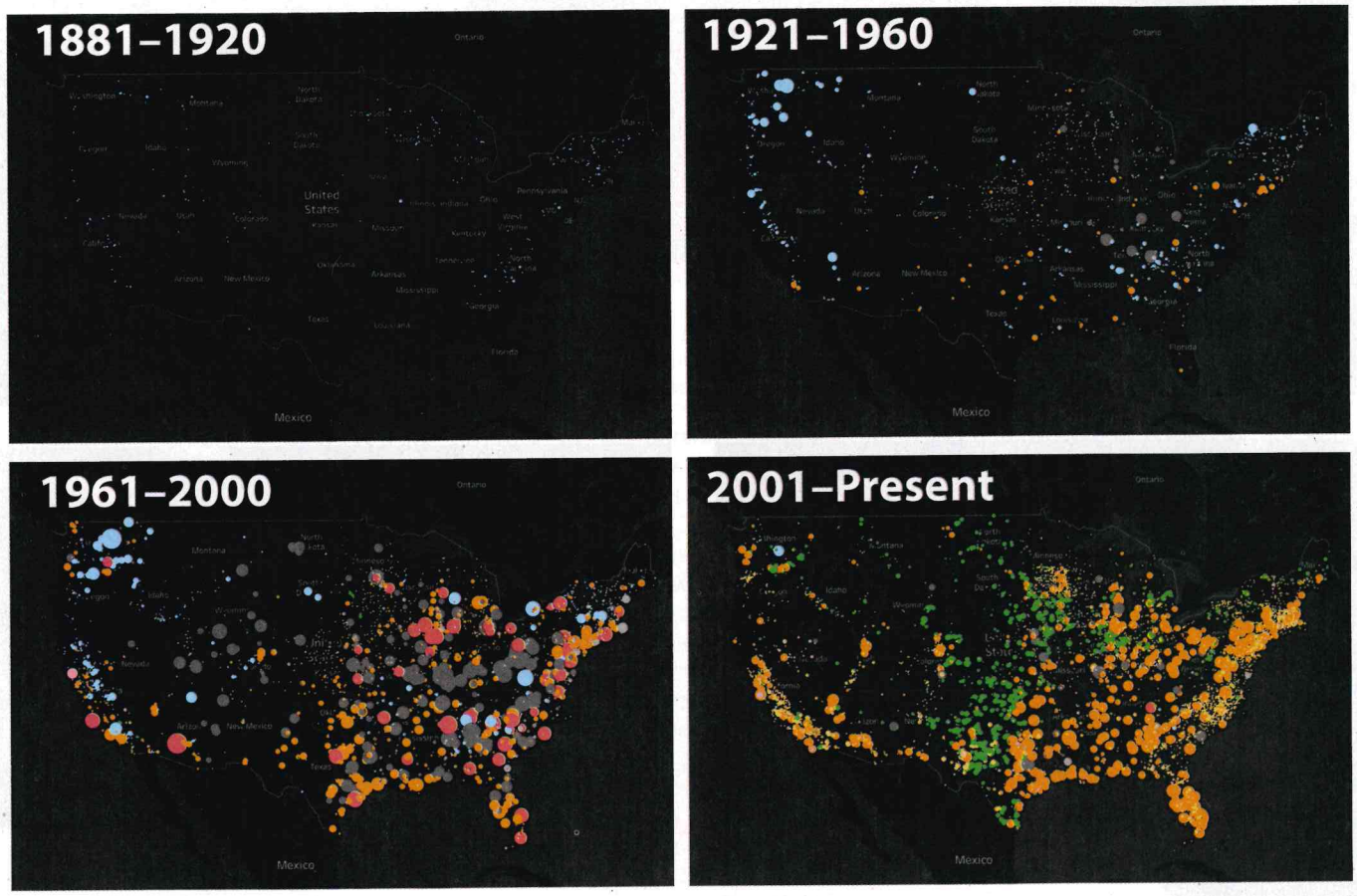
THE BIG PICTURE: Power Plant Additions Over the Decades

The deployment of new power plants in the U.S. over the past 14 decades has hinged on policies, markets, technologies, and new industry players. Every decade has presented its own state of multidimensional, multivariate complexity. The ongoing "energy transition," which has been characterized by the addition of smaller, carbon-free resources, marks another pivotal period in the industry's history. It is currently being compounded by concerns about energy security, affordability, and sustainability. *Source: Energy Information Administration (EIA-860, June 2022)*

*—Copy and artwork by **Sonal Patel**, a POWER senior associate editor.*



Technology

- Batteries
- Coal integrated gasification combined cycle
- Conventional steam coal
- Conventional hydroelectric
- Hydroelectric pumped storage
- Geothermal
- Natural gas–fired combined cycle
- Natural gas–fired combustion turbine
- Natural gas internal combustion engine
- Natural gas steam turbine
- Natural gas with compressed air storage
- Other natural gas
- Landfill gas
- Other gases
- Nuclear
- Offshore wind turbine
- Onshore wind turbine
- Petroleum coke
- Petroleum liquids
- Solar PV
- Solar thermal with energy storage
- Solar thermal without energy storage
- Wood/wood waste biomass
- Municipal solid waste

AGL Energy, another Australian power group, earlier this year estimated it will cost more than $970 million to replace its Liddell coal-fired plant in the Hunter Valley mining region of NSW. AGL plans to close the Liddell plant (Figure 1) next year, and already has begun a phased shutdown of the station's four 500-MW units. The company said it wants to add a 500-MW BESS, along with renewable energy resources, a gas-fired peaker plant, pumped-hydro storage, and a synchronous condenser at the site. Hunter Valley also will be home to the Hunter Energy Hub, a planned development featuring a grid-scale battery, solar thermal storage, wind power, hydrogen production, and pumped-hydro storage.

Renewable resources are well-positioned to fill in the demand gap caused by the decline in coal generation. Solar is the best option for Australia; the sunny country with a sparsely populated desert interior has the highest solar radiation per square meter of any continent. The country's utilities and regulators have realized this, with solar power having a big increase in recent years.

However, Australia is still a far way off from being able to fully rely on renewables, as the electricity troubles of the past few months demonstrated. While this year's energy crisis is accelerating the adoption of renewables, it will still be many years before enough solar and other renewable projects are brought into the wholesale energy market to match coal generation.

On the upside, the clean energy transition is highlighting technologies that can help Australia as the country decommissions its coal plants. Energy storage (Figure 2) will be increasingly important so that intermittent renewables can be an effective replacement for dispatchable fossil fuel energy. But energy storage also is key for the gradual decommissioning of coal plants. Operators can add storage to existing coal plants so that they can operate at financially reasonable levels of generation while grid operators prepare to offset the loss in coal generation. These plants will still be decommissioned, but in a manner that doesn't cause a shock to the grid, a pressing concern as closures come years earlier than planned due to market conditions. Australia can still meet its clean energy goals with more gradual shutdowns of coal plants, but without also destabilizing the grid.

Decommissioned coal plants are also a prime site for energy storage because they already possess the infrastructure needed to connect batteries to the grid. Power producers and regulators are recognizing former coal plants for their energy storage potential. These efforts are likely to be ramped up, and more decommissioned coal sites are expected to be used for energy storage for Australia to fully meet demand with renewables.

In concert with energy storage, smart software solutions can assist Australia's energy transition as coal plants retire. Grid control software like distributed energy management systems (DERMs) and microgrid controllers give utilities and operators the tools they need to maximize their renewable assets and energy storage. Such autonomous solutions use artificial intelligence to analyze historical demand and usage patterns, develop optimized asset usage plans, and then match them in real time to current grid conditions, updated weather forecasts, and predicted demand.

These software-based solutions can help Australia aggregate the thousands of incremental local contributions of DERs into meaningful impacts on the grid that reduce reliance on centralized generation sources. Plus, built-in optimization functions automatically shape, shift, and redistribute power, virtually eliminating power waste, and thereby requiring less generation and capacity to serve the same network needs.

Australia has already realized the benefits of assets like distributed energy, battery storage, and grid control software. For instance, rural communities in Western Australia, far from main grid connections, are hosting novel projects that pair storage and solar to take the place of fossil fuels. One of these has demonstrated that it's possible for a microgrid to remain fully operational solely using renewables, without spinning generation.

In more densely populated areas, the country is embracing DER marketplaces to create local and wholesale markets for renewable energy, and operators have already realized the benefit of using old coal sites for energy storage. Australia has demonstrated the need to accelerate coal plant decommissioning, and also is demonstrating how it can repurpose those sites as it transitions to renewable energy.

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2. This energy storage project in Onslow, Western Australia, is providing electricity to a remote community. It's among several such projects that are deployed or being developed across Australia as the continent closes coal-fired power plants and replaces that generation with renewable resources and energy storage. Courtesy: Horizon Power

Can Power Plant Wastewater Be Valuable?

The rise and rapid adoption of the circular economy—a systems solution framework that seeks to keep materials, products, and services in circulation for as long as possible—is triggering an interesting shift in how wastewater is being viewed. One view posits that wastewater should no longer be seen as waste, owing to the possibility that industry may recover several valuable resources from it. These include water, energy, fertilizers, biofuels, biopolymers, and critical minerals.

This type of resource recovery has thrived, primarily in higher-income countries, as part of established efforts relating to general wastewater treatment. However, their uptake in the power industry has suffered setbacks, given complex water quality. Still, several research and development efforts in recent years suggest promise.

Optimizing Coal Plant Wastewater Desalination. A May 2022 study published in the journal *Membranes* by researchers from Dianzi University in Hangzhou, China, evaluated benefits associated with the simulation and operational optimization of coal-fired power plant wastewater treatment. The study, motivated by wastewater environmental concerns, along with water scarcity concerns, was focused on a plant system in Inner Mongolia as an example. China's coal plants account for a large share of the nation's energy production, and the country is exploring measures to treat and reuse power plant wastewater, especially in central and western China, which have recently been stricken with water shortages.

Coal plants, however, have a "complex water quality," owing to high pH

3. Australian firm Controlled Thermal Resources (CTR) is developing a project in California's Imperial County near the Salton Sea. The project seeks to co-produce geothermal power and lithium via direct extraction, and potentially other minerals including rare earth elements, potassium, zinc, manganese, and rubidium. The project is staged to deliver 50 MW and 25,000 tonnes of lithium in 2024. This image shows thermal mud pots at the project site. Courtesy: CTR

and chemical oxygen demand, the researchers noted. Some plant wastewater is organic, produced from gasification processes, coal-water slurry, and black water from dry coal pulverized entrained flow gasification. It mainly contains phenol, naphthalene, anthracene, and thiophene, which are refractory organics with poor biodegradability, and require biochemical treatment.

The majority of coal plant wastewater, however, is saline water, which comes from recycling systems, such as circulating water systems and chemical water station drainage. Saline water mainly contains inorganic salts, such as Cl^-, SO_4^{2-}, Na^+, and Ca^{2+}. Desalination methods for saline wastewater treatment at coal plants include membrane technology and thermal technology. Reverse osmosis (RO) technology is also extensively employed, though these systems' operational efficiency is greatly affected by "the feeding conditions of wastewater," the researchers said.

The study studied the membrane treatment process. Researchers first developed a mechanistic model equation of the RO process based on the seawater desalination process and then a system model suitable for coal-power wastewater treatment. A simulation analysis and optimization analysis were also carried out. The study's results suggest that optimization promises increases of water recovery rates of up to 20.7% depending on energy consumption, which optimization could also decrease by up to 42.6%. That could amount to big savings gains for the nation's coal plants, they said.

Rare Earth Element Recovery. As the value of rare earth elements (REEs) ramps up, given their extensive use in electronics and other applications, so have efforts to recover them from unconventional streams such as coal and coal waste. In September 2021, Midwest Energy Emissions Corp. (ME_2C), an environmental technologies company, announced it had completed an initial round of testing to evaluate its REE technology capture capacity and regeneration. ME_2C is most prominently known for its Sorbent Enhancement Additive (SEA) system, widely used in the coal power industry for mercury emissions capture. Its REE technology, which is still under development, comprises a sorbent technology based on chemisorption and focuses on acid leaching as a capture method.

"Acid leaching is widely used to extract rare earth elements. ME_2C's new technology will be introduced into the leaching process and will significantly reduce the amount of caustic acid required. This new technology will also capture contaminants and other minerals from coal ash ponds and wastewater," the company says.

Penn State's College of Earth and Mineral Sciences has evaluated the technology, and ME_2C completed in-field pilot testing in March 2022. Plans are now underway to carry out full-scale testing with a commercial vendor. "With confirmation of our technology's ability to capture certain rare earth elements, we will continue to evaluate the commercial viability, including the ability to effectively reuse this sorbent," said Richard MacPherson, president and CEO of ME_2C.

REE extraction from coal fly ash and power plant wastewater is also under investigation at the Department of Energy's (DOE's) Los Alamos National Laboratory (LANL). The lab has explored a hydrothermal process using coal ash and wastewater sludge collected from a power plant near Detroit, Michigan.

A separate project DOE spearhead by Wyonics LLC and the University of Wyoming has meanwhile successfully demonstrated the extraction of REEs from coal and fly ash into specifically designed ionic liquids (ILs) "in a simple and energy-efficient manner." The lab said REE extraction and recovery from coal was performed "via direct treatment of coal with intelligently designed task-specific ILs. The IL chosen for these processes possesses an ideal combination of excellent solvation ability, nonvolatility, low toxicity, proven recyclability, and availability at the multi-ton scale." Preliminary studies suggest the process can be applied to other sources of coal and ash from different U.S. mines.

Wastewater Heat Recovery. In another notable project, researchers from the Institute for Sustainable Technologies (AEE INTEC) in Gleisdorf, Austria, set out to evaluate whether it was economic for a wastewater treatment plant (WWTP) in Austria's region of Styria to deploy a biogas combined heat and power (CHP) plant along with effluent water heat pumps to provide thermal energy for facility-wide heat demands, as well as send surplus heat to a district heating network. The facility, like most large WWTPs in Austria, produces biogas via an anaerobic digestion process. However, it currently flares 11% of its biogas.

While there is no natural gas grid connection at the facility, a biogas CHP is envisioned to replace the existing biogas boiler to provide the facility with electrical and thermal self-sufficiency. The study published in the journal *Frontiers in Sustainable Cities* showed that integration of heat pumps using effluent water (which ranges between 60C and 75C) using a serial water concept could allow the facility to take advantage of lower flow temperatures while also delivering heat to the district heating network.

Algae for Animal Feed, Biofuels. In another project that seeks to explore sector coupling, Springfield, Illinois, public power utility City Water, Light and Power has embarked on a project to utilize carbon dioxide from its 200-MW Dallman 4 pulverized coal-fired power

plant and nutrients from a local WWTP to cultivate algae for animal feeds. The $2.5 million engineering-scale project announced in December 2021 will span three years.

Algae is fast-growing compared with traditional terrestrial feed crops. It also makes an attractive alternative for use in taking up CO_2 from power plants because it requires less land, according to Illinois Sustainable Technology Center (ISTC) principal investigator Lance Schideman. The project will use the algae species Spirulina because it is already Food and Drug Administration approved for use as a food ingredient and has a high protein content, "which commands higher prices."

In the current commercial technology, managers buy liquid CO_2 and various commercial fertilizers for the nutrient supply. "Using wastewater is a cost savings in the production process and it helps to solve problems that wastewater treatment plants are experiencing in trying to minimize nutrient discharges in the environment," Schideman added. "In Illinois, the treatment plants are under increasing scrutiny, and regulations that are now voluntary are expected to become more stringent and potentially mandatory within the next decade."

While the Dallman 4 example doesn't specifically utilize power plant wastewater, it illustrates a potential pathway for power plants. Although it remains challenging to deploy, algae cultivation in power plant wastewater has been much explored for its potential benefits, including as a novel source of biomass and carbon dioxide utilization. In 2018, researchers from Shiraz University in Iran showed microalgae can be used to treat wastewater for sulfate reduction and production of microalgae biodiesel. The much-cited study's results suggest algae species Oocystis sp. had a higher sulfate uptake rate, but that Chlorella produced more biomass.

Lithium Extraction from Geothermal Brine. If there is a prominent buzz around power plant wastewater as an unexploited resource today, it is largely centered on recovery of freshwater, minerals, and energy from geothermal brine. Considerable interest is growing in extracting lithium—a principal component of high-energy-density batteries–from lithium-rich geothermal brines. Several companies have centered their operations on lithium mining from brine to leverage what they say is a burgeoning opportunity. These include Controlled Thermal Resources (Figure 3), Cornish Lithium/Cornish Metals, and Vulcan Energy Resources.

According to a comprehensive overview of direct lithium extraction technologies that Lawrence Berkeley National Laboratory published in late 2021, the most technologically advanced approach involves adsorption of lithium using inorganic sorbents. Other separation processes include extraction using solvents, sorption on organic resin and polymer materials, chemical precipitation, and membrane-dependent processes. The lab notes that initial studies have demonstrated that lithium extraction and recovery from geothermal brines are technically feasible. However, "challenges still remain in developing an economically and environmentally sustainable process at scale," it says.

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Europe Turns to LNG to Avert Energy Crisis

European nations are looking at ways to increase their imports of liquefied natural gas (LNG), including from Russia, as concerns about a shortage of natural gas across the European Union (EU) continue ahead of the upcoming winter. The EU has said it wants to end its reliance on Russian gas after Russia's invasion of Ukraine, with officials in March of this year saying the goal is to reduce dependence on Russian gas by as much as two-thirds by the end of 2022. EU officials also have said they want to end most or all of their imports of natural gas from Russia by the end of the decade.

Russian exports of gas to Europe continue, though; a mid-September report from Bloomberg said Greece is set to accept the first cargo of LNG from Russia's new Portovaya LNG plant, located near the Nord Stream 1 pipeline that Russia has kept offline since late August. Sweden also is importing Russian LNG; Greenpeace activists in early September blocked an LNG tanker from unloading Russian gas at a Swedish port. Swedish officials in August said a new LNG/bio-LNG terminal will be built in the Port of Oxelosund, as part of a deal signed between small-scale LNG provider Avenir LNG and port operator Oxelösunds Hamn AB.

Meanwhile, two floating LNG terminals are setting up in the Dutch port of Eemshaven. The floating storage and regasification units (FSRUs) would convert LNG into gas for onshore distribution, with LNG reportedly coming via carrier (Figure 4) from the U.S. The FSRU units, usually moored just offshore, can be built more quickly than onshore LNG terminals. Analysts have told *POWER* that more than two dozen new FSRUs are expected to be installed in EU member nations in the next few years. The German government has contracted for five FSRUs, with two additional private set-ups planned. At least three of the projects are expected to be in service no later than this winter. Italy, France, Poland, and other countries also are planning projects.

Russia on Aug. 31 shut Nord Stream 1 for what it said would be a brief period of maintenance, but the pipeline has not reopened. Russian officials have said economic sanctions imposed by other countries due to the invasion of Ukraine are responsible for the indefinite halt to gas supplies via Europe's main pipeline.

4. An LNG carrier is a tanker specially designed to transport liquefied natural gas. A feature of an LNG ship that makes it different from other bulk cargo carriers are the insulated, temperature-controlled tanks that ensure the gas is kept in a liquid state at about –162C. Source: Shutterstock

Other pipelines remain in operation.

Gazprom, Russia's state-owned multinational energy group, on Sept. 12 said it was shipping 42.4 million cubic meters of natural gas to Europe via Ukraine, a volume that has been steady for days. "EU members want to move away from Russian-sourced gas, but they also recognize they can't abandon natural gas, so they must find new supplies. Some are still sourcing gas from Russia, but this represents an opportunity for U.S. LNG exporters and U.S. natural gas producers to support the European market," said Dan Kish, senior vice president of policy at the American Energy Alliance. "The U.S. can set itself up as a chief energy supplier for Europe."

Energy analysts have said Europe depends on Russia to supply about 40% of the natural gas the region needs for both gas-fired power plants, and home and business use. Countries for the past several months have been looking for alternative sources for this gas due to concerns about an energy crisis this winter.

"Because the EU needs to reduce its reliance on Russian gas, the reduction in gas and power demand as well as an increase in LNG imports have become crucial in the EU energy strategy," said Francois Le Scornet, president and senior consultant at Carbonexit Consulting. "The LNG sourcing aspect remains particularly critical and pretty difficult as the market is under strong constraints that could be further exacerbated by a cold winter or by stronger than expected economic growth in China, for instance."

"When we talk about European reliance on Moscow's LNG, we're primarily discussing Germany being most heavily reliant," said Richard Gardner, CEO at Modulus, an Arizona-based company providing technology products and services to clients across a variety of industries, including the energy sector. "The country's consumption is far too great to consider moves similar to those made by Baltic countries earlier this year. In fact, since Nord Stream 1 was completed, Germany has relied more heavily on Russian gas. While the EU attempted to diversify its energy sources in 2010 and 2014, Germany's dependence rose higher to 55% by 2021, even after Russia annexed Crimea."

Germany already has postponed plans to close all its nuclear power plants, saying in September it would keep at least two of its three remaining facilities on standby until the middle of next year. The country earlier this year acknowledged it would increase its used of coal-fired power in an effort to avoid an energy crisis.

Gardner told *POWER*, "It is comparably less difficult to end reliance on Russian coal, given the varied import alternatives, but gas imports are more difficult. As of 2020, Germany imported roughly 30% of its supply from Norway. While the country has cut its Russian imports to 35% this year, it still has a long way to go before winter, and that isn't even including the sizable volume historically relied upon by France, Italy, and Poland."

Gardner noted, "This year, Europe has raced towards reducing gas consumption, in addition to attempting to find alternative imports. Notably, Germany's gas storage sites are already filled to more than 85%, nearly a month before its goal of October 1. While it is possible that Europe will see shortages this winter, at least on a regional basis, one of

Europe's greatest strengths is its purchasing power. Because of their combined volume, major users could attempt to come together and fight back against Moscow's weaponization of gas with its own ultimatum, dictating a lower price on imports. While this would further fuel shortages over the winter, over the long-term, the move would provide greater security and remove energy as Putin's greatest source of economic leverage."

Le Scornet told *POWER*, "Of course, the EU needs to source all the LNG currently available on the market, and contracts are probably taken with all the producing countries, and the U.S. in particular, obviously plays a major role as an LNG provider to the EU." Le Scornet said political pressures could impact the amount of U.S. LNG made available for export, since exporting U.S. natural gas could increase prices for U.S. gas consumers. "[The Biden administration] may see increasing internal domestic pressure to control exports," he said.

Le Scornet noted that European countries need to establish new LNG import terminals "in strategic locations in Europe in order to connect LNG imports to onshore domestic gas transportation and distribution systems. Germany and many landlocked central European countries are indeed still highly dependent on Russian gas that is transported by pipeline because the supply between countries with LNG terminals like France, for instance, and countries like Germany is limited by the existing connecting pipeline capacities."

Le Scornet said the FSRUs, like those in the Netherlands, "are supposed to be short-term solutions, and long-term planning and strategic decisions must probably be taken. Two terminals should open in Germany at Wilhelmshaven and Brunsbutell, but this should only happen during the coming winter."

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POWER Digest

Saft Installs Batteries on Italian Islands. **Saft,** a subsidiary of **TotalEnergies**, has installed seven maintenance-free Flex'ion lithium-ion battery systems supporting a microgrid with solar plants on the Italian island of Favignana, part of Sicily. The systems are expected to be fully operational by the end of this year. In addition, Saft Flex'ion batteries will support a microgrid powered by hydroelectric and solar plants, as well as diesel generation, on the island of Ustica. The batteries will be connected to the distribution network and integrated into a smart grid. The installations are the first pieces of the "I-Sole project," which involves local utilities as well as scientific expertise from the **University of Palermo** and the **Italian National Research Council**. The project is supported financially by the European Union and the Region of Sicily, under the technical lead of **Layer Electronics**, a local power electronics company. The I-Sole project aims to develop innovative technical solutions for monitoring and control of power generation and distribution, with a focus on increasing the use of renewable sources and storage systems on small Sicilian islands while supporting the security of power supply. Flex'ion batteries are assembled in Saft's Raskovice factory, in the Czech Republic, using lithium-ion cells manufactured in Saft's Nersac factory in France.

Financing Closed on Polish Solar Plant. An agreement was reached at the end of August among **ib vogt**, **BayernLB**, and **Siemens Financial Services** for a solar farm already under construction in Poland. The facility is expected to come online early next year. The three groups

together are financing the $90 million project, which will have 135 MW of generation capacity. The plant is located near the towns of Zamosc and Szczebrzeszyn in the Lublin voivodeship, or regional area, in the southeast of Poland. Officials said the project is sited in an area with high solar irradiation and low-quality soil, and will feature more than 250,000 solar panels. **CMS Poland** provided legal advice for construction of the project. **Wind Prospect Polska** provided technical advice, and **Marsh Poland** served as insurance adviser. ib vogt, which is headquartered in Berlin, Germany, is the engineering, procurement, and construction lead for the solar farm, and will continue to provide operations and maintenance services after the plant is commissioned. The project has an agreement with **Next Kraftwerke** to the trading of the project's electricity on the Polish exchange.

'Hydrogen-Ready' Gas Plant Announced for Singapore. Keppel, an infrastructure conglomerate working in the energy sector, in early September said it has made a final investment decision to build a 600-MW "hydrogen-ready" natural gas-fired facility in Singapore. Keppel officials said the plant would initially be powered by natural gas, but would be designed to eventually run on 100% hydrogen. The Keppel Sakra Cogeneration Plant, scheduled to come online in 2026, would be a combined cycle plant "designed to operate on fuels with 30% hydrogen content and has the capability of shifting to run entirely on hydrogen," according to officials with the Singapore-based company. Keppel said the plant would utilize **Mitsubishi Power** JAC-series gas turbines, which at present can only accommodate a fuel mix of up to 30% hydrogen. Keppel officials had not addressed whether the original turbines would be replaced at a future time to burn a higher percentage of hydrogen.

British Group Will Produce Green Hydrogen in Egypt. Globeleq, a British independent power producer, has received approval from Egyptian officials to produce green hydrogen and derivatives in the Suez Canal Economic Zone. Globeleq said it is looking at a 3.6-GW electrolysis plant. Globeleq signed the agreement with the **New and Renewable Energy Authority**, the **Suez Canal Economic Zone General Authority**, the **Egyptian Sovereign Wealth Fund for Investment and Development**, and the **Egyptian Electricity Transmission Co.** Globeleq under the terms of the agreement would develop, finance, build, and operate the electrolysis plant, which will produce hydrogen from electricity generated from wind and solar farms. Globeleq said the project will be built in several phases. An initial pilot phase will have an electrolysis capacity of 100 MW. The hydrogen produced will be converted into green ammonia, a needed ingredient for the production of fertilizer. Globeleq also said it plans to produce other hydrogen-derived fuels, including e-methanol, obtained by mixing carbon dioxide and hydrogen.

Rolls-Royce Will Develop SMR Technology in the Netherlands. The nuclear power group **Rolls-Royce SMR** in August announced an agreement with **ULC-Energy BV**, a Dutch nuclear energy development company, to collaborate on the deployment of Rolls-Royce small modular reactor (SMR) power plants in the Netherlands. ULC-Energy is based in Amsterdam. The company is a newcomer to the energy sector—it was established in 2021—and has quickly taken the lead in nuclear power development in the Netherlands. ULC-Energy has said nuclear is important to support decarbonization. It plans to develop projects that would use nuclear power to support industrial and residential energy networks. The Netherlands' new coalition government late last year said nuclear power would be paramount in its energy policy with regard to combating climate change. Officials outlined a multi-year plan, committing $50 million to the program in 2023, $200 million in 2024, and $250 million in 2025. The government said it expects cumulative financial support for nuclear will hit $5 billion by the end of the decade. Rolls-Royce SMR's current design is a 470-MWe unit based on pressurized water reactor technology.

Norway-Based Group Obtains Permit for South African Solar Project. Magnora, a Norwegian energy company, in August said it had received an environmental permit for a solar project the group is developing in South Africa. The 260-MW project is being designed to include a battery energy storage system. Oslo-based Magnora in a statement said, "The environmental clearance means that the project has the majority of the most important permits." Magnora said the solar farm, whose specific location was not disclosed, is being built "in an area with extremely good solar radiation," with an expected annual production of more than 600 GWh. ■

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