If I Had A Billion Dollars

By Ed Malley, TRC Companies

If I had a billion dollars, I could spend it on retrofitting vintage coal-fired steam boilers and turbines with SO2, NOx and mercury scrubbers. Or I could build new, state of the art combined-cycle gas turbines for a similar price.

Power production today is dominated by an aging fleet of power plants that are expensive to operate, even in a mothballed state. At a minimum, costs include management, labor, security, environmental compliance and taxes. While these dated plants can run at peak levels and recover operating costs, running new and more efficient plants can produce even greater profits.

Furthermore, removing many of the small, high polluting plants enables cleaner, more efficient plants to offset costs associated with plant closures. It no longer makes sound business sense to extend the useful life of out-of-date facilities.

In addition, the price of gas, a cleaner fuel, has become competitive with coal. Domestic gas supplies, with the advent of the shale plays, are plentiful. The EPA continues to propose new regulations that will ultimately lead to the installation of expensive retrofits, the creation of offset credits, or the closure of marginal plants. Most states have established renewable objectives, creating targets that shift the energy generation portfolios of regulated utilities toward technologies such as wind and solar.

As a result, industry experts estimate the closure of 50 GWs of capacity over the next 10 years, and predict increased industry profits due to the shuttering of approximately 100 inefficient coal-fired power plants.

Traditional generating facilities have a window of opportunity to trim costs, reduce emissions and become profitable after many years of difficult market conditions by rationalizing capacity, adjusting portfolios of power generation, and ultimately, decommissioning obsolete plants.

Replacing power generation portfolios is not a short-term activity. It takes years to seek permission to close plants, decommission facilities, address fuel shifting issues, and permit and construct new capacity. Progressive thinking power generators must start planning now to address antiquated facilities, economic uncertainty, shifting fuel price patterns, and increasing regulatory burdens.

Several factors have eroded the advantage that coal-fired generation had historically enjoyed, including lower natural gas prices; higher coal prices; surplus capacity at efficient natural gas plants; and the cost of complying with current environmental regulations.

Coal-fired electric generation is declining- down by 11 percent in 2009. Over the last 10 years, the number of coal-fired plants has decreased, as has their usage. On the other hand, natural gas-fired power generation increased by 4.3 percent in 2009, increasing its share of the electricity market to 23.3 percent—its highest share since 1970.

To comply with environmental regulations, including the Greenhouse Gas Tailoring Rule, strict 1-hour National Ambient Air Quality Standards for SO2 and NO2, the Cross State Air Pollution Rule, and the Mercury Air Toxins Rule (not to mention the regulatory uncertainty around coal ponds) generating companies will be required to install costly emissions control technologies. Those costs can run into millions of dollars and may only be a temporary fix at best. If even more stringent regulations are passed, the retrofit may need a retrofit. The cost of decommissioning and demolition is relatively small compared with the cost to retrofit the existing facility or rebuild it altogether. Scrap and salvage alone may be valuable enough to offset demolition costs.

Generators are reluctant to decommission existing conventional power production because they do not want to give up generating sites, or because they can't yet make sense out of the uncertain regulatory and economic environment. Eventually the shifts toward natural gas production will become site constrained. Existing inefficient production properties are an ideal location for new production. Avoiding compliance issues only serves to delay project development options. Regulatory ambiguity will always exist. It is only by directly developing site specific closure strategies that new generation can be developed.

"Recycling and reusing" may be sound environmental principles, but they are not always the best economic or environmental options for antiquated electric generation plants. Decommissioning should be an important consideration in the new generation development process. It is often the one that requires the most time to plan. There are often complications that arise with closing permits, addressing environmental issues above the surface, below grade, and in ancillary facilities such as coal ponds. Any actions contemplated today may take years to fully implement.

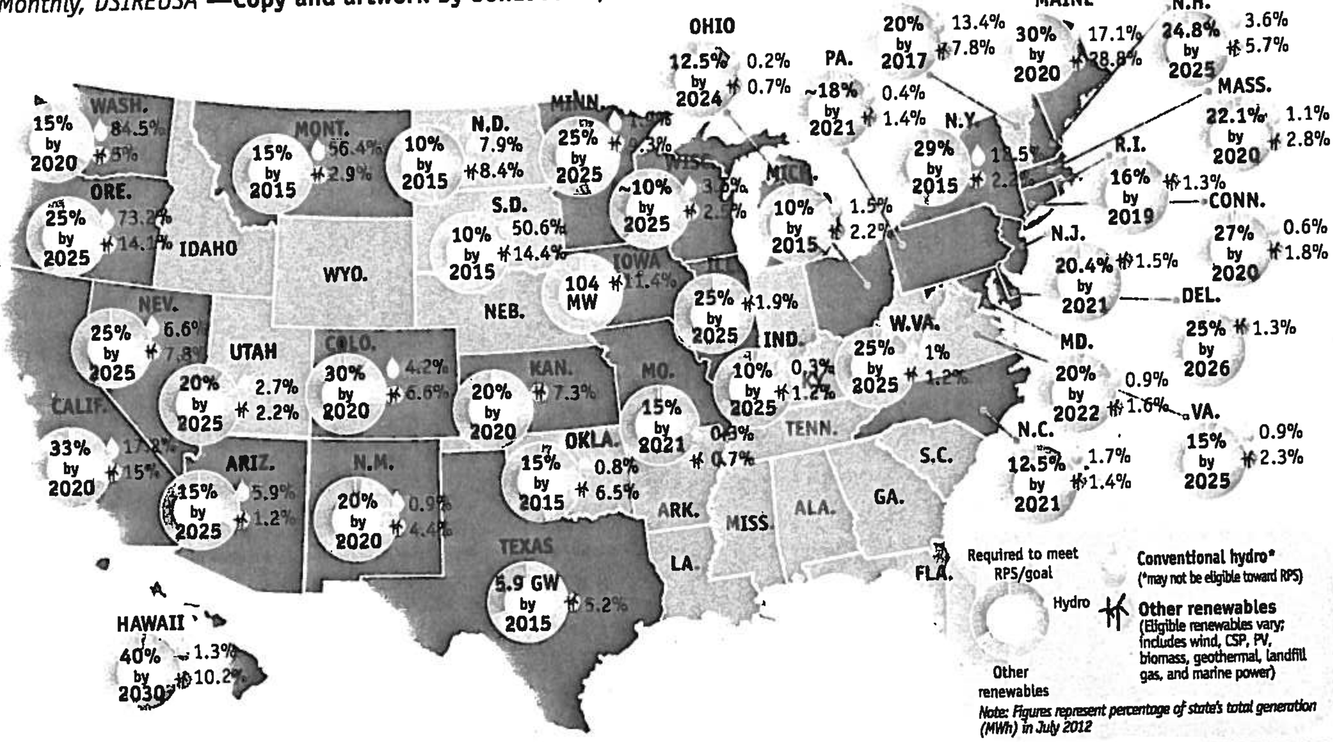
Investors may ultimately decide whether to invest in back end control scrubbers or choose new gas-fired combustion technology. Smart planning, starting now, is the key to successful power plant closure.

There is no time to lose. The time to act is now.

Ed Malley is a vice president at TRC Companies, a national engineering consulting and construction management firm serving the energy, environmental and infrastructure markets. pe

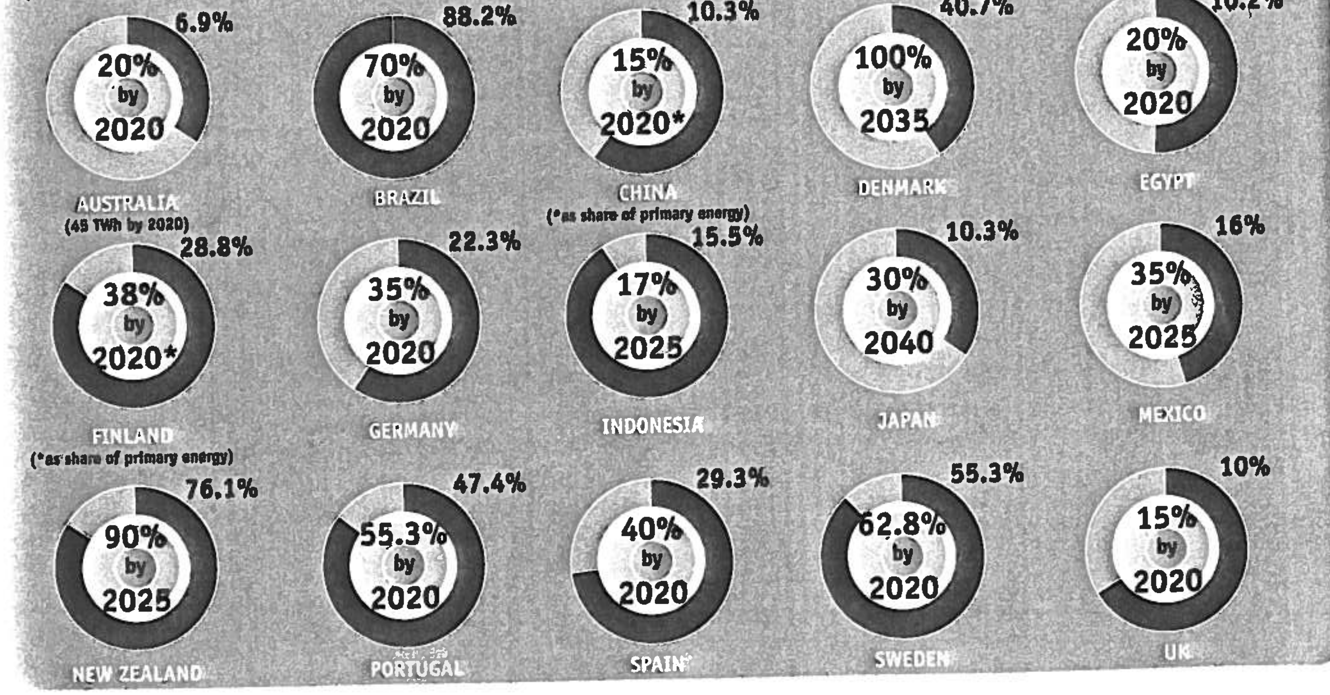
THE BIG PICTURE: A Renewables Quest

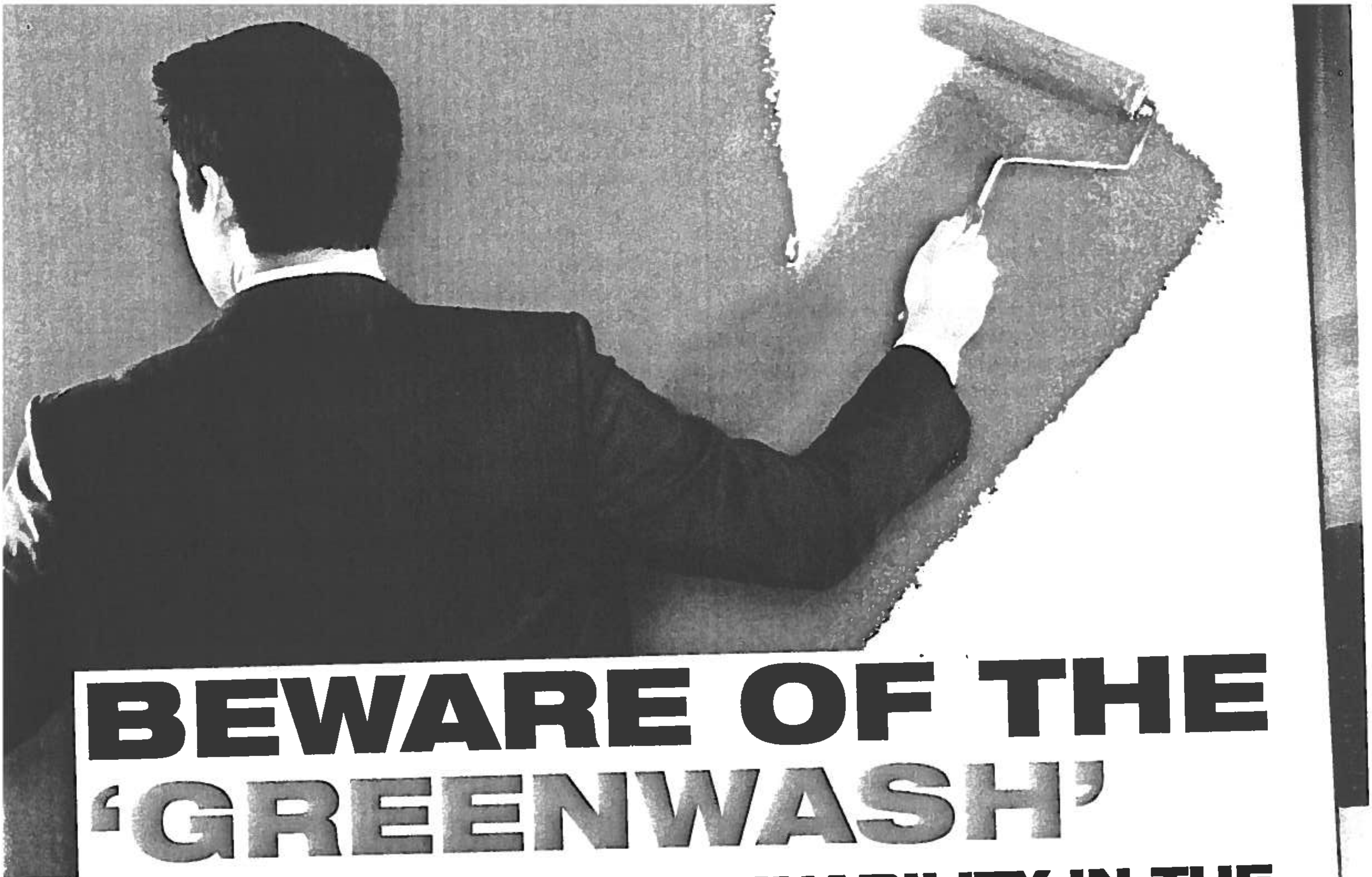
As of October 2012, 29 states had mandatory renewable portfolio standards (dark green), while eight states had voluntary goals (light green). Here's how each was faring as of July 2012. (The outer circle represents 100% of the target/goal; blue and yellow segments show the percentage of total generation by source.) *Sources: EIA Electric Power Monthly, DSIREUSA* —**Copy and artwork by Sonal Patel, senior writer**



AROUND THE WORLD

Worldwide, the share of renewables in power generation slightly exceeded 20% in 2011. The outer circle represents 100% of the goal; dark purple represents the renewables percentage of total electricity consumption in 2011 (including hydro). *Sources: REN21, IRENA, Enerdata, Danish Energy Agency*





BEWARE OF THE 'GREENWASH'

FOCUSING ON SUSTAINABILITY IN THE RENEWABLE ENERGY SECTOR

While a global focus on sustainability means more business for renewable energy companies, it's important for the sector to show that, in terms of environmental responsibility and sustainable development, renewable energy companies mean business. **Tildy Bayar** explores the issues and looks at what companies can do to avoid getting caught in the greenwash net.

Sustainability is increasingly in the news and on the minds of corporate decision makers – and it applies not only to a company's products, but to its entire manufacturing, supply and distribution chain. And customers and shareholders want reassurance that their investment is supporting environmentally friendly policies and practices – or, perhaps more importantly, that it isn't supporting destructive ones.

Help is available for companies wanting to 'go green'. The corporate sustainability service sector offers assistance with increasing energy efficiency, implementing sustainable procurement and complying with legislation. In a recent *REW* feature (see Vol. 14, No. 6, pages 47–50) we explored the rise of the 'energy executive' within existing organisations: new roles being created for sustainability managers, engineers and investment professionals in response to a growing awareness that – no matter how 'green' its products – every aspect of the way a company functions may eventually come under scrutiny.

The role of the sustainability executive includes both inward-facing and outward-facing responsibilities. It can be crucial not only to implement sustainable business practices – to 'be green' – but also to let the public know that you've done so – to 'be seen to be green'. In many cases this is merely a matter of getting the correct information into the hands of customers and shareholders, but in some cases a company's desire to be seen to be green has resulted in accusations of the dreaded 'greenwash'.

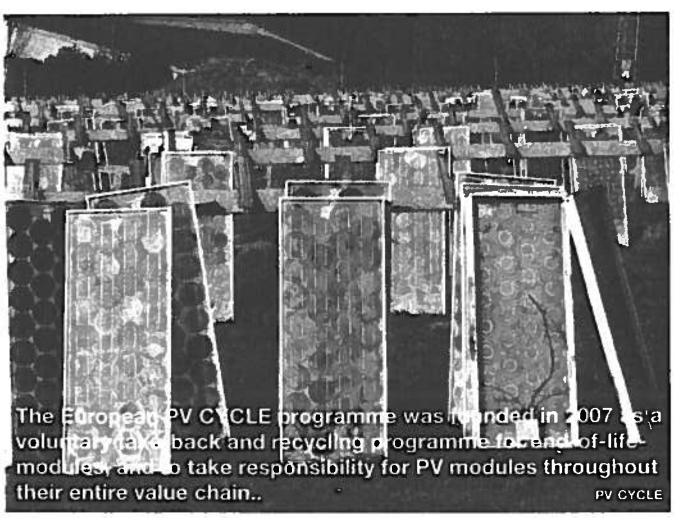
The term, modelled on the older 'whitewash' (meaning to gloss over or cover-up scandal), is defined by Greenpeace as 'the act of misleading consumers regarding the environmental practices of a company or the environmental benefits of a product or service'. And greenwash is a media issue. For example, from 2007–2010 UK newspaper *The Guardian* famously ran a series of articles on greenwash, for which it invited readers to email examples of 'exaggeration, absurd claims or downright lies that big business makes about its green credentials'. From the oil and gas and pharmaceutical industries to politicians, municipalities and national governments, no one was safe. The EU was the final entity to be tarred with the newspaper's greenwash brush, in a 2010 story on its implementation of an eco-label in the form of a flower, designed to indicate environmentally friendly products. *The Guardian* reported that two of these EU-labelled products, both popular brands of copy paper, were actually made in part from wood pulp logged from a rapidly disappearing Indonesian rainforest.

BUT WE'RE ALREADY GREEN!

Renewable energy companies might think they have less to worry about than other industries in terms of greenwash: after all, if the basis of your business is green energy, you're already way ahead in your green credentials. However, there have been cases such as PV panel manufacturer Jinko Solar's 2011 suspension of operations after local protesters called attention to high numbers of dead fish in a brook near one of its factories. In a televised interview, Jinko Solar said that rainstorms had caused containers of solid waste containing fluoride to spill over into the brook. The company apologised and temporarily suspended operations while fixing the problem, but the irony of a renewable energy company causing environmental damage was not lost on the international media.

When Viking Energy, an SSE subsidiary, proposed building a 550 MW wind farm in 2009 on the Shetlands' main island as part of the UK's plan to meet EU 2020 emissions targets, *The Guardian* pointed out that the proposed site, located on 187 km² of peat bog, was a natural carbon repository that, if disturbed on a large scale, could release more than 5000 tonnes per hectare of CO_2 into the air, substantially offsetting any carbon reduction represented by the wind farm. Peat slides are a common risk in boggy areas, resulting in the oxidation of large amounts of peat, and the construction of roads, drainage areas and the turbines themselves could easily cause such slides, according to environmental experts consulted by the newspaper. Viking Energy's own environmental assessment, however, stated that the risk of peat slides was 'zero'. Due to this negative media coverage Viking Energy's efforts to engage the local community with the project were widely viewed as greenwash. Although the project finally received planning permission in April, the community has formed a campaign group, Sustainable Shetland, that has vowed to 'fight on' against development of the wind farm.

In the bioenergy sector, public protest over the environmental impact of biofuel production and its contribution to the worldwide food crisis almost derailed the US industry in 2011. And global biofuel producers, especially Malaysian and Indonesian palm oil producers, have been dogged by reports of mass-scale rainforest destruction in order to make room for oil palm plantations. The Malaysian government has been criticised for its conversion of more than 1 million hectares of forest land into oil palm plantations; critics say this threatens to create enough carbon emissions to offset the carbon reductions represented by the use of waste from palm oil production in renewable energy projects (and by the government's own carbon reduction programme). The Malaysian Palm Oil Council's series of television advertisements, with the tagline 'Sustainably Produced Since 1917', was widely condemned as greenwash.



The European PV CYCLE programme was founded in 2007 as a voluntary take back and recycling programme for end-of-life modules, and to take responsibility for PV modules throughout their entire value chain.. PV CYCLE

WHAT COMPANIES CAN DO

These days, any corporate communication regarding a company's carbon emissions or 'green' business practices may be viewed with a frisson of suspicion. One reason is that, while many companies issue mandatory and, increasingly, voluntary statements about their commitment to sustainability, most consumers have no way to verify these claims – opening the companies to charges of greenwash.

One option available to companies wishing to present their green credentials is external verification. For example, risk assessment firm DNV offers verification of sustainability reporting which, the company says, can help with inward-facing tasks by ensuring appropriate reporting processes are in place, and can address outward-facing issues by enhancing the credibility of a company's sustainability report.

Green certification is another option. In the US, non-profit groups such as the American Consumer Council (ACC) offer their stamp of approval, and detailed reports for publication, to companies which meet sustainability criteria. But many smaller municipal and for-profit green certification agencies also exist, resulting in a bewildering field of options. The ACC recommends that businesses choose a certification programme that has itself been independently certified.

For companies that use wind energy in their organisations or production, there is the new WindMade consumer label, backed by a group of non-profit groups, trade associations and companies including WWF, AWEA, Bloomberg New Energy Finance and Vestas. WindMade offers two types of labelling for companies and organisations. The first identifies companies that use 100% wind energy, while the second labels those that use a mix of energy sources. The right to use the WindMade label is based on a company's certified electricity use for the past year of operations. The standard is now available, while the first WindMade labels for products will be issued this year, the group says. The European Wind Energy Association's (EWEA) annual gathering in April was the first event to be awarded the WindMade label.

In March, the US Solar Energy Industries Association (SEIA) released its *Solar Industry Commitment to Environmental and Social Responsibility*, a document that promotes the implementation of sustainability standards throughout the solar industry. Adoption of the document's principles is voluntary, and includes compliance with company and supplier requirements in the areas of labour, ethics, health and safety, environmental responsibility, human rights and management systems. Participants on record include Suntech, SunPower, Dow Solar, Trina Solar, and Yingli Solar.

The European Photovoltaic Industry Association (EPIA) has a Sustainable Development Working Group, which aims to increase understanding of the PV sector's role in positively contributing to sustainable development. The Working Group has produced fact sheets on the carbon footprint of PV systems and their energy payback time; a background document responding to common misconceptions about the availability of raw materials; and fact sheets on land use and biodiversity, water consumption, and external costs (forthcoming).

THAT'S WHAT GETS RESULTS

These strategies appear to work. Sustainability has been linked to shareholder value, and with building a brand as part of a long-term profit strategy, a good thing to have in these days of shakeouts and looming consolidation in high-profile renewable energy sectors.

In the UK, a survey in advance of the government's Carbon Reduction Commitment (CRC) scheme revealed that 60% of respondents believed that participation in the scheme would give them a competitive advantage over other companies. 'Our experience is that companies want to perform better than their competition in the public league tables when they are published,' stated Bobby Collinson, managing director at energy procurement and carbon strategy consultancy Power Efficiency, which conducted the survey. 'Nobody wants to appear behind a competitor, but the jury is still out on how this information will be perceived by customers. Of course, competitive advantage will be gained through improved recycling payments from the scheme and lower carbon usage, which reduces the costs to a company.'

A research report from the Economist Intelligence Unit (EIU) revealed that global companies that showed strong share price growth over a three-year period were more proactive on corporate sustainability issues than companies whose share prices stagnated or declined. And 57% of executives surveyed believed the benefits of implementing sustainable business practices outweighed the costs, although eight out of 10 expected any direct profit increase to be negligible. But, cautioned the EIU, sustainable practices do reduce costs, particularly the costs associated with energy expenditure. Sustainable practices can also open up new markets and improve a company's reputation as part of a long-term brand-building strategy.

The survey also found that communication is key. Choosing from a list of 10 sustainability objectives, 61% of respondents rated communicating their company's environmental performance to investors and stakeholders as a 'leading' or 'major' priority.

In a recent conversation, Jan Jacob Boom-Wichers, Benelux managing director at Norway-based REC Solar, discussed a life-cycle analysis which assessed the environmental impact of REC's products, from manufacturing to recycling. The Energy Research Centre of the Netherlands (ECN) conducted the analysis and identified energy consumption as the most important footprint of a c-Si module. In response, REC developed its Fluidised Bed Reactor (FBR) technology, which uses granular polysilicon and, the company says, reduces energy consumption to less than 10 kWh/kg, compared with the 65–150 kWh/kg used in traditional production processes.

For REC, sustainability has paid off. 'Our partners buy REC modules because of our commitment to the environment. That is very clear,' said Boom-Wichers. 'They want high-quality modules with the highest performance ratio, but in addition they want environmental values. Also with companies who want to improve their image of being a green company, [REC's environmental stance] is definitely something they can relate to.'

A GREENER GREEN BUSINESS MODEL

The 'greener' your business, the less you can afford not to 'be seen to be green'. The renewable energy sector has risen to this challenge with some notable 'greener green' projects.

In the solar industry, the Europe-wide PV CYCLE initiative was designed to make photovoltaics 'double green'. It was founded in 2007 as a voluntary return and recycling programme for end-of-life-modules, and to take responsibility for PV modules throughout their entire value chain. Its list of more than 200 members reads like a 'who's who' of solar companies around the globe.

The recycling of wind turbine blades at the end of their life cycle was explored in 2005 by a consortium including energy consultancy KEMA, the Polish Industrial Chemistry Research Institue (ICRI) and HEBO Engineering, funded by the European Commission. The group built and tested a shredder that could handle 2.5 tonnes per hour, and make the materials in turbine blades reusable. But demand for the recycled material was low due to its reduced strength. While many believe that the EU will ultimately legislate the recycling of wind turbine blades, in the interim the industry is still actively seeking solutions to the problem.

Sustainability makes business sense. The 'greener' your business, the less you can afford not to be 'seen to be green'.

LOOKING AHEAD

While a global focus on sustainability means more business for renewable energy companies, it's important for the sector to show that, in terms of environmental responsibility, renewable energy companies mean business. Addressing supply chain, manufacturing, product end-of-life and environmental impact issues before they become problematic is crucial for a 'green' business model. The initiatives underway are a great start, but as global sustainability competition accelerates, the roles of sustainability managers, planners and engineers will be vital to ensure that a company's activities are not perceived as greenwash, but as truly green.

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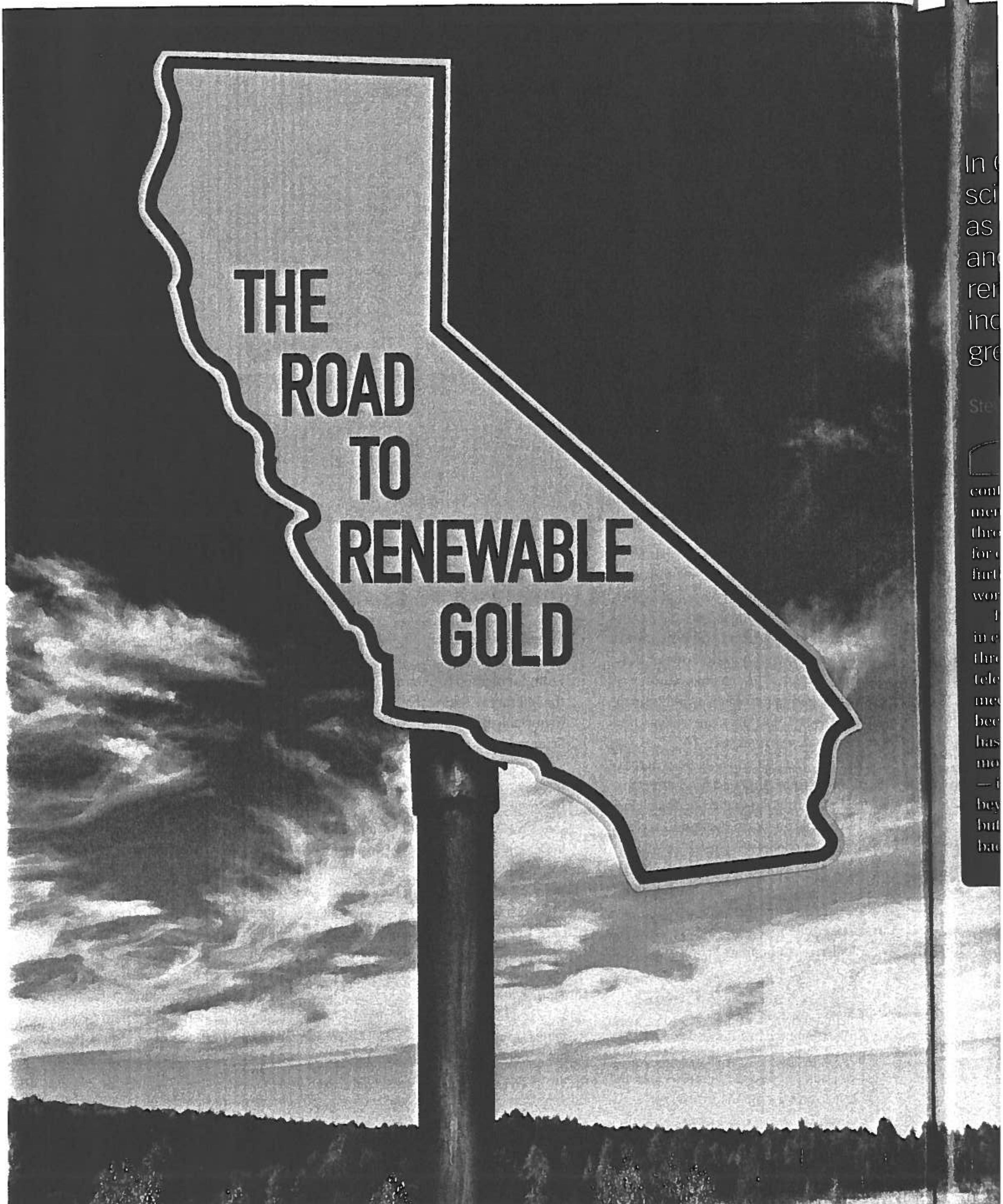

THE
ROAD
TO
RENEWABLE
GOLD

In California, science is still king as projects big and small push renewable energy industries to greater heights.

Steve Leone, Associate Editor

California was long ago picked clean of its gold, but the state continues to foster a prospector's mentality and a willingness to sift through the swift current of ideas for one more discovery that will further cement its place as the world's center for innovation.

It's been done in recent decades in electronics, computing, and through the rise of the dot-com and telecom industries. It's where social media blossomed and where Google became a verb. The Golden State has also been home to some of the most novel approaches to energy — ideas that originally extended beyond the traditional power plant, but ones that ultimately circled back as mainstream solutions.

It's also where failure is seen as an acceptable part of the exploration process, much like the many gold-diggers who paid small fortunes only to come up empty-handed. It's this pioneering mentality that has long fueled the state, spurring equal parts risk and business acumen.

This spirit of invention remains alive and prosperous today in California, an economic giant that by itself represents the world's eighth largest economy. And no industry in this state offers as much transformative potential than those companies and institutions pushing the boundaries of clean energy, and those looking to create new pathways to getting there.

It is widely recognized that most new technologies will fail to deliver on the promise envisioned at the outset. Often times, though, the discoveries far outlive their inventors, and the new products and new methods created forge a path for even bigger and greater achievements.

Below, you will find a collection of projects that are working to change the landscape of our energy future. Some were born and raised in the labs of small companies. Others received funding from the federal government, which saw the technology as worthy of investment. Some are outwardly daring. Others provide subtle shifts to established technologies. For all, their potential is great and their mission is unwavering.

Solar

California is known for its wide expanses and long commutes. But one short 10-minute car trip will take you across the solar spectrum. On one side of Santa Barbara, a tourist haven known to some as the "American Riviera," is a solar company reinventing how the sun is captured by a solar cell. On the other side of town is an equally entrepreneurial venture where solar power is being used to create, of all things, a form of natural gas.

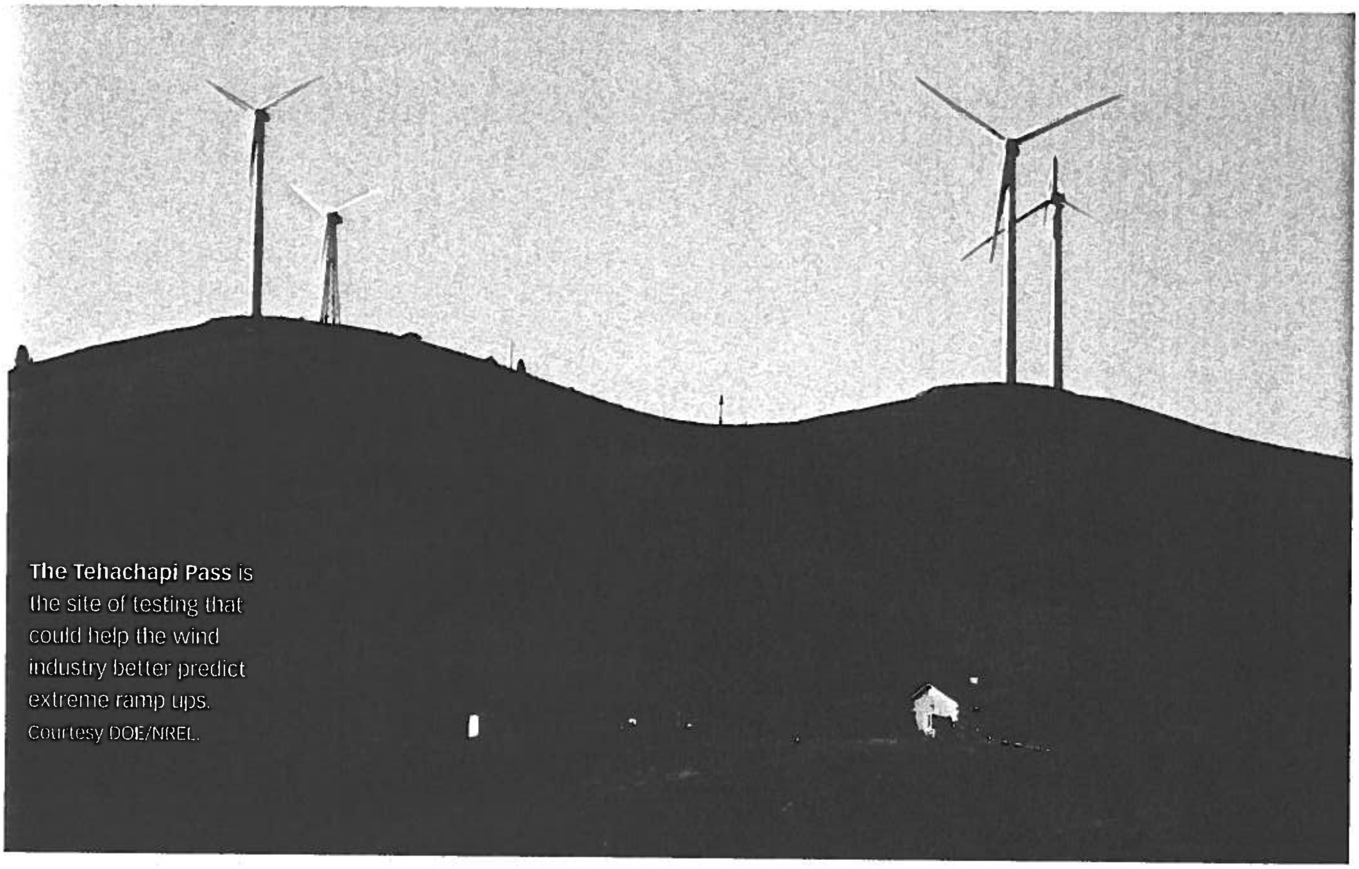
Solar3D sees efficiency as the Holy Grail for the industry. According to the company, solar panels have a couple of serious limitations that impact their efficiency. First, 30 percent of the sunlight that strikes a traditional panel is immediately reflected. Many of the electrons that are impacted by the remaining 70 percent of sunlight never make it to their destination — the metal contacts that create the current. And the contacts themselves are often on the surface of the panel, creating a shadow that renders a portion of the cell useless.

The company is working to overcome all three challenges. It is using an optical element on the surface of the panel to essentially trap the light within the cell. It is also using thinner collection areas to reduce efficiency lost through the materials and it is locating contacts beneath the surface to eliminate shadows. Still in the development stage, these design changes will increase the price, but the company says the increased efficiency will give the product a higher return on investment.

In preliminary testing, the company says it has surpassed 25 percent efficiency, surpassing the levels reached by current technology in the marketplace. The company is working on a prototype and is hoping to enter production by the end of this year.

On the other side of town, Hyper Solar is taking a new approach to creating natural gas by turning direct sunlight into a renewable fuel. Once in the production stage, the company could conceivably source carbon via emissions from coal and natural gas power plants to make its product, reducing greenhouse gas emission while creating a renewable product.

To get the natural gas, Hyper Solar mimics photosynthesis with billions of nanoparticles that use sunlight to separate hydrogen molecules out of water. The free hydrogen is then reacted with carbon dioxide to produce methane. In its vision of "world-scale operation," the company says it would install acres of low-cost reactors on vacant lands and then pipe the renewable natural gas to homes, vehicle filling stations, industrial facilities and even power plants.



The Tehachapi Pass is the site of testing that could help the wind industry better predict extreme ramp ups. Courtesy DOE/NREL.

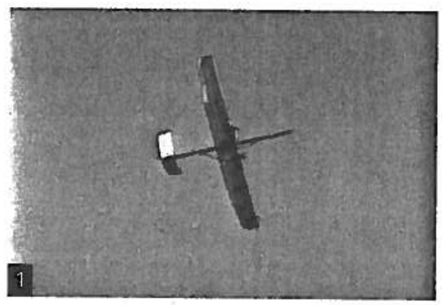
Wind

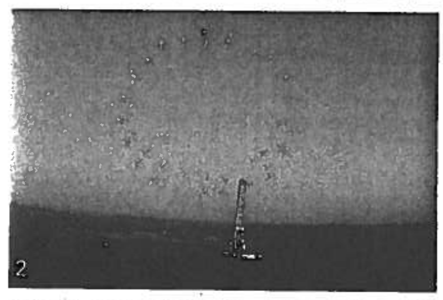
In the quest to better manage the intermittency of wind, researchers must look no farther than California's Tehachapi Pass. The area is vital to the state's long-term goal of high levels of renewable energy integration. It's also home to some of the country's most consistent wind resources, and today you can find wind turbines with a collective capacity of 700 MW lining the rugged landscape. With expansion plans for sprawling wind farms, such as the Alta Wind Energy Center, coming to fruition, the area will soon be home to 3 GW of wind power capacity.

That balance of supply and demand was one of the reasons that the Lawrence Livermore National Laboratory in Livermore, Calif., chose to make the Tehachapi Pass a focal point of its Department of Energy-funded WindSENSE program, which aims to use data mapping to better understand the extreme events that most disrupt grid operators.

The question researches are grappling with is, "Can you look back at past events to better predict when ramp events may occur?" Armed with this information, control room operators would be better able to manage the delicate balance between supply and demand.

According to lead researcher Chandrika Kamath, getting the right wind speed prediction — especially during a ramp event when the energy can change by more than 1,000 MW in a hour — is vital to the success of an operation.





1 **Wing 4d** generating power under autonomous control. Courtesy Makani Power.

2 **Makani power** demonstrating its fully autonomous high-speed flight with a rigid, tethered wing. Courtesy Makani Power.

3 **Wing 1,** Makani Power's first rigid wing prototype that will demonstrate tethered, autonomous hover at Makani's development facility in Alameda, CA. Courtesy Makani Power.

While the Lawrence Livermore lab continues to work with AWS Truepower on a wind modeling system that can be used by operators in the short-term, other companies in California are taking a much longer view of the wind industry. For a company like Alameda-based Makani Power, that means a virtual reinvention of the wind turbine.

The industry is racing against itself to reach new heights, literally, because that's where the best wind resources can be found. But that almost always means taller turbines that come at a greater cost in materials, construction and environmental pushback. Makani is working on the Airborn Wind Turbine, which in theory works like a traditional turbine. But the Google-backed company's 10-kW prototype veers from the norm in its execution. Instead of longer and longer blades affixed to a hub, it uses a kite-like wing tethered to the ground to achieve the large circular areas that are capable of generating more power. The energy extracted from the "blade" drives

The industry is racing against itself to reach new heights, literally, because that's where the best wind resources can be found.

small wing-mounted high-speed generators, which then transmit energy to the ground via conductors in the tether.

The company sees itself as a lighter-weight, less-expensive and higher-efficiency turbine, especially deep offshore and in areas where traditional turbines would be unable to access the stronger more consistent winds found at higher altitudes.

In development since 2006, Makani reached a milestone in the fall when it demonstrated the wing's onboard computer system, which guides its circular path and allows it the ability to hover during periods of low wind.

Biofuel

Researchers across the industry are mining plants — both onshore and offshore — for the potential to create low-cost biofuels. So far, the gains have been consistent, but a viable economic model has been elusive. It's not that they can't convert the switchgrass or algae into biofuels — it's that they can't do it directly and at a low-enough cost to achieve the scale required.

To help in this effort, researchers at Stanford University in Palo Alto are taking a hard look at a bacteria universally maligned for its ability to make us sick. From the scientists' perspective, however, it also has the ability to make our cars move. E. coli is touted because it can convert plant sugars into biofuels. But how to get the bacteria to work faster and more effectively remains a challenge. To better understand this, researchers are going inside E. coli in a quest to engineer a better germ. By tweaking the internal functions of the bacteria, they hope to move past the biological limitations and toward a more cost-effective model.

Similar work is being carried out by the U.S. Department of Energy's Joint BioEnergy Institute, which is based in California. The group in late November announced a milestone in which it engineered strains of e. coli that can digest switchgrass and synthesize its sugars into gasoline, diesel and aviation fuels without the use of enzyme additives, which today adds a costly and time-consuming step.

The developments at both labs are seen as significant steps toward achieving a long-term vision of a viable alternative to petroleum.

E. coli is touted because it can convert plant sugars into biofuels. But how to get the bacteria to work faster and more effectively remains a challenge.

Geothermal

By California standards, the Salton Sea is not prime real estate. For the geothermal industry, though, the region is a fertile area for growth.

A couple of hundred feet below sea level in the vast, dry expanse north of the Mexican border, the region sits atop the San Andreas Fault. Its geothermal potential is unsurpassed in the United States. Its mineral makeup, though, has long posed some challenges, leaving the development of that geothermal potential to a select few.

El Centro-based EnergySource is putting the finishing touches on the Salton Sea area's first standalone geothermal plant in 20 years. The 49-MW Hudson Ranch I project is expected to come online by the end of the first quarter, and the company plans to start drilling for Hudson Ranch II, also 49 MW, at some point this summer.

The project, which will represent the first geothermal plant to come online in the U.S. since 2010, is employing the best available technologies previously used in the Salton Sea area, according to EnergySource President and CEO Dave Watson.

Perhaps the biggest challenge is how it plans to deal with the high levels of mineralization that define the region. To overcome the hurdles, the company has teamed with Bay Area-based Simbol Materials, which will help extract minerals such as lithium, manganese and zinc, which the company could then export to battery developers. Those batteries, created partly from minerals extracted from the geothermal brine, could conceiv-

The Hudson Ranch I project in the Salton Sea area is expected to open by the end of the first quarter. Courtesy EnergySource.

ably be used for battery storage for other renewable technologies.

The relationship between the two companies solidifies both as they strengthen their positions in the Salton Sea region. The region has up to 2 GW of long-term potential power generation, but so far existing plants represent a nameplate capacity of about 350 MW. So there is immense potential for growth, and perhaps the Hudson Ranch project will pave the way for more developments that manage to turn the high mineralization into a valuable resource.

Hydropower

The Sacramento Municipal Utility District (SMUD) is the sixth largest publicly owned utility in the U.S. It's also, perhaps, the most aggressive — public or private.

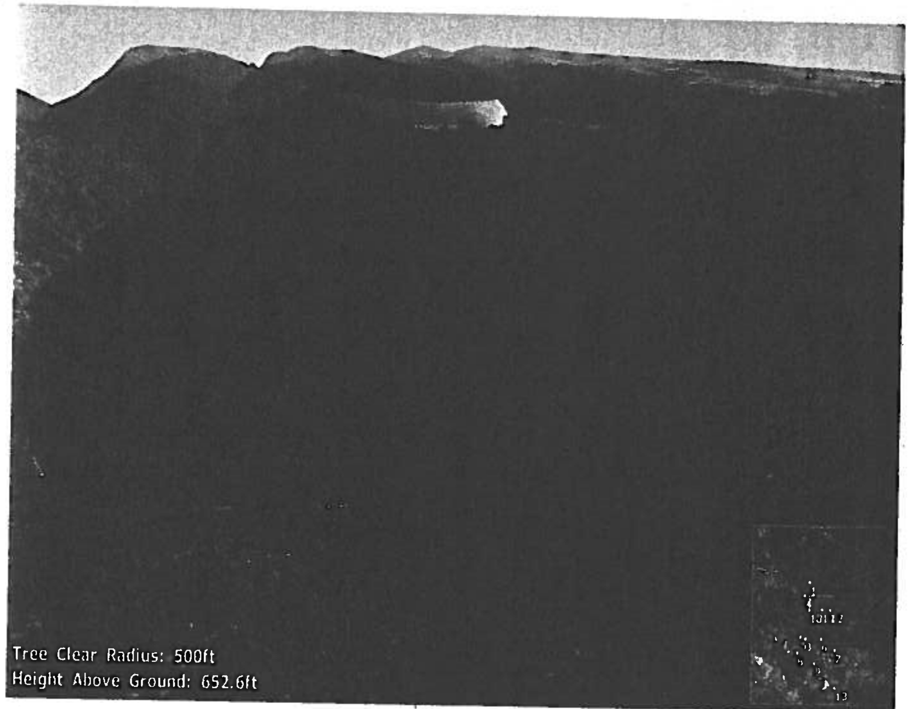
In 2008, it set off on an ambitious course that by 2050 would cut its greenhouse gas emissions from electrical generation to 10 percent of 1990 levels. In 2010, the utility supplied 24 percent of its retail sales with renewable energy, and its 2020 goal of 37 percent is four percent higher than the state's already lofty goal.

Central to that long-term renewables strategy is the work it is doing on the hydro front, and two projects were awarded seven-figure grants by the Department of Energy. The bigger of these is the Iowa Hill Pumped Storage Development, which received nearly $5 million from the DOE. If the project receives state approval, the DOE grant will help the utility address construction challenges related to underground excavation. According to the DOE grant application filed by SMUD, the facility will break ground on two technologies — the variable-speed turbines and a lining to eliminate leaks in the upper reservoir.

The project would use the existing Slab Creek Reservoir as a lower reservoir and it would build a 6,400-acre-foot reservoir atop Iowa Hill. It would then dig underground shafts and a cavern to enclose a 400-MW powerhouse and pumping facility inside the hill.

Once complete, the volume presented by the pumped storage facility will give SMUD the dispatchable capacity to respond quickly to shifting demands. Even more importantly from SMUD's perspective, the project will be central to the utility's stated renewable energy goals, and it creates the flexibility to take on more and bigger projects from intermittent sources like solar and wind.

If history is any indication, the growing appetite for renewable projects within the utility's territory will spur more growth and will take the industry in a new direction. And much of that innovation is likely to happen in California.



An artist rendering of the Iowa Hill Pumped Storage Development. Courtesy SMUD.

Spain: A Renewable Kingdom

Spain has served as both exemplar and scapegoat when it comes to renewable energy policy. Though power policy must necessarily accommodate specific national resources and goals, Spain's experience as an early and eager adopter of renewable energy technologies and subsidies is a cautionary tale of how the best intentions can have unintended consequences.

By Sonal Patel

Spain, the fifth-largest economy in the euro zone, has been slammed by the global economic crisis and faces a critical energy dilemma. Struggling to tamp down power prices, but unable to afford billions of euros in funding, the debt-burdened government has been forced to retroactively slash its subsidies for renewables—a measure that has frozen investment in renewables and battered the nation's once-booming solar industry. Meanwhile, policies to phase out coal power have destroyed Spain's domestic coal mining industry and prompted debilitating strikes by coal miners. The nation's nuclear power sector, too, is under siege: A moratorium on building new reactors has driven the government—amid opposition that was intense even before the Fukushima Daiichi emergency this March—to extend the lives of aging reactors.

The Kingdom of Spain saw more than two decades of dizzying economic growth before the abrupt contraction in its economy in mid-2008. Its gross domestic product (GDP) growth rate reached a historic high of 1.53% in December 1997 and a record low of –1.70% in March 2009. The nation exited the recession last year, but it continues to face soaring unemployment. Nearly 20% of Spain's 45.9 million people are jobless—the highest rate in the 27-member European Union (EU). Despite government efforts to boost the economy through stimulus spending and loan guarantees, the government budget deficit increased from 3.8% of GDP in 2008 to about 11% in 2011. To control the deficit (and reduce it to 6% by next year), as well as avoid financial contagion from other highly indebted euro zone members like Ireland and Greece, the government has implemented austerity measures, tried to privatize industries, and attempted to boost competitiveness through labor market reforms.

Most economists blame the economic woes on a burst housing bubble and the international credit crunch. Others, like Dr. Gabriel Calzada Álvarez, an economics professor at the Universidad Rey Juan Carlos in Madrid, point to the government's substantial subsidies for the country's inflated renewable energy sector, which Álvarez has said created large debt bubbles and artificially created a new market that would collapse without more public funding.

In a much-cited, controversial March 2009 report on the effects that renewable subsidies have on employment, Álvarez contends that between 2000 and 2008, Spain's government spent more than $36 billion to subsidize renewable projects, while consumers paid almost $10 billion more for renewable power than set market cost. Álvarez also suggests that the resulting higher energy costs and "green" jobs may have more than doubled job losses economy-wide. Critics of the report say his analysis was "too simplistic" to be applied as a real-world model and that he deviated from peer-reviewed methodologies to estimate job impacts.

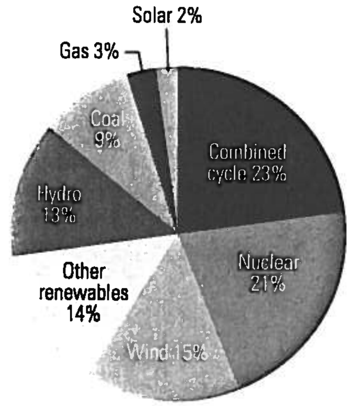
Creating a "Sustained" Renewable Policy Framework

In 1980, Spain's social-democratic Socialist Workers Party enacted a law after the second international oil crisis to support what they called a "sustained" framework for the development of renewable energy. In 1997 another law was ratified that deregulated the power market while mandating that 12% of primary energy demand was to be met with renewable sources by 2010. By 2005, when it became apparent that objective would be difficult to achieve, the government approved a new Renewable Energies Plan calling for 29.4% of gross electricity demand to be covered by renewable sources by 2010.

To support sales of renewable power, the government put in place a feed-in tariff system, establishing fixed tariffs to be paid on top of market prices for renewable power installations. (See "The Feed-in Tariff Factor" in our Sept. 2010 issue or in the archives at www.powermag.com.) Later, in June 2009, a directive based on targets set by the EU called for 20% of final gross energy demand to be met with renewables (and for cutting greenhouse gas emissions by 20% compared with 1990 levels).

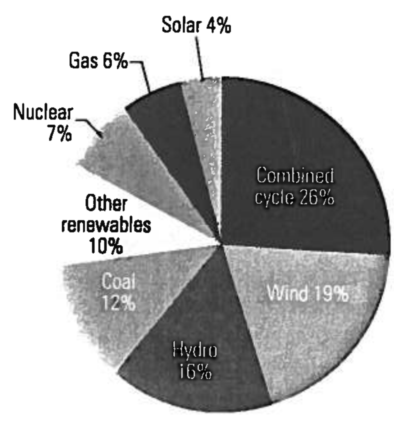
The mandates have transformed Spain's generation mix. Compared with the 1990s, when coal, hydro, oil, and nuclear facilities

1. Spain's electricity profile. Installed power capacity in Spain's electricity system in 2010 amounted to 103,086 MW. Power actually generated totaled 275,252 GWh, including reductions for self-consumption, pumped storage consumption, and international exchanges. "Factoring in the effects of seasonal and working patterns, the annual [demand] growth was 2.9%, compared to a fall of 4.8% registered in 2009," grid operator Red Electrica de Espana (REE) said in its annual report. *Source: REE*



Note: Total does not include 7,555 GWh used for self-consumption. "Gas" includes power generated by integrated gasification combined-cycle, conventional gas, combined-cycle gas turbines, and oil/diesel generation.

Power generated, 2010



Installed capacity, 2010

generated nearly 99% of the nation's electricity, in 2010, those four sources accounted for 69%. Gas-fired generation has grown exponentially in response to increasing amounts of variable wind power that require back-up generation and to meet swelling demand (a report by Spanish law firm Gomez-Acebo & Pombo notes that "Spain has one of the highest rates of energy consumption per unit of [gross national product] in the EU"). Wind power, meanwhile, surged from 5 TWh in 2000 to 42 TWh in 2010 (Figure 1).

"Without doubt, the main factor underpinning our success in integrating [renewable] sources into the electricity generation system has been the economic and legal framework comprising a system of regulated premiums and feed-in tariffs, which has been in force for the last 30 years and has been subject to ongoing improvements and modifications," says Miguel Sebastián Gascón, minister for Industry, Tourism and Trade in a government renewables-specific website. The minister also says the country's solar thermal, wind, and other sectors are among the largest in the world, and that it is on course to exceed the EU's 20% renewable target. He adds: "This framework is stable but adaptable to the current status of each technology as it matures."

Industry Structure

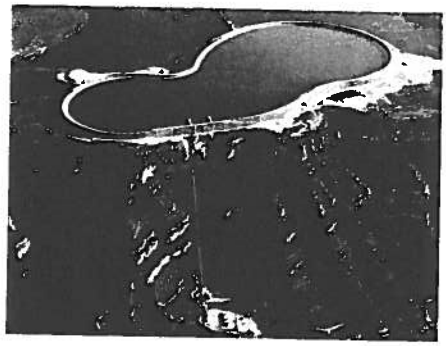
Spain today splits its generating units into two groups—ordinary and special regimes—based on how they interact with the competitive electricity market. Five companies generate the bulk of conventional power, which includes large hydro, nuclear, coal, and gas: Iberdrola, Endesa, Gas Natural Fenosa, E.ON, and HidroCantábrico. All generators under the ordinary regime sell power to suppliers through the wholesale market pool or bilateral contracting and receive remuneration for power sold on the market, plus capacity payments (including 10-year investment payments that vary according to the net power of the plant).

Special regime generators—those that produce power from renewables with installed capacities of up to 50 MW and cogeneration facilities—are not required to bid in the power pool and are permitted to sell power at government-ordained tariffs or at the Spanish pool price, plus premiums and incentives. In 2010, according to grid operator Red Eléctrica de España (REE), special regime generators produced 33% of the country's peninsular power.

Growing Demand and Capacity

Peninsular Spain's electricity demand (excluding its islands) currently exceeds 259,940 GWh, having risen 30% since 2000. The increase would have been more dramatic were it not for the economic slowdown, when demand plunged 5%, from 265,281 GWh in 2008. In 2007, industry consumed 38% of Spain's generated power, followed by the services and agricultural sectors. Households consumed 33% of all power generated.

2. Pumping up wind. Spanish renewables giant Iberdrola's 1989-built 635-MW La Muela pumped storage facility will be followed by the 852-MW La Muela 2, slated to be operational in 2012. The ability to dispatch pumped storage power helps to mitigate the variability of wind power. *Courtesy: Iberdrola*



National energy plans drawn up before the recession call for substantial increases in total generation (72 TWh between 2008 and 2016) to fuel future growth, including further ramping up of gas power by 42 TWh and wind power by 33 TWh, but cutting coal-fired generation by 23 TWh and oil by 10 TWh. An increase of nuclear power is also foreseen—but only through uprates.

Spain has already made great strides in adding new capacity. The International Energy Agency (IEA) reported that from 2001 to 2008, total capacity increased by 87%—one of the largest hikes for a member country. As of 2010, about 95% (97,447 MW) of capacity was installed in the peninsular system and the rest, 5,639 MW, was installed in other territories, including the Canary Islands and Balearic Islands.

The Renewable Future

Because of its size and geography, Spain's climate varies substantially by region (see a map of all of Spain's power plants at http://bit.ly/hiFN3h). And climate has influenced its choice of renewables.

Hydro. About 1,200 hydro plants with a total installed capacity of 18.97 GW have been built in Spain, 20 of which are 200 MW or larger, and at least 2,400 MW of which is pumped storage (Figure 2). Though these represent about 50% of the hydro total, they have been underperforming since 2004, mostly because of increased droughts (blamed by the government on climate change). In 2010, however, the nation saw abundant rainfall that allowed hydroelectric facilities to generate 36.6 GWh—30% higher than the historical average and 65% above the 2009 figure.

But droughts and fierce opposition by environmental groups aren't the only reasons large hydropower plants will not be counted on as significant future energy sources. In addition, "there are [no more] available spaces in our rivers for the installation of a big hydro plant," explained David Gomez, the director of energy for Spain's Trade Commission, based in Los Angeles. The country intends to exploit all its hydro potential, he told *POWER*, through so-called "mini-hydro plants" of less than 10 MW, which are subsidized through feed-in tariffs.

Wind. Wind is faring better. Spain boasts that wind power produced 42,976 GWh in 2010—15% of total generation. The sector's rapid growth, reportedly boosted by premiums and feed-in tariffs, has been aided by a burgeoning wind manufacturing industry. Several wind turbine makers have set up shop in Spain, including Gamesa, Eólica, Acciona Windpower, and Alstom-Ecotècnia, and Spanish wind farm developers like Iberdrola and Acciona Energía have projects all over the world. The component supply chain, too, is thriving: 75 industrial centers related to wind exist in Spain, 18 of which are wind turbine assembly plants.

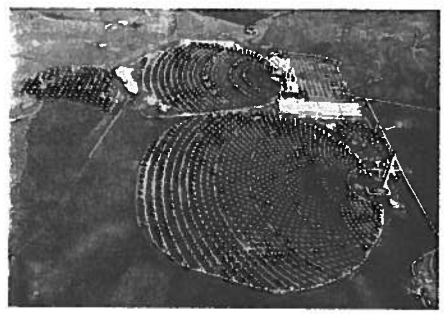
Solar. In contrast, the solar photovoltaic (PV) sector, which over the past five years saw a similar—maybe even more pronounced—boom driven by high subsidies, has been frozen by uncertainty following the government's December 2010 decision to retroactively slash previously agreed-upon subsidies to solar energy producers.

Meanwhile, the country maintains its dominance in the solar thermoelectric sector (see the sidebar). More than a third of worldwide solar thermal electric capacity is installed in Spain. The country that commissioned the world's first commercial central tower plant (the PS10 plant in Seville, Figure 3) in 2006 after establishing a feed-in tariff, is actively developing projects to increase solar thermal capacity to 2,400 MW by 2013—and it is building and managing several projects around the world. Of new capacity planned, 93% will likely be parabolic trough receiver technology, central towers will make up 3%, and the remainder will be Stirling dish and Fresnel receivers.

Biomass. Feed-in tariffs for biomass were also implemented in 2007, but growth for that sector has been slow because the remunerative framework that could spark significant growth was "enacted practically as the recession hit," the Ministry of Industry said. Today, Spain has some 400 MW of installed biomass capacity, fueled by products from the pulp and paper, timber, and olive oil industries.

Other Renewables. Spain has yet to fully develop its marine and geothermal power sectors. Valencia-based Iberdrola Renovables is spearheading a project to install 10 Ocean Power Technology buoys for a total rated capacity of 1.35 MW at a pilot marine energy plant in Santoña. Meanwhile, though studies have shown Spain has substantial geothermal resources, no power plants exist. Geothermal energy is being developed for heating, however.

3. A solar beacon. The €35 million ($49 million) 11-MW PS10 concentrating solar power tower, a facility featuring 624 heliostats, went into operation in 2007. In 2009, owner Abengoa Solar completed PS20, a 20-MW solar tower facility at the same platform in Sanlúcar la Mayor. It later began operating Solnova 1, 3, and 4, three of five planned 50-MW parabolic trough plants. Along with two other 50-MW projects (Solnova 2 and 5), another 20-MW tower plant (AZ20) and an 80-kW concentrating solar plant based on Stirling dish technology are under construction there. *Courtesy: Abengoa Solar*



Energy Technology Investments

Spurred by policy drafted by the country's Ministry of Science and Innovation and boosted by public funding that covers basic and applied research to pilot and demonstration projects, Spain has quickly become a well-respected hub for energy technology. Three primary institutions have been pivotal in the rollout of new technologies, from carbon capture to solar thermal: CIEMAT, CENER, and CIUDEN.

CIEMET, the center for energy, environment, and technological research, is best known for its 250-acre Plataforma Solar de Almería, a facility that tests and optimizes numerous concentrating solar power concepts. CENER operates a major wind turbine test facility that includes an experimental wind farm. CIUDEN, located in the coal-mining region of El Bierzo, carries out research and development on clean coal technologies. The institute is building a €72 million demonstration plant for carbon capture with oxyfuel combustion.

Privately funded research is also making headway. Wind turbine maker Gamesa in February, for example, announced it was developing two families of offshore turbines, the 5-MW G11X (to be tested in late 2012 in collaboration with German power company E.ON) and the G14X, which could have a capacity of up to 7 MW (a pre-series is expected to be ready in 2014). Gamesa and Spanish firms Acciona and Iberdrola, among others, are also spearheading the Azimut initiative, which seeks to develop a 15-MW offshore wind turbine using only Spanish technology.

Subsidies: The Shadow on Solar and Wind

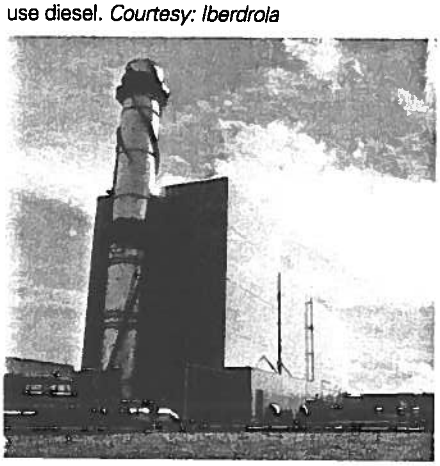
Spain began subsidizing renewable and combined heat and power sources after the adoption of its Electric Power Act in 1997. In 2004, a new law allowed renewable power generators to choose between a regulated tariff or a market price plus premium. And in 2007—after the EU established a target for member countries to source 20% of their power from renewables by 2020—another law set high and low electricity purchase price levels for some technologies.

The level of public financial support and total revenues per kilowatt-hour varied significantly. In 2008, for example, wind generators received €0.069 to €0.086/kWh ($0.10 to $0.12/kWh), while solar PV producers got almost quadruple that: €0.32/kWh. This subsidy mechanism, the so-called "feed-in tariff," was guaranteed for 25 years, or for the lifetimes of the systems, to increase investor confidence.

And it worked. Generous subsidies rapidly boosted PV development in Spain. By the end of 2008—just as the economic crisis hit the country—solar PV capacity had exceeded the initial capacity target for 2010 more than eightfold.

After the onset of the financial crisis, the price of electricity from new PV projects was lowered to €0.259/kWh from €0.440/kWh, reports The Global Subsidies Initiative (GSI), an international watchdog that monitors "the transfer of public money to private interests."

4. Gas-guzzling. Since 2000, gas-fired generation has grown by 101 TWh, driven by requirements for fast capacity increases, wind power backup, and Europe's cap-and-trade program. Today, combined-cycle gas turbines (CCGT) have an installed capacity of 26.8 GW—more than any other fuel source in Spain. This image shows HC Energía's Castejón CCGT Plant in Navarre. The 2002-built Unit 1 has a capacity of 424.9 MW; the 418.5-MW Unit 3 started commercial activity in January 2008. Should the supply of natural gas be interrupted, Castejón 3 can also use diesel. *Courtesy: Iberdrola*



By comparison, the market price for electricity from natural gas, for example, has been under €0.045/kWh. According to the GSI, in 2009, solar PV tariffs alone amounted to €2.7 billion, though the sector supplied only 2% of Spain's electricity. GSI points out that wind producers received €600 million for supplying 12% of the country's power.

Another critical problem with Spain's feed-in tariff system is that instead of allowing utilities to charge more for renewable power bought at above-market prices (and letting consumers bear the brunt of the hikes), the nation has preferred to keep the price of power artificially low. That means that utilities have shouldered the burden, operating at a loss and trusting in a government guarantee to eventually pay them back. Sources say the sum of this "tariff deficit" has ballooned to more than €16.5 billion since 2000.

Then, last year, faced with an economic crisis and buckling under an overall burden of debt, Madrid drastically cut spending and implemented austerity measures that included slashing renewable subsidies. On Christmas Eve, the Industry Ministry announced it would slash PV solar subsidies between 10% and 30% for existing projects until 2014—or €3 billion over the next three years.

PV backers, including foreign private equity groups and specialist funds, are outraged by the possibility that cuts will be imposed retroactively (on plants built before 2008). Filing lawsuits, they say government's "sudden reversal in policy" breaches long-term contracts, and it could drive many of them out of business. Legal challenges have already been filed by the regional authorities of Extremadura, Murcia, Navarra, and Valencia; at least 15 international investors, who have pumped more than €4 billion into Spanish solar PV projects, are also seeking reparations.

European Commissioners Guenther Oettinger (for energy) and Connie Hedegaard (for climate) have also chimed in about the cuts ordained by Royal Decree 14/2010 and approved by the lower parliament earlier this year. They warned that "forward-looking changes [to tariffs] may be understandable and necessary," but that the European Commission "will not accept retroactive amendments." Further, they argue, the nation's cap on the number of production hours when solar generators can earn above-market rates adds to a perceived risk of investing in renewables. "Without stability and predictability, there will be more risk of delays," the commissioners wrote to Industry Minister Miguel Sebastian on Feb. 22. "You must not forget that the negative consequences for investors' confidence from retroactive changes in the economic conditions of one type of renewable facility may spread and produce similar effects for other types of facility in other countries."

In March, Industry Minister Miguel Sebastian promised PV investors his department would "find solutions to prevent irreparable damages" to the sector. Key participants are hopeful: In July last year, the government managed to reach an agreement with the wind power sector under which it would cut top-up rates to wind producers by 35% until 2013—a measure that could save it €1.3 billion.

In the last week of March, Reuters reported that Spanish energy regulator Comision Nacional de Energia (CNE) had suspended subsidies for 350 PV systems alleged to have been providing fraudulent power production figures. PV Tech quoted the Spanish Renewable Producers Association as saying that owners of as many as 9,000 of Spain's 55,000 registered PV systems could be questioned (most, for technical issues dealing with registration, it claimed). CNE had drafted a bill to prevent solar fraud in January 2009 after some plants were exposed for receiving subsidies without actually generating power.

Coal Use Contracts, Natural Gas Use Expands

The rise of renewables in Spain has increased natural gas use and, as expected, constricted coal use. Spain—a once-thriving coal exporter—in recent decades has turned to importing nearly 73% of its supplies, mostly from South Africa, but also from Indonesia and Russia. About 90% of all coal is used to generate electricity, producing 25,851 GWh—or about 9% of total generation. This compares with 74 TWh of coal-fired power produced in 2007, which made up almost 24.8% of total generation.

Coal use, as frequently explained by industry analysts, has been affected by pollution requirements and competition with natural gas. Electricity industry association UNESA claims that coal-fired power plants in Spain have an average efficiency of 37% and emit 930 kg of carbon dioxide/MWh, whereas combined-cycle gas turbines are 52% efficient and emit 365 kg of the greenhouse gas per MWh. That makes coal generation expensive to operate under the EU's cap-and-trade program. Other reasons for the drop are that coal plant operators have had to take plants offline to abide by increasingly rigid EU directives, and the operation of coal plants that are used to supplement hydro is dependent on hydrological conditions.

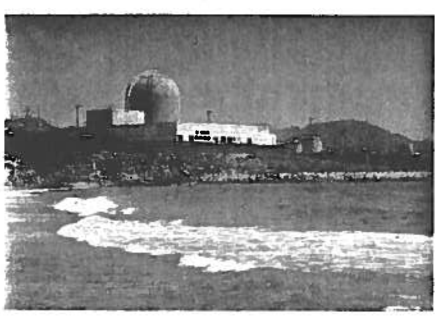
This is not to say that the sector will disappear altogether. Spain's Prime Minister José Luis Rodríguez Zapatero, who comes from the coal heartland of León, in October 2010 won the European Commission's approval to subsidize—but only until 2015—utilities that are operating coal-fired power plants in return for their use of Spanish coal rather than imported coal, which is more affordable and of higher quality. Zapatero was looking to cushion conditions for tens of thousands of workers in coal mines, who have been protesting nonpayment, but as he told the commission, coal is also necessary to protect the country from power supply shocks caused by intermittent generation.

Spain's government is also pouring public funding into several cleaner coal technologies. In October 2010, energy firm ELCOGAS started capturing carbon dioxide from a 14-MW pilot plant built at its 335-MW integrated gasification combined-cycle (IGCC) facility at Puertollano. The Puertollano IGCC plant some 200 km south of Madrid—which began commercial operation in 1996 with natural gas and in 1998 with syngas from gasification of an equal mixture of local coal (with an ash content of more than 40%) and high-sulfur petcoke—is one of only five utility-scale IGCC facilities in the world.

Also under way is the much-watched Integrated Carbon Capture and Sequestration Technology Development Plant under construction at Endesa's Compostilla power plant in Ponferrada. The Spanish utility is collaborating with research institution CIUDEN to set up a 30-MWth Foster Wheeler–built circulating fluidized bed unit and test Foster Wheeler's Flexi-Burn carbon capture technology. The unit, which will test burn a wide range of domestic (mostly anthracite) and imported coals—as well as biomass—is expected to start operations by the second half of 2011. Testing programs are expected to follow thereafter.

Natural gas, on the other hand, has become the most significant component of Spain's power profile. The amount of gas consumed for power generation depends on the availability of wind and hydropower. In 2010, 68,828 GWh were generated by combined-cycle gas turbines (CCGT)—23% of total generation (Figure 4). CCGT installed capacity surged nearly 10% from 2009 to 2010. However, Spain imports more than 99% of its gas, mostly from Algeria, Nigeria, and Qatar.

5. No new nuclear. Spain has no plans to build new nuclear plants. Since the Fukushima Daiichi emergency, license renewals for plants like Santa Maria de Garoña, the oldest in Spain's fleet, have been criticized. Spain's newest reactor is the 1,045-MW Vandellos 2 (shown here), built in 1988 near Tarragona in northeastern Spain. *Courtesy: Foro Nuclear*



Phasing Out Nuclear

Spain's eight nuclear reactors—accounting for a total installed capacity of 7.7 GW—produce a fifth of the nation's power. The sector got its start in June 1965, when construction began on the country's first nuclear plant, the Jose Cabrera Zorita, a pressurized water reactor. In 1971, the 460-MW Santa Maria de Garoña, a boiling water reactor (BWR), began commercial operation, followed two years later by the 500-MW Vandellos-1, a gas-cooled reactor. All three plants were turnkey projects.

In the 1970s, construction began on seven reactors, but just five were completed. Construction of five other plants began in the 1980s, but only two were completed (Trillo-1 and Vandellos-2) after the socialist government imposed a moratorium on new nuclear in 1983, citing economic reasons. In 1994, after the Minister of Industry and Energy proposed a plan in which alternative energy would phase out nuclear—and vowed to shut down older plants when they reached the end of their 40-year lifetimes—five other units under construction were abandoned.

Spain is planning to add 810 MW of nuclear capacity through uprates. The Iberdrola-owned Confrenetes BWR that came online in 1985 has been uprated four times, taking it to 1,063 MW or 112% of its original capacity. Plans to be implemented later this decade will increase the plant's power to 120% of original capacity. In March—just a day before workers began their long struggle to cool the quake-stricken Fukushima Daiichi reactors in Japan—the Spanish government recommended a 10-year extension for the operating license of the Confrenetes plant. In February, Spain's parliament removed a legal provision limiting nuclear plant lives to 40 years. It remains opposed to new construction, however.

Since Fukushima, the government is reviewing key renewal decisions, such as the highly controversial 2009 decision by the Nuclear Safety Council (CSN) to renew an operating license for the country's oldest plant, the Santa Maria de Garoña. The government had already shut down Vandellos-1, the gas-graphite reactor, in the mid-1990s, after a turbine fire made the plant uneconomic to repair, and Jose Cabrera in 2006, after it reached its 40-year limit. Although CSN said plant owner and operator Nuclenor had implemented a €155 million work program to keep the 40-year Santa Maria de Garoña serviceable, the current socialist government—which campaigned on an anti-nuclear platform—forced the regulatory body to grant it only a four-year, rather than a 10-year, license, taking it to 2013.

Several reactors' licenses have been approved since then, including Almaraz 1 and 2, and the 1,045-MW Vandellos 2, the newest and largest plant of Spain's fleet (Figure 5). In response to recent pressures to shut down Garoña, CNE's Antonio Cornado told Agence France Presse that the question was "not if Fukushima is similar to Garona" but whether Japan had the same seismic or tsunami risks as Spain. "The answer is 'no,'" he said.

Spain's uranium resources are limited to Salamanca, where the metal was mined from 1974 to 2000, when activities trickled to a close due to low uranium prices. According to the World Nuclear Association, most of the 1,600 metric tons of uranium used in Spain each year are imported from Niger.

Currently, the country stores some 6,000 metric tons of spent fuel at reactor sites. Though it has no reprocessing plans, the government has called for construction of temporary dry storage facilities at the Trillo nuclear plant and at the now-closed Jose Cabrera plant, until a longer-term storage facility can be established. Two options are being considered for longer-term storage: the preferred, centralized nuclear spent fuel and high-level waste storage facility (whose site selection began in December 2009) and a deep geological facility. Nuclear waste management strategies, funded by a 1% tax on nuclear power revenues, also include research on extended onsite storage conditions and advanced recycling options.

Balancing Renewables on the Grid

Spain's management of its transmission system has blazed a trail for countries looking for examples of how to balance a national grid that is fed by a large amount of renewable generation. The variability of wind generation in particular—which made up 15% of the nation's power profile in 2010—keeps grid operator REE precariously balancing load. The challenge has recently become riskier: REE in 2004 warned that trying to integrate more than 14% of wind power could significantly increase the possibilities of a major power cut.

One way REE says it manages large amounts of renewable power is through its Renewable Energies Control Centre (CECRE). Opened in 2007, that pioneering operational unit within the REE Power Control Centre is used to supervise and control sources of intermittent generation. Every 12

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seconds, CECRE analyzes connectivity and wind speed from all wind farms rated at 10 MW or more and uses that data to calculate wind-powered generation levels. It also assesses the real-time risk of a sudden loss of or surge in wind power.

Still, every day brings new challenges. On Nov. 9, 2009, for example, Spain's wind farms generated record power—315,258 MWh—enough to meet 43% of demand (at around 2 a.m.). Earlier, on June 26, at 10:32 a.m., wind farms barely covered 1%. Intense fluctuations are dealt with by using pumped storage plants as much as possible while switching off CCGT plants on a daily basis.

"Spanish legislation gives priority to renewable energies when it is possible and secure," María Pachón, REE spokesperson, told *POWER* in March. "Red Eléctricas' role consists just of putting into practice [the Industry Ministry's political] decisions under secure conditions." Solutions being considered in the near term include international interconnections, using surplus wind for pumped storage, and, in the long term, charging electric vehicle batteries.

Meanwhile, Spain is pressing on with plans to build new transmission links. Currently, the grid is divided into primary (at least 380 kV) and secondary (220 kV to 380 kV) transmission networks composed of over 35,797 kilometers of transmission lines and more than 3,000 substations. It also has, through the 2007-created integrated Iberian electricity market (MIBEL), interconnections with France, Portugal, Morocco, and Andorra, equal to some 5% of generating capacity. The Energy Infrastructure Investment Plan (2008–2016) calls for projects developing the 220-kV and 400-kV networks, including a high-voltage power link between the mainland and the Balearic Islands and reinforcing international links with France and Portugal (with whom Spain plans to exchange, at minimum, 3,000 MW).

Key Challenges Remain

Spain must monitor and resolve the key challenges posed by the large, rapid development of renewables—striving, above all, to "balance objectives of environment, competitiveness, security of supply and efficiency in its policy formulation," says the IEA in a 2009 country analysis.

It should also end a mechanism that uses capacity payments as a substitute for market-based incentives to build new generation capacity because it tends to lead to inefficient investment decisions, the agency says. These payments provide participants with the "perverse incentive of withholding their plans for new capacity in order to receive the payment," and are "complex" to administer. Another critical needed improvement is to increase retail prices and resolve government-incurred tariff deficits of up to €16 billion.

The country's emphasis on the long-term integration of renewable power is commendable, the IEA said, but it is crucial that the nation establish clearer policies regarding other sources, such as nuclear. It also must ensure a streamlined and transparent siting and permitting process that includes interconnection to the grid for renewable developers.

Another concern is that the nation has not adequately assessed the need to build and operate backup capacity to compensate for the unavailability of intermittent renewable sources. CCGTs were and will continue to be the best option for peak-load supply and backup capacity, but they increase greenhouse gas emissions and raise security-of-supply issues owing to the volatility of international gas markets.

"Uncertain policies are bound to affect the investment climate," the IEA concluded. ■

***—Sonal Patel** is POWER's senior writer.*

Using Fossil-Fueled Generation to Accelerate the Deployment of Renewables

It may seem counterintuitive, but the strategic coupling of simple- and combined-cycle technologies with renewable generation could establish the conditions necessary for adding more renewable megawatts to transmission grids around the world.

By Dr. Justin Zachary, Bechtel Power Corp.

Xcel Energy's coal-fired Cameo Station in southern Colorado ran a pilot program from July 2010 to Dec. 2010 that integrated concentrating solar generation until the Cameo plant was retired at the end of 2010. A parabolic trough solar field provided thermal energy to produce supplemental steam for power generation in order to decrease overall coal consumption, reduce emissions, improve plant efficiency, and test the commercial viability of concentrating solar integration. *Courtesy: Xcel Energy*

Although many nations and most U.S. states have goals for increasing the percentage of electricity generated by renewable energy, meeting those goals means facing several challenges. In particular, the variable nature of wind and solar power creates difficulties for grid stability, especially as the percentage of variable power increases. The large penetration of wind power in some parts of the U.S., for example, affects the existing grid in terms of system capacity, harmonics, safety, and protection.

Fortunately, two separate but related technologies are already being developed and deployed to help resolve these problems: a "smart grid" and fast-start gas-fired generation. The use of these technologies could facilitate the deployment of more renewable generation and help states and countries meet their renewable portfolio goals.

However, questions remain. How will new generation assets influence the back-up power demand and its daily profile? How well will the design of the new conventional plants currently at the planning stage in the U.S. (mostly combined-cycle plants) cope with rapid changes in demand due to the ever-increasing penetration of renewable power? [Editor's note: For more on this issu, see the top story in this issue's Global Monitor.] Will anticipated CO_2 capture and sequestration legislation require these facilities to develop higher efficiency and reduce their carbon footprint? Will smart grid initiatives change the way gas turbine loading is done? This article attempts to answer these questions and offer solutions for integrating renewable sources with conventional fossil-fueled plants.

Currently, all of the major equipment suppliers are offering solutions for these problems based on their specific gas turbine technologies and capabilities. However, contradictory requirements for maintaining high efficiency and emissions at part load, uncertainty about CO_2 capture legislation, and difficulties in financing projects that employ innovative solutions make the process complex and highly challenging—not only for original equipment manufacturers (OEMs), but also for project developers and engineering, procurement, and construction contractors.

What the Grid Wants—and What It Gets

Electric utilities and grid operators would like renewable energy sources to behave as conventional, dispatchable power plants. For example, they would like to see a constant level of voltage from wind and solar plants. But wind farms and solar power plants require reactive compensation. In fact, rigorous reactive compensation standards are likely to become a reality for renewable energy power plants in North America, Europe, and Asia. An example is the recent "Interconnection Standards Initiative Draft Straw Proposal" set forth by the California Independent System Operator in the spring of 2010.

Meanwhile, solar power plants are being asked to meet power factor constraints, provide voltage control, and follow low- and high-voltage ride-through requirements. Renewable energy power plants, particularly solar plants, also must be able to provide day-to-day voltage support to maintain smooth and stable system voltages, even if the plant's power output varies due to clouds, insufficient wind speed, or other factors during the course of the day.

It is imperative that renewable sources remain connected to the grid when they are most needed, particularly during power system disturbances, to help the grid recover.

Wind Power Variability. Because wind resources shift suddenly and dramatically, wind farms do not operate all the time; therefore, additional capacity is needed when they are not producing power, and differences between forecast and actual production have to be balanced.

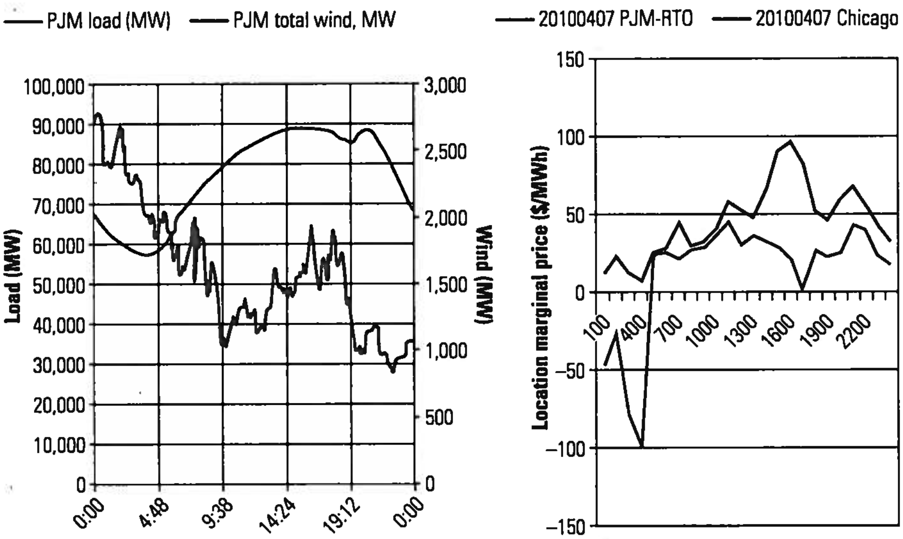
Balancing and backup come at a cost, as does building new transmission infrastructure. These facts apply to wind energy just as they apply to other power-producing technologies that are integrated into electricity grids.

And although a wind turbine's output is more variable and less predictable than that of conventional generation technologies, from a system operations perspective, the output of a single wind farm is just as irrelevant as the demand of a single consumer. The real challenge is matching the simultaneous collective demand of all customers with the entire available production from all sources. That has been the guiding principle of grid operation since its inception and will remain so regardless of which technologies are used.

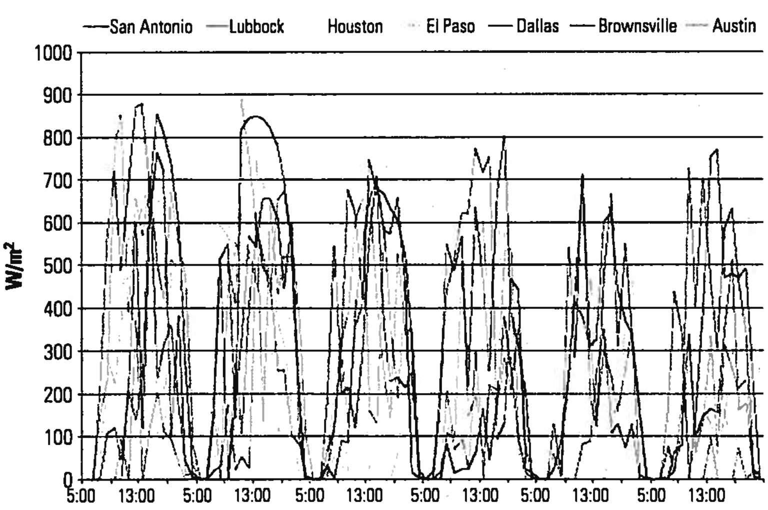
That said, wind power is different from other power technologies, and integrating large amounts of it into the existing power system is a challenge. Here are some of the reasons:

- According to the Electric Reliability Council of Texas, less than 10% of total wind capacity is counted as being "available" during peak summer days.
- The PJM Interconnection regional transmission organization credits wind with about 13% capacity factor during peak periods. PJM coordinates the movement of wholesale electricity in all or parts of 13 states and the District of Columbia.
- Midwest ISO operators curtail thousands of megawatts of wind daily; 1,800-MW swings over hourly periods are common.

1. Mismatch. In this example from grid operator PJM, during peak load demand, wind production is close to its minimum. The economic impact is evident in the graph on the right, which shows that the premium price for power occurs when wind production is lower. *Source: PJM*



2. Sun and shade. This chart shows a five-day period in the summer for several locations across Texas, a span that includes clear periods and periods with intermitten sunshine. Night hours have been omitted. Hourly data is from Aug. 10 through Aug. 15, 2005 and was derived from the 1991–2005 National Solar Radiation Data Base. El Paso data has been adjusted from its local Mountain time zone to coincide temporarily with the Central time zone. *Source: Texas State Energy Conservation Office*



Without energy storage or fossil-fuel backup, integrating large quantities of wind power is difficult. Figure 1 provides one example of the discrepancies between wind power generation and demand.

Solar Power Variability. Figure 2 presents a dramatic illustration of the intermittent nature of solar photovoltaic (PV) power. It is important to evaluate not only the rate of change in generation, but also its magnitude. In seconds, the system can go from full output to 20% output and back again. At higher levels of PV penetration, such variability will significantly affect grid operation and power factor.

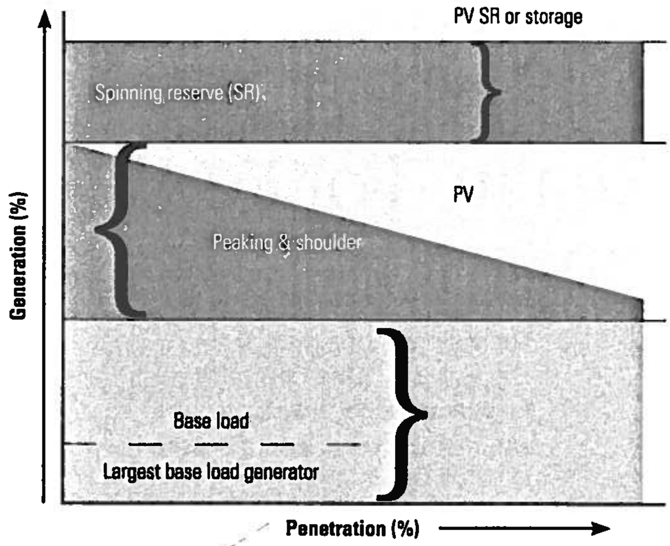
For direct electrical power generation renewable technologies such as wind and solar PV, there is no way at present to match grid demand. Though some forms of energy storage exist for solar thermal (molten salt is one example), only conventional fossil-fueled generation systems can cover the gap for other solar and wind generation.

The remainder of this article looks at technologies for bridging that gap and the design and operation considerations they raise.

The Smart Grid Part of the Solution

A smart grid differs from a conventional grid in that it is able to apply digital control to electricity supply and demand. A smart grid uses the analysis of vast amounts of data plus two-way digital communication to optimize the delivery of electricity from suppliers to consumers and, in some cases, to control demand at consumers' homes or businesses. The ability to remotely fine-tune power generation

3. Solar backup. This scenario from a DOE study shows that as solar photovoltaic generation accounts for an increasing percentage of total generation, the need for spinning reserve or storage also increases. *Source: DOE*



and delivery can save energy, reduce costs, and increase reliability and transparency.

A smart grid is made possible by sensing, measurement, and control devices equipped with two-way communications capability that are applied to electricity production, transmission, distribution, and consumption parts of the power grid. Information about grid conditions is communicated to system users, operators, and automated devices, making it possible to dynamically respond to changes in grid condition. For example, automated demand-side management programs can allow system operators to reduce electricity demand during periods of low renewable plant output that would otherwise result in an overall shortage of power on the grid. (To learn more about the smart grid, use the Smart Grid tab at the top of the *POWER* home page at www.powermag.com to view previous articles on the subject.)

A fully developed smart grid includes an intelligent monitoring system that keeps track of all electricity flowing in the system. It is also capable of better integrating conventional and renewable sources of power generation, such as solar and wind. When combined with emerging technologies that are improving the ability of renewable power generators and system operators to predict more accurately, in smaller time increments, the output of wind and solar plants, a smart grid can maximize the benefit of these resources.

As regional and national grids incorporate smart technologies, the grid's new capabilities will affect the behavior of simple-cycle and combined-cycle plants. In combination with larger quantities of renewable generation, the requirements for gas turbines will certainly change:

- The tendency will be to move toward smaller and dispersed plants.
- The type and frequency of cycling operation will be significantly different than is seen today.
- More-frequent cycling will affect component life and plant efficiency and will result in much more stringent environmental emissions at part-load operation.
- A significant reduction in peak load should occur due to better grid management and intermittent renewables, while some baseload resources will see an increase in the percentage of their utilization share.

The Gas-Plus-Renewables Option

As wind and PV capacity increases, these renewable sources are used to meet intermediate and peaking loads. However, during periods when PV or wind generation output is low, additional backup power is needed to ensure that the grid demand is met. Figure 3 illustrates the need for spinning reserves or storage. In the absence of large electrical, thermal, or pumped storage options, providing backup power and maintaining spinning reserve will be a major role of fast-starting and rapid-loading gas turbines.

Gas turbines are particularly well-suited to operate in conjunction with wind and PV sources (see sidebar). Their well-known fast-start and fast-ramping capabilities are better able to meet rapid changes in grid requirements than coal, steam, or nuclear plants. Consequently, until alternative solutions are widely available, there is a real need for manufacturers to adapt gas turbines specifically to compensate for renewable power variability. Grid codes and customers are continuously demanding more operational flexibility, faster starts, and accelerated loading response times.

As a rule of thumb, for each installed 400 MW of wind power, 100 MW of gas-fired backup power is required. Hence, the requirement that gas-fired generation support renewable generation is driving modern power plant design to strongly focus on operational flexibility.

When compared with a continuous baseload regime, gas turbine operation over wide power ranges not only increases fuel consumption but also impacts NO_x and CO emissions. The inability to achieve premix combustion operation at low power levels makes this particular requirement difficult to meet.

The good news, according to a Brattle Group study, is that a wind-plus–gas turbine plant could achieve at least 75% reduction of the maximum possible CO_2 emissions. It is obvious that emissions-free power from wind generation is compensating for some of the conventional fossil-generated power.

The bad news is that the economics of gas turbine operation under these conditions are different than for a conventional standalone gas plant. All parties involved in determining the price of electricity must account for increased costs incurred by the gas turbine power generators. Forcing these facilities to operate at less than full capacity reduces their revenue stream. Cycling operation also affects maintenance schedules and gas turbine availability.

In response to these diverse requirements, OEMs have developed both heavy-duty and aero-derivative gas turbines with greater capability to support a wide range of operational flexibility enhancements, enabling customers to effectively use equipment for peak and cycling applications. The relative ease and speed of installing gas-fired generation also gives it an advantage when it comes to meeting emergent and urgent power demand.

Some features of OEMs' solutions to the new demands on gas technologies are examined below.

Simple-Cycle Developments

All major manufacturers have realized the importance of fast start-up and rapid loading for gas turbines in simple-cycle operation, particularly for installations designed for cycling operation. Current gas turbines can ramp at the rate of 3% per minute (though their efficient operating range is narrow), which is a much higher rate than that of pulverized coal plants. The coal-fired steam cycle exhibits substantial power losses each time a steam turbine is shut down or restarted. Major ramp-downs in under 15 minutes may require wasting (venting) the steam, and major ramp-ups in less than 15 minutes may be impossible.

Here is a short list of published features

Combining Gas and Photovoltaics

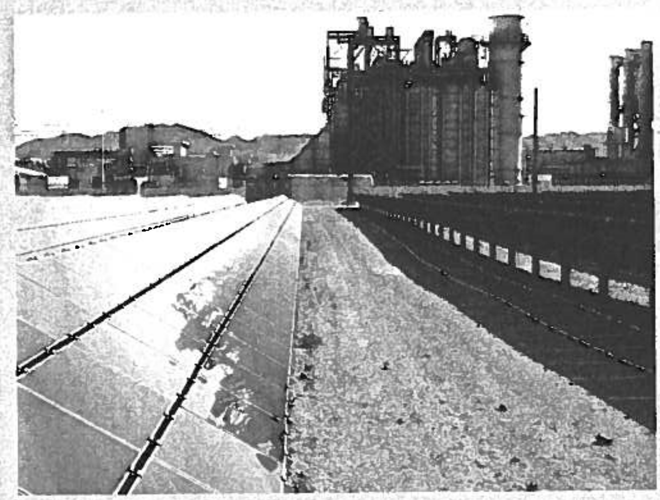
Sempra Generation's El Dorado Energy plant has merged two generation technologies that are flourishing together in the desert south of Las Vegas. Sempra Generation, the unregulated power plant–operating subsidiary of Sempra Energy, sells the output from the 480-MW gas-fired combined-cycle plant into the Southwest power markets.

In 2009, it added ten 1-MW thin-film photovoltaic (PV) power modules arranged on 80 acres adjacent to the plant. The combined PV power is then connected with the main electrical bus of the combined-cycle plant to simplify interconnection with the grid (Figure 4).

The staff of the gas-fired plant have been cross-trained in PV plant operation and maintenance to reduce operating costs and to improve overall plant reliability. A single technician is responsible for managing the PV side of the plant. First Solar, designer and supplier of the PV modules, provides remote monitoring and maintenance as part of the ongoing support contract.

For more information on this unique hybrid plant, see "El Dorado Energy's Solar Facility, Boulder City, Nevada," December 2009, in the *POWER* archives at www.powermag.com.

4. Side by side. A photovoltaic installation shares a grid connection and real estate with the combined-cycle El Dorado Energy plant. *Source: POWER*



of gas turbines in simple-cycle operation that demonstrate this technology's attractiveness for supporting variable renewable generation:

- GE has a 100-MW gas turbine (LMS 100) capable of a 10-minute start for lower-megawatt applications and a recently announced GE-7FA.05 gas turbine, also with 10-minute start-up capabilities. Similar start-up and ramping features are offered by Siemens and Mitsubishi Heavy Industries (MHI).
- Due to a unique sequential combustion design, Alstom turbines' efficiency at part load is higher than others. The same capability of shutting off one combustor at part-load operation offers an additional advantage for operating in this manner: continuous operation at close to 30% of baseload while remaining in compliance with baseload emissions levels.
- An alternative to frame gas turbines are the aero-derivatives. One of the owners of large wind farms (Westar Energy) uses GE's LM6000 gas turbines to meet demand for peak load and to cover for shortfalls in wind farm generation. The LM6000 can reach its full load output from cold start in less than 10 minutes and operate for 1 hour or less. When a number of LM6000 gas turbines are on standby, they can be dispatched immediately and are able to respond to situations when high-speed and wide-ranging wind fronts are cutting wind turbines' production by hundreds of MW.

Combined-Cycle Developments

The real challenge for the industry is to develop capabilities for fast start-up and rapid loading of equipment without affecting its availability and reliability. Cycling operation must be performed without increasing the number of equivalent operating hours or accelerating the maintenance schedule. To that end, here are some of the actions initiated by OEMs:

- Use high-starting-reliability systems for the gas turbine and balance of plant.
- Implement complex control systems capable of providing adequate ramp rates for each specific state of the hardware.
- Employ a high degree of start-up automation for both gas and steam turbine.
- Implement measures aimed at heat retention during shutdowns, such as stack dampers and the use of auxiliary steam.
- Provide sophisticated monitoring systems for major equipment conditions, allowing operators to evaluate the impact of accelerated start-up or cycling operation on component life.
- Allow the gas turbine to rapidly ramp without the constraints of the heat-recovery steam generator (HRSG) and steam turbine.

Table 1. Summary of concentrated solar technologies. *Source: Bechtel Power*

Technology type	Working fluid	Maximum temperature
Tower direct steam	Steam	550C (1,022F)
Tower molten salt	Mixture of salts	575C (1,067F)
Trough	Synthetic oil HTF'	395C (743F)
Linear Fresnel	Steam	270C (518F) or higher

Heat-Recovery Steam Generator. It should be remembered that for CCs, the element requiring the most time to reach baseload is not necessarily the gas turbine. For HRSGs, the most appropriate solution to accelerate the start-up process is the use of the Benson-type high-pressure (HP) circuit. Following are some of the well-known mechanisms affecting the performance and integrity of the HRSG components in cycling operation:

- Low cycle fatigue
- Creep
- Thermal shock
- Oxidation and exfoliation
- Differential expansion
- Corrosion fatigue
- Corrosion in tubes
- Flow-accelerated corrosion (FAC)
- Corrosion product migration
- Deposits
- Erosion

All components in an HRSG are subject to the operating-life-affecting mechanisms listed above. However, some components may be more vulnerable because of their location, construction, or exposure. Critical components in an HRSG generally include these:

- Superheater and reheater outlets
- Tube-to-header joints in hot sections
- Drum to downcomer nozzle in HP drum
- Bent portion of the heat transfer tubes
- Attemperators
- Bypass valves

These need to be designed and monitored more closely for any kind of life-affecting conditions. Solutions offered by OEMs include:

- Designing hot section outlets to minimize side-to-side variation.
- Using full-penetration welds, generating a joint with longer fatigue life.
- Limiting the use of dissimilar materials.
- Designing an adequate draining system aimed at reducing quenching effect.
- Employing various methods to keep the drums warm during shutdowns.
- Equipping the stack with a stack damper.
- Using special alloys to mitigate the exposure of critical components to FAC.
- Including special features such cascading bypass to minimize thermal shock during start-up.

Steam Turbine. Design and operability improvements in steam turbines in CC operation have allowed overall start-up and turbine rolling to baseload in record times. As mentioned above, new and complex control features and stress measurements for steam turbines permit CCs to respond much faster than before, particularly during hot starts and load-following mode. Without appropriate flexibility for the start-up times of steam turbines, the viability of CC as a power-controlling element for renewables will be significantly reduced.

It should be noted that the most logical solution for this type of application is a 1 x 1 (one gas turbine, one HRSG, one steam turbine generator) arrangement. Other configurations (2 x 1 and 3 x 1) will require larger turbines with a longer start-up time. A modern G or H class gas turbine in a 3 x 1 CC configuration might require a 400-MW to 500-MW steam turbine and therefore be more suitable for baseload operation.

Considering these constraints, the preferred configuration of CCs for renewable back-up power must be selected as a result of detailed feasibility studies combining the start-up curves of all CC components and their control systems.

Integrating Solar and Fossil Generation

An additional role that a CC can play in the deployment of renewable power, specifically solar thermal, is to accept the steam produced by a solar thermal source into its steam cycle. This arrangement is called integrated solar combined cycle (ISCC). By including an additional source of heat, such as solar energy, the efficiency of the system is dramatically increased. Annual electricity production is increased because the steam turbine is already in operation, avoiding lost time for start-up. During solar operation, the steam

Controls and Transient Behavior in Hybrid Plants

As noted earlier, any contractor involved in the design of large cogeneration plants will understand how to deal with complex integration and control issues. However, cogeneration plants are not usually faced with the degree of variability that comes with the integration of solar technology.

Due to the variability of the steam conditions from the solar source, any hybrid configuration needs to be evaluated to assess the impact of changes in steam supply on the behavior of the conventional generation facility. Therefore, the transient behavior of the entire system, including the solar steam source and power plant, should be modeled in the early plant design stage.

The complex issues associated with proper transient representation of different types of equipment and their controls must be developed using computer simulation programs. The aim of such studies is to create a representative transient, integrated system capable of predicting steam temperature and pressure variations during steady-state and transient conditions. Finally, the complete system has to be optimized based on not only operational considerations, but also cost.

produced by the solar heat source offsets the loss of power typical for a CC when the ambient temperature is higher.

Hybrids involving conventional coal-fired plants are also possible in regions with reasonably good solar conditions, as was the case for Xcel Energy's Cameo Generating Station in southern Colorado, pictured at the top of this article. For these plants, where the steam pressures and temperatures are higher than for ISCC, the type of solar conversion technology used (linear Fresnel, parabolic trough, or tower) will dictate how solar is integrated into the plant. Table 1 summarizes the types of technology and their thermal output.

When planning to integrate steam generated by solar energy into a CC, several questions must be answered. What solar technology should be used? How much solar energy should be integrated into the CC? Where is the best place in the steam cycle to inject the solar-generated steam? Unfortunately, there are no simple answers to these questions. A detailed economic analysis must be performed to determine the levelized cost of electricity for the specific site under consideration. This analysis must look at different MW thermal solar inputs to the CC and different solar technologies that generate differing steam conditions.

How to integrate steam generated by a solar technology obviously depends in large part on the steam conditions that can be generated by that technology. One must remember that all power generated in the steam cycle of a CC is "free" from a fuel perspective. In other words, steam cycle power is generated without burning any additional fuel (all steam cycle power is generated based on the energy provided in the gas turbine exhaust gases). Thus, one must be careful to not just substitute the free energy from solar power for the free energy in the gas turbine exhaust gases. When integrating solar into the steam cycle of a CC, it is important to try to maximize the use of both sources of free energy.

Next we look at how various solar technologies can be integrated into CC power plants. Because technologies are evolving and improving, each technology has been categorized based on fluid temperature capability: High temperature is >500C/>932F); medium temperature is 400C/752F; low temperature is 250C–300C/482F–572F. Medium-temperature technology is presented first, as it is the most proven technology.

Medium-Temperature Solar Technology. The most common medium-temperature solar technology is the parabolic trough. Studies have indicated that, for parabolic trough systems that can generate steam up to ~380C, it is best to generate saturated high-pressure (HP) steam to mix with the saturated steam generated in the HRSG HP drum. Integrating HP saturated steam into an HRSG is very common in integrated gasification combined-cycle plants.

Solar thermal input to an ISCC can also be used to reduce the plant's fuel consumption. Reducing gas turbine fuel consumption also reduces gas turbine power and exhaust energy. For the same plant net output with 100 MWth of solar energy input, plant fuel consumption is reduced by ~8%.

High-Temperature Solar Technology. Solar tower systems can generate superheated steam at high pressure and up to 545C. These conditions allow admission of solar-generated superheated steam directly into the HP steam line to the steam turbine. In addition, steam can be reheated in the power tower much as it is in the HRSG. This minimizes impact on the HRSG, because superheating and reheating of solar steam take place in the solar boiler.

Low-Temperature Solar Technology. Most linear Fresnel systems fall into this category. These systems generate saturated steam at up to 270C/55 bar (518F/800 psia). (More recently, the technology has been enhanced to reach higher temperatures.) This pressure is too low to allow integration of the steam cycle into the HP system. Basically, two options exist:

- Generate saturated steam at ~30 bar (435 psia) and admit to the cold reheat line.
- Generate steam at ~5 bar (73 psia) and admit to the low-pressure steam admission line.

As with the other solar systems, taking the feedwater supply from the optimum location in the steam cycle is of great importance to maximizing system efficiency. At the same time, low-temperature systems allow less flexibility in selecting the feedwater takeoff point, because the takeoff temperature must be below the saturation temperature of the steam being generated.

Pairing Fuels

An increasing number of states and countries mandate that a portion of new generation must be renewable. In the absence of adequate storage solutions, the energy generated by wind or solar typically has to be absorbed into the grid regardless of load demand.

Predicting the output of renewable generation in time to allow grid operators to adjust to sudden losses of many megawatts could be a daunting task—at least until a fully functional smart grid is in place. Another way to compensate for shortfalls in power and maintain grid stability is to use gas turbines in simple- or combined-cycle operation.

OEMs have introduced many creative solutions to allow fast start-up and operation at part load without affecting equipment availability and reliability. Large frame industrial turbines and, in particular, aero-derivatives—with their rapid output rate increase—are suitable options for maintaining grid stability and meeting customer demands for power. ISCC also offers a solution in that the steam output of solar thermal plants could be combined with that of conventional gas-fired units, typically resulting in lower fuel consumption and lower capital costs than a standalone solar plant.

As the renewable power generation portfolio continues to grow, so too will the role of the gas turbine industry. ■

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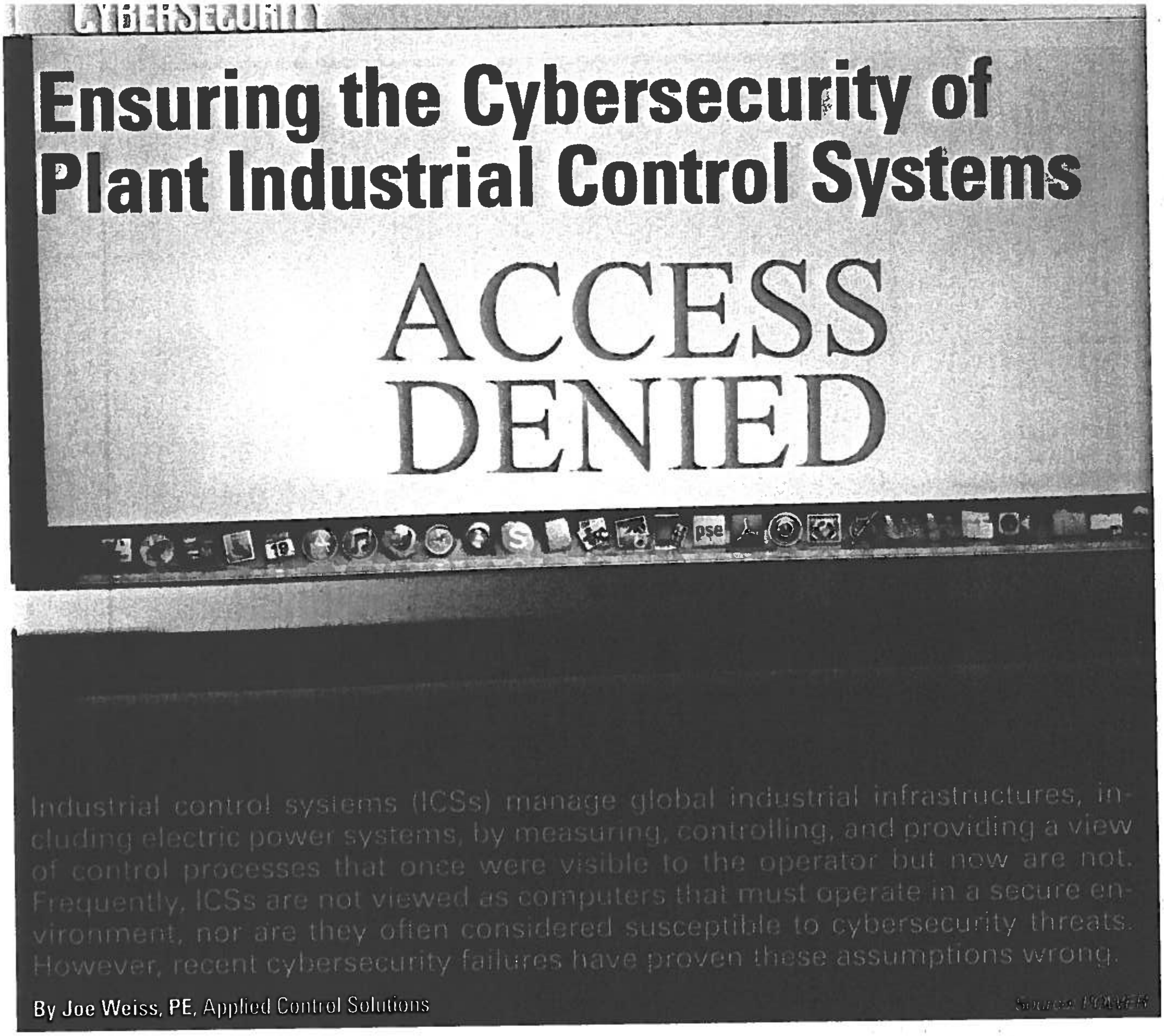
Ensuring the Cybersecurity of Plant Industrial Control Systems



Industrial control systems (ICSs) manage global industrial infrastructures, including electric power systems, by measuring, controlling, and providing a view of control processes that once were visible to the operator but now are not. Frequently, ICSs are not viewed as computers that must operate in a secure environment, nor are they often considered susceptible to cybersecurity threats. However, recent cybersecurity failures have proven these assumptions wrong.

By Joe Weiss, PE, Applied Control Solutions

Source: POWER

Industrial control systems (ICSs) are commonly used throughout global industrial infrastructures. The fundamental reason for securing ICSs is to maintain the mission of the systems, be it to produce or deliver electricity, make or distribute gasoline, provide clean water, or enable other vital societal functions. We may not be able to fully electronically secure ICSs from every possible vulnerability. However, we can make them much more secure than they are today.

Secure ICSs will minimize the possibility of unintentional incidents like those that have already cost hundreds of millions of dollars in damages and taken a number of lives. The three case studies discussed later in this article demonstrate the difficulties of designing a cyber secure environment for ICSs.

What Are ICSs?

ICS networks and workstations, including the human-machine interface (HMI), are generally similar to information technology (IT) systems and may be susceptible to standard IT vulnerabilities and threats. Consequently, IT security technologies and traditional IT education and training processes apply. But that's not all. Field instrumentation and controllers generally do not use commercial off-the-shelf operating systems and are computer resource constrained. They often use proprietary, real-time operating systems or embedded processors. These systems have different operating requirements and can be impacted by cyber vulnerabilities typical of IT systems as well as cyber vulnerabilities unique to ICSs (Figure 1).

Infrastructure owners continue to upgrade their ICSs with advanced communication capabilities and network connections to improve process efficiency, productivity, regulatory compliance, and safety. This networking can be within a facility or even between facilities that are continents apart. Regardless, with increased system complexity comes greater system vulnerability, and few qualified experts have a holistic view of the complete system. When an ICS does not operate properly, the results can range from inconsequential to catastrophic.

Securing ICS and IT Systems

A properly secured industrial system requires one part physical security, one part

Cyber Wars: Stories from the Front Lines

Join other control system users and cybersecurity experts as they discuss recent events and intriguing case histories at the 12th annual Industrial Control System Cyber Security Conference—hosted by the Virginia Modeling, Analysis, and Simulation Center—in Norfolk, Va., starting October 22, 2012. For more information, visit www.icscybersecurityconference.com.

IT security, and one part ICS security to properly function. Physical security is generally well-understood and is often addressed by experts coming from the military or law enforcement. IT security typically deals with commercial off-the-shelf hardware and software and connections to the Internet, with experts coming from IT and the military. ICS security, in contrast, is an engineering problem requiring engineering solutions. Resilience and robustness are the critical factors in the survivability of compromised ICSs.

ICS security requires a balanced approach to technology design; product development and testing; development and application of appropriate ICS policies and procedures; analysis of intentional and unintentional security threats; and proactive management of communications across view, command and control, monitoring, and safety. It entails a lifecycle process, beginning with conceptual design and ending with retirement of the systems. In other words, ICS security is not only more difficult to design than physical and IT security, but it also requires an added level of expertise not usually held by physical and IT security experts.

The triad of confidentiality, integrity, and availability (CIA) effectively defines the attributes needed for securing systems. In the IT domain, cyber attacks often focus on the acquisition of proprietary information. Consequently, confidentiality is the most important attribute, which usually dictates that encryption is required.

However, in the ICS domain, cyber attacks tend to focus on the destabilization of assets. Moreover, most ICS cyber incidents are unintentional and often occur because of a lack of effective message integrity and/or appropriate ICS security policies. Consequently, integrity and availability are much more important than confidentiality in ICSs, which lessens the importance of encryption and significantly raises the importance of authentication and message integrity. That is why ICS security research and education should focus on technologies that address integrity and availability over confidentiality.

Differences Between IT and ICS Systems

Cybersecurity in the U.S. is generally viewed in the context of traditional business IT systems and Department of Defense systems. IT systems are "best effort" in that they complete the task when they get the task completed. Unlike IT systems, ICSs are not general-purpose systems and components but are designed for specific applications. The ICS design criteria are performance and safety, not security. ICS systems are "deterministic" in that they must do their jobs immediately; they cannot wait, because later is too late.

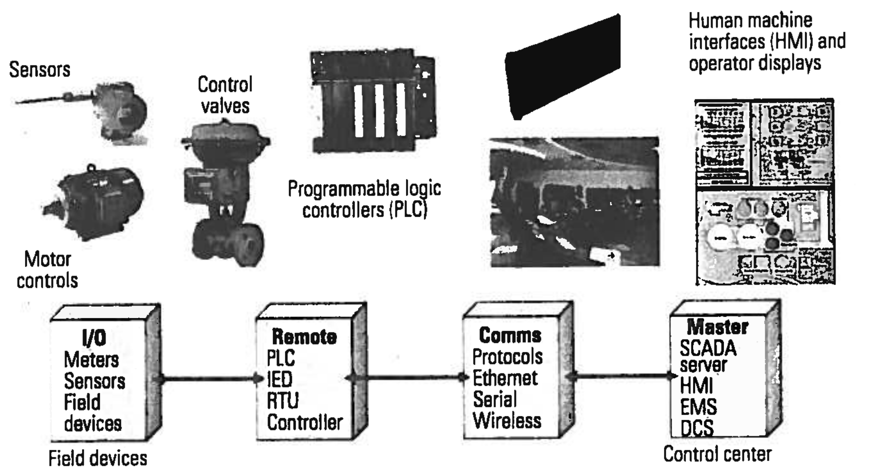
Legacy ICSs were not designed to be secured or easily updated. Nor were they designed to enable efficient security troubleshooting, self-diagnostics, and network logging. A security—not a design or safety—flaw was exploited by the Stuxnet virus. (Enter "Stuxnet" in the search box at www.powermag.com for POWERnews coverage of related events.) The same flaw exploited by Stuxnet is inherent in all of the programmable logic controller (PLC) designs and cannot be easily fixed. It was never a problem because it did not affect performance or safety. This leads to a double negative conundrum for the IT security practitioner: When it comes to security, control systems don't do what they weren't designed to do.

The table compares key characteristics of business IT systems and ICSs. These differences can have very dramatic impacts on ICS operation and education.

Unfortunately, the distinctions between IT systems and ICSs are not recognized by regulators and politicians, and the consequences of this are grave. The smart grid initiative is already providing real case histories of what happens when those without an understanding of the operational domain try to set the rules for systems they do not understand.

The smart grid today is actually two domains "bolted together." The first is the "smart home," including smart meters and (in some cases) home area networks. This is where the majority of smart grid security efforts are being focused by industry and the National Institute of Standards and Technology smart grid program. The second piece is the electric grid and power plants. There is significantly less research and investment focused on these critical facilities.

1. Control system basics. This diagram shows the different aspects of an ICS using a Windows-based workstation with secure field elements but with generally little to no security in the overall control system. *Source: Applied Control Solutions*



Comparison of typical IT system and ICS characteristics. *Source: Applied Control Solutions*

Attribute	Information technology	Industrial control systems
Confidentiality (privacy)	High	Low
Message integrity	Low–medium	Very high
Availability	Medium	Very high
Authentication	Medium–high	High
Time criticality	Delays tolerated	Critical
Security skills/awareness	Usually good	Usually poor
Security education	Good	Usually poor
Engineering education	Usually none	Required
Certification	Certified Information Systems Security Professional (CISSP)	Professional Engineer (PE)
Life cycle	3–5 years	15–25 years
Forensics	Available	Minimal
Impacts	Business impacts	Business impacts, safety, environmental

The Need for ICS Experts

Figure 2 characterizes the relationship of the different types of special technical skills and certifications needed for ICS cybersecurity expertise and the relative quantities of each at work in the industry today. Most people now becoming involved with ICS cybersecurity typically come from a mainstream IT security background rather than an ICS background. This trend is certainly being accelerated by the smart grid initiatives, where the apparent lines between IT and ICS are blurring. Many of the entities responsible for control system cybersecurity, industry, equipment suppliers, and government personnel do not fully appreciate the difficulties created by this trend.

As can be seen in Figure 2, IT encompasses a large realm, but it does not include control system processes. The arrows indicate that most people coming into the ICS security domain (from academia and the workforce) are coming from an IT background. This needs to change. It does not take "rocket science" to compromise an ICS; however, it does require multiple, specialized skills to adequately protect an ICS while ensuring that it can perform its functions—which is what an ICS security expert does. Arguably, there are fewer than several hundred people worldwide who fit into the tiny dot labeled ICS security experts.

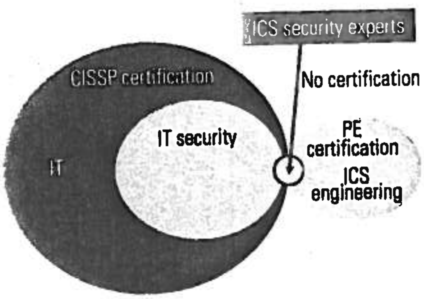
There are many explanations for this imbalance. First, there are simply more trained IT security personnel than ICS security personnel. However, now that some money is available for securing critical infrastructure, that may soon change.

Also, recall the old adage: "To a carpenter, everything looks like a nail." As ICS systems get more of an IT look, IT people view them as IT systems and believe they are qualified to work on ICSs.

Finally, there is often little funding for training ICS personnel in cybersecurity, as plant operations managers often do not view this area as within their purview.

Together, the result is many more IT-trained security personnel than ICS-trained ones. The timing is ripe for the academic community to address the need to educate more ICS technologists, researchers, and real experts.

2. Why so few experts? The number of people with ICS cybersecurity expertise is much smaller than the number of IT experts because the level of expertise required is much higher. *Source: Applied Control Solutions*



Tip of the Iceberg: Industrial Controls and Cybersecurity

Cybersecurity professionals understand that the greatest cyber vulnerability lies with industrial control system (ICS) interfaces within power plants. The first step, in what will surely be a long-term program to minimize these vulnerabilities, is to develop a clear understanding of ICS cybersecurity. This includes clarifying the associated impacts on system reliability and safety—not just the networks.

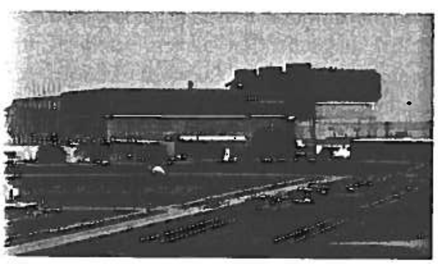
Here are 10 specific tasks that must be addressed before a secure ICS operating environment is achieved:

- Change the culture so that security is considered in the same context as performance and safety. (It is not as critical, but it is as important to consider.)
- Get senior management support, as the process fails without it. Identify the division of responsibilities, budgets, and reporting structure all the way to the board of directors, because cybersecurity is a corporate risk. Recognize that cybersecurity is critical to safe and reliable ICS operation, which translates directly into the corporate bottom line. Incorporate security into executive and employee performance measures. Ensure that appropriate awareness and training is regularly provided to all personnel.
- Mandate effective cybersecurity requirements so this is not a compliance exercise. An effective, living program is critical. Take ICS cybersecurity as seriously as you take enterprise cybersecurity. Secure system elements based on electronic connectivity, not just the size of the facilities or equipment.
- The hardware, software, and firmware that affect cybersecurity are often not identified in any formal system diagrams or vendor documentation, so your first task is to identify and document the complete control system hardware and communication infrastructure. Establish a living configuration management/configuration control program that includes the ICS as well as cybersecurity-specific software (for example, patch versions), hardware (such as network interface cards), and firmware.
- Determine what you really need from the ICSs in terms of functions, features, and communication. This requires obtaining input from throughout the organization, because cybersecurity will affect new systems as well as existing ones.
- Traditional approaches to defining risk probabilities and consequences must be modified. Probability should be 1 (it will happen), and consequences should be based on "design basis threat" (worst case). Risk assessments also require a cost-benefit trade-off between performance/safety and security. This would involve assessing the risk of both security and performance features. It also addresses externalities, including external personnel (such as vendors and contractors), economic conditions, and social concerns.
- Develop ICS-specific policies and procedures. This is what I consider to be one of the most important tasks in the entire process. Recognize that complexity significantly adds security overhead and potential performance/safety impacts. Policies and procedures related to IT and ICS should be consistent. First and foremost, policies must be developed for the specific equipment to be secured but be consistent with how the equipment is operated.
- Make your equipment suppliers and contractors partners in securing your systems. Require detailed documentation of what has been provided and how it has been tested and secured. Do appropriate background checks to ensure that key vendor and contractor personnel, as well as your own critical employees, are competent and vetted (not just "cleared").
- Establish a process for vetting ICS experts rather than using traditional security clearances or IT certifications.
- Consider lifecycle issues. ICSs can be cyber vulnerable from initial design until they are retired or destroyed.

Recognizing the specialized nature of ICS cybersecurity is also necessary to foster needed research and development in the field. The ICS community understands what is required to perform a root-cause analysis of an incident and has developed detailed forensics for physical parameters such as temperature, pressure, level, flow, motor speed, current, and voltage. However, the legacy/field device portions of an ICS have minimal to no cyber forensic capability. This area is ripe for research and development to determine what specific types of forensics are needed and how they would be performed in the most non-invasive manner.

3. High-stress job. Lower Colorado River Authority's Sim Gideon power plant overstressed a steam turbine when an unexpected external signal cycled the steam turbine multiple times. *Courtesy: LCRA*

4. Storm warning. TVA's Browns Ferry Nuclear Plant experienced a "broadcast storm" of too much traffic on its integrated computer systems network that caused a malfunction of the reactor recirculation pumps and, consequently, a Unit 3 shutdown. *Courtesy: TVA*



5. Complex connections. A remote user made changes to software on the company's business local area network that automatically updated Southern Co.'s Hatch Nuclear Plant's operating software, causing Unit 2 to trip offline. *Source: NRC*

ICS Cybersecurity Incidents Have Happened

To date, I have been able to document more than 225 actual control system cyber incidents globally in electric power, water/wastewater, chemicals, pipelines, manufacturing, transportation, and other major infrastructures. Even though most of these incidents were not malicious, they caused considerable problems. Moreover, most of the unintentional events could easily have been instigated maliciously. Impacts of these events range from trivial to significant environmental discharges to significant equipment damage to major electric outages to deaths.

The following three case studies describe ICS cyber incidents that could just as easily have been caused by a system cyber attack (see the sidebar "Tip of the Iceberg").

Fossil Plant Cycling Event. A paper was presented at the 2006 ISA Power Industry Conference in San Jose, Calif., entitled, "Optimizing Turbine Life Cycle Usage and Maximizing Ramp Rate." Its purpose was to demonstrate how the Lower Colorado River Authority and its distributed control system (DCS) supplier were able to increase the ramp rate at the Sim Gideon gas-fired power plant to meet dispatch requirements (Figure 3). (See "Old Plant, New Mission," in the June 2007 issue of *POWER* or in the archives at www.powermag.com.)

This project was motivated by a cyber incident. According to the paper, in April 2004, incorrect dispatching instructions were sent to the unit, and that unit alone carried out all the utility's dispatch obligations for over 3 hours. The unit was ramped back and forth across its full load range at the maximum ramp rate.

The DCS effectively maintained the control variables within constraints. However, the utility's engineering analysis of turbine metal temperatures determined that the rotor was subjected to significant stress. The GE SALI curves indicated that the cyclic life curve corresponding to 1,000 cycles was exceeded three times in that 3-hour period.

The event prompted strong concern about the impact of the fast dispatch on the turbine rotor cyclic life expenditure, so the maximum ramp rate was lowered to 18 MW/min (from 40 MW/min).

The event also uncovered the need for a first line of defense against erroneous dispatch instructions sent electronically to plant control systems that call for the unit to operate out of the design specifications of plant equipment. The reduction in ramp rate impacted the dispatch status of the unit and reduced revenue generation from the ancillary services market. The consequences of this event threatened to permanently damage the steam turbine and the unit's viability to compete in the marketplace in the future with less-than-competitive unit ramp rate.

This unintentional cyber incident could have affected all plants in the region that were being dispatched by the system operator. There were no alarms, as the boiler controls were kept within limits and the steam turbine was not instrumented to alarm when operated outside of its performance envelope.

In this case, the SCADA system was the threat to the plant and could have caused catastrophic failures with potential loss of life.

Browns Ferry Nuclear Plant Broadcast Storm. On August 19, 2006, operators at Tennessee Valley Authority's (TVA) Browns Ferry Unit 3 manually scrammed (shut down) the nuclear power plant following a loss of both main reactor recirculation pumps (Figure 4). The initial investigation info the dual pump trip found that the recirculation pump variable frequency drive (VFD) controllers were nonresponsive. TVA determined the root cause of the event was a malfunction of the VFD controllers because of excessive traffic on the plant's integrated computer systems network, an event known as a "broadcast storm."

The Browns Ferry Unit 3 broadcast storm event was documented in Nuclear Regulatory Commission (NRC) Information Notice 2007-15, "Effects of the Ethernet-Based Non-Safety Related Controls on the Safe and Continued Operation of Nuclear Power Stations," April 17, 2007.

The Browns Ferry Unit 3 broadcast storm is representative of many unintentional ICS cyber incidents that occur because of inadequate ICS design, inadequate ICS cybersecurity policies and procedures, and/or inappropriate testing. In this case, a bad electronic card, scanning of the ICS network, or communication problems due to the design could have caused the incident. This incident did not violate any IT cybersecurity policies, but the lack of ICS forensic capability made identification of the root cause of the failure impossible.

It should be noted that many non-nuclear facilities have experienced similar broadcast storms that have impacted the operation of power plants, refineries, and even energy management systems. However, there is no legal obligation to report these events to regulators, and few voluntarily report them.

Hatch Nuclear Plant Software Glitch. Southern Nuclear Operating Co.'s Hatch Unit 2 was operating at approximately 100% power on March 7, 2008, when all seven

Unit 2 condensate demineralizers' outlet valves closed at approximately the same time, resulting in a temporary loss of normal feedwater injection and automatic reactor shutdown (Figure 5).

The reactor shutdown was later determined to be the result of an engineer testing a software change on the plant's chemistry data acquisition system (CDAS) server from a computer attached to the business local area network (LAN). The vendor software automatically synchronized changed data tag values between the server and the local control system vendor software. The test application sent data to a dedicated application server on the business LAN. This server was used in the CDAS to feed view-only data to users' workstations on the business LAN. However, the CDAS server uses vendor software that communicated with the same vendor software running on the condensate demineralizers' control PC. The CDAS server and local control computer were separated by a firewall.

The engineer did not realize that the vendor software automatically synchronizes data tags between connected computers running the software unless the data tags are written in a specific manner. When the local tag values in this vendor software on the CDAS server were updated by his code (not read-only, as they should have been), the changes were synchronized with the partnered vendor software running on the condensate demineralizer control PC. The updated values were subsequently sent to the PLC operating the demineralizers. Because the values written were zeros, the PLC switched to manual control with 0% flow demand. This action isolated the demineralizers, which resulted in a temporary loss of feedwater flow. An automatic low reactor water level scram was the result. Reactor water level was restored by the emergency safety systems.

As a result of this incident, the network connections between the condensate demineralizer control computers on both Hatch units and the CDAS server were physically removed. Other plant control systems were evaluated for similar interconnections. Only one similar interconnection was found, located between the Mark VI turbine control network and the safety parameters display system network on Unit 1. This connection was also physically removed.

The system design was also such that any rebooting that would reinitialize the system would cause the same failure, including software patch installs.

Note that the software failure did not violate an IT security policy, and the action could have been done maliciously. In fact, a similar failure occurred at another nuclear facility and other non-nuclear facilities, including one nuclear plant where the software failure impacted the safety systems.

Another similar case occurred recently in which control system logic was lost in all of the two-unit coal-fired plant's DCS processors for approximately 3 to 4 hours. Only the presence of hard-wired analog safety systems prevented a disaster.

These and other case studies about cybersecurity breeches will be discussed at the upcoming 12th annual Industrial Control System Cyber Security Conference (see the first sidebar in this article). ■

*—**Joe Weiss**, PE, CISM, CRISC, ISA Fellow, and IEEE Senior Member is the principal of Applied Control Solutions and the author of Protecting Industrial Control Systems from Electronic Threats, published by Momentum Press. Follow Weiss' "Unfettered Blog" at community.controlglobal.com/unfettered for the inside story of the latest cybersecurity news.*

Guidance on Cybersecurity for the Electricity Sector

The cybersecurity needs of the electric power industry are unique, due to the critical nature of the product and the wide range of technologies that must be considered—from complex, modern industrial control systems to aging infrastructure elements.

By Annabelle Lee, Electric Power Research Institute

Smart grid technologies are introducing millions of new, intelligent components to the electric grid—such as those that enable two-way communications, dynamic optimization, and wired and wireless communications (Figure 1). These devices communicate in much more advanced ways than was possible in the past. Cybersecurity is increasingly important to our industry because the bidirectional flow of communication and control capabilities that will enable an array of new functionalities and applications also introduces new potential vulnerabilities.

The interconnectedness of domains of the grid is also changing, as shown by the conceptual model of the smart grid illustrated in Figure 2. Another change is the interconnection of systems across organizations, for different purposes such as the export/import of electricity, providing situational awareness data, and receiving market data.

For each utility, modernization of the electric grid will take many years, possibly decades to complete. Throughout this long transition period, legacy equipment will be operated in conjunction with new equipment. In the current grid environment, legacy SCADA systems may have limited or no cybersecurity controls in place. Whatever stage of modernization a utility's transmission and distribution system is at, it must continually evaluate and plan to prevent and mitigate cybersecurity threats.

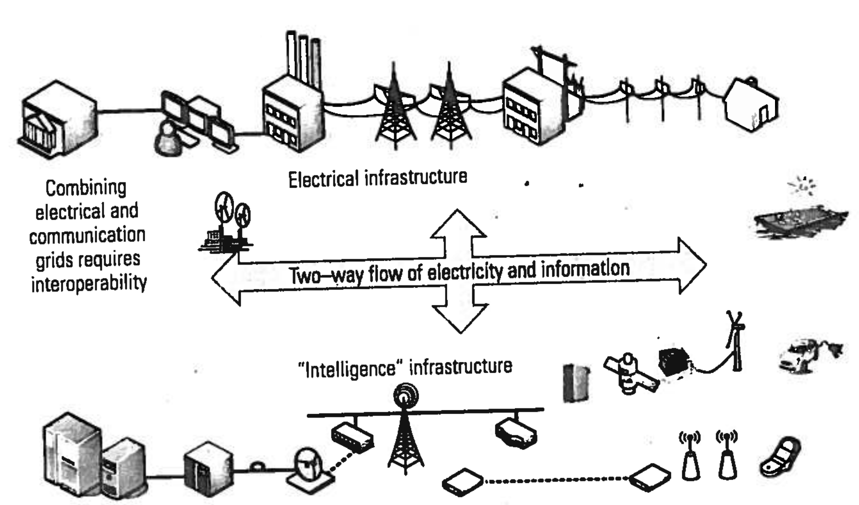
Cybersecurity Threats and Risks

Cybersecurity must address not only deliberate attacks launched by disgruntled employees, agents of industrial espionage, and terrorists, but also inadvertent compromises of the information infrastructure due to user errors, equipment failures, and natural disasters.

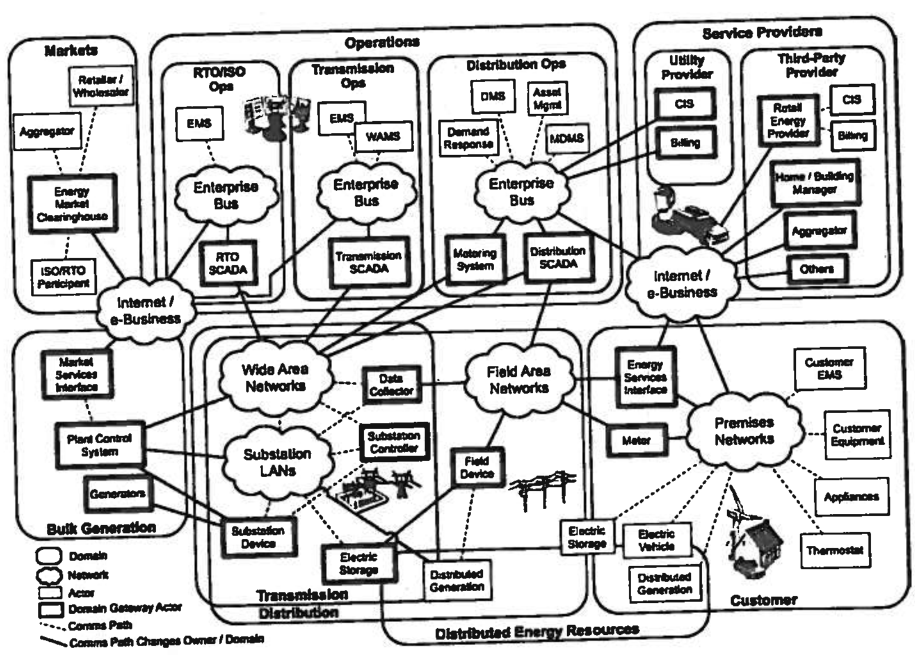
Potential risks to the grid include:

- Increasing the complexity of the grid could introduce vulnerabilities and increase its exposure to potential attackers and unintentional errors.

1. Smart grid = electric infrastructure + intelligence. *Source: EPRI*



2. Conceptual reference diagram for smart grid information networks. This conceptual model of the evolving smart grid includes potential communication paths and intra- and interdomain interactions. *Source: National Institute of Standards and Technology*



- Interconnected networks can introduce common vulnerabilities.
- Increasing vulnerabilities to communication disruptions and the introduction of malicious software/firmware or compromised hardware could result in denial of service or other malicious attacks.
- Increasing the number of interconnected digital devices increases the number of entry points and paths for potential adversaries to exploit.
- Interconnected systems can increase the amount of private information exposed and increase the risk when data is aggregated.

Figure 3 illustrates the paths that malicious and nonmalicious individuals may take to initiate a cybersecurity event. Control systems may be accessed directly or through corporate systems. Currently, the majority of cybersecurity events are nonmalicious. Regardless of the source of the cybersecurity event, the impact is likely to be the same: destabilizing the grid in unpredictable ways.

Developing a Cybersecurity Strategy

To adequately address potential threats and vulnerabilities, cybersecurity must be included in all phases of the grid system development life cycle—from design through implementation, maintenance, and disposition/sunset—and it must address prevention, detection, response, and recovery. Prevention is the first line of defense. But because cybersecurity prevention controls can be defeated, utilities have to be able to detect incidents, respond to mitigate damage, and recover systems and data in a timely manner.

A cybersecurity strategy must address not only deliberate attacks but also inadvertent compromises due to user errors, equipment failures, and natural disasters. It also must include both domain-specific and common requirements when developing a risk mitigation strategy.

Cybersecurity Risk Management Framework. The focus in the first phase of a cybersecurity strategy is to develop an overall cybersecurity risk management framework. Included in that framework are risk assessment and the selection and tailoring of cybersecurity requirements and measures/controls.

Typically, a cybersecurity risk management framework is a high-level framework that is common across the organization. This framework may be tailored at lower levels in an organization, such as for business and operational components.

Cybersecurity Risk Assessment Process. One component of a cybersecurity risk management strategy is the cybersecurity risk assessment. Risk is the potential for an unwanted outcome resulting from an incident, event, or occurrence, as determined by its likelihood and the associated impacts. Cybersecurity risk is just one component of organizational risk, which can include many types of risk (for example, investment, budgetary, program management, legal liability, safety, and inventory risk, as well as the risk from information systems). Because the smart grid includes systems from the information technology, telecommunications, and electric sectors, the risk assessment process is applied to all three sectors as they interact.

A cybersecurity risk assessment includes identifying assets, vulnerabilities, and threats and then specifying impacts. The output is the basis for the selection of security requirements and subsequent risk-mitigation strategies (security measures/controls). As with any assessment, a realistic analysis of the impact of inadvertent errors, acts of nature, and malicious threats is critical.

Specification of Cybersecurity Requirements. Security requirements may be used by strategists, designers, implementers, and operators of the electric sector such as utilities, equipment manufacturers, and regulators in the security lifecycle of an electric sector system.

Power system operations pose many security challenges that are not found in most other industries. In particular, strict performance and reliability requirements are needed by power system operations. Additional criteria must be used in determining the cybersecurity requirements before selecting and implementing cybersecurity measures/solutions. These additional criteria must take into account the characteristics of the interface, including the constraints and issues posed by device and network technologies, the existence of legacy components/devices, varying organizational structures, regulatory and legal policies, and cost criteria.

In addition, each utility's implementation of cybersecurity requirements should evolve as a result of changes in technology and systems, as well as changes in techniques used by adversaries.

Selection of Cybersecurity Controls/Countermeasures. Once security requirements have been specified, a utility selects its cybersecurity controls/countermeasures. The security controls should be selected and implemented based on an acceptable level of residual risk.

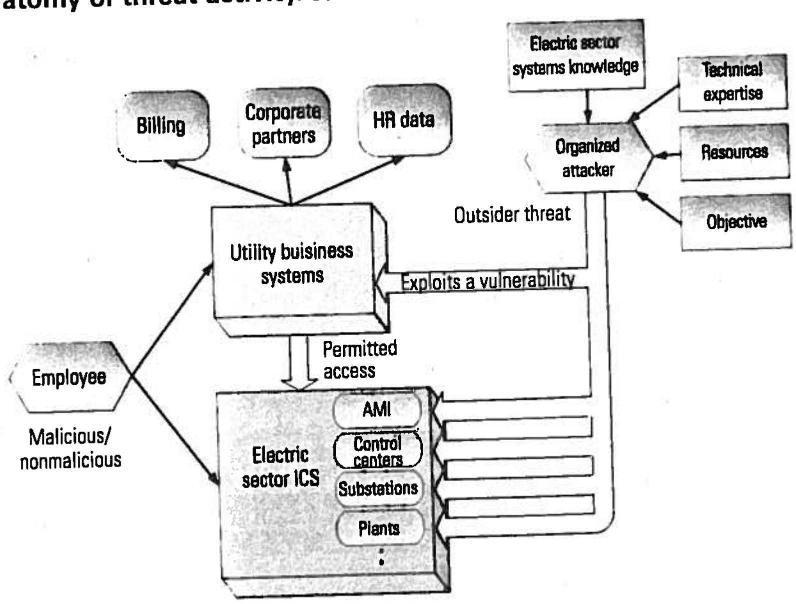
For the risk assessment during the operations and maintenance phase, the major difference is to make decisions about residual risk and whether the risk should be accepted, avoided, mitigated, shared, or transferred. In addition, the definition of the security controls is at a more granular level of specificity than the security requirements.

And, because there will be some security breaches, attention should be given to response and recovery efforts.

Guidelines for Smart Grid Cybersecurity

To address the cybersecurity requirements for the smart grid, the Smart Grid Interoperability Panel Cybersecurity Working

3. Anatomy of threat activity. *Source: EPRI*



Group (SGIP CSWG), led by the National Institute of Standards and Technology (NIST), developed the NIST Interagency Report (NISTIR) 7628, "Guidelines for Smart Grid Cyber Security," September 2010. (A pdf of the report can be downloaded from www.nist.gov/smartgrid/index.cfm.)

NISTIR 7628 is for individuals and utilities that will be addressing cybersecurity for all smart grid systems in all operational domains—generation, transmission, and distribution. NISTIR 7628 includes an approach for identifying cybersecurity threats and risks and selecting and tailoring cybersecurity requirements. Such an approach recognizes that the electric grid is changing from a relatively closed system to a complex, highly interconnected environment. Each utility's implementation of cybersecurity requirements should evolve as a result of changes in technology and systems, new threats, and changes in techniques used by adversaries. Approaches to securing cyber technologies must be designed and implemented early in the transition to the smart grid. That is, cybersecurity should be "built-in" to each smart grid system.

The first volume of NISTIR 7628 describes a cybersecurity strategy, including a risk assessment process, used to identify high-level security requirements. The volume also presents a high-level architecture followed by a logical reference model used to identify and define categories of logical interfaces within and across seven domains. High-level security requirements for each of the 22 logical interface categories are then described. The first volume concludes with a discussion of technical cryptographic and key management issues across the scope of smart grid systems and devices.

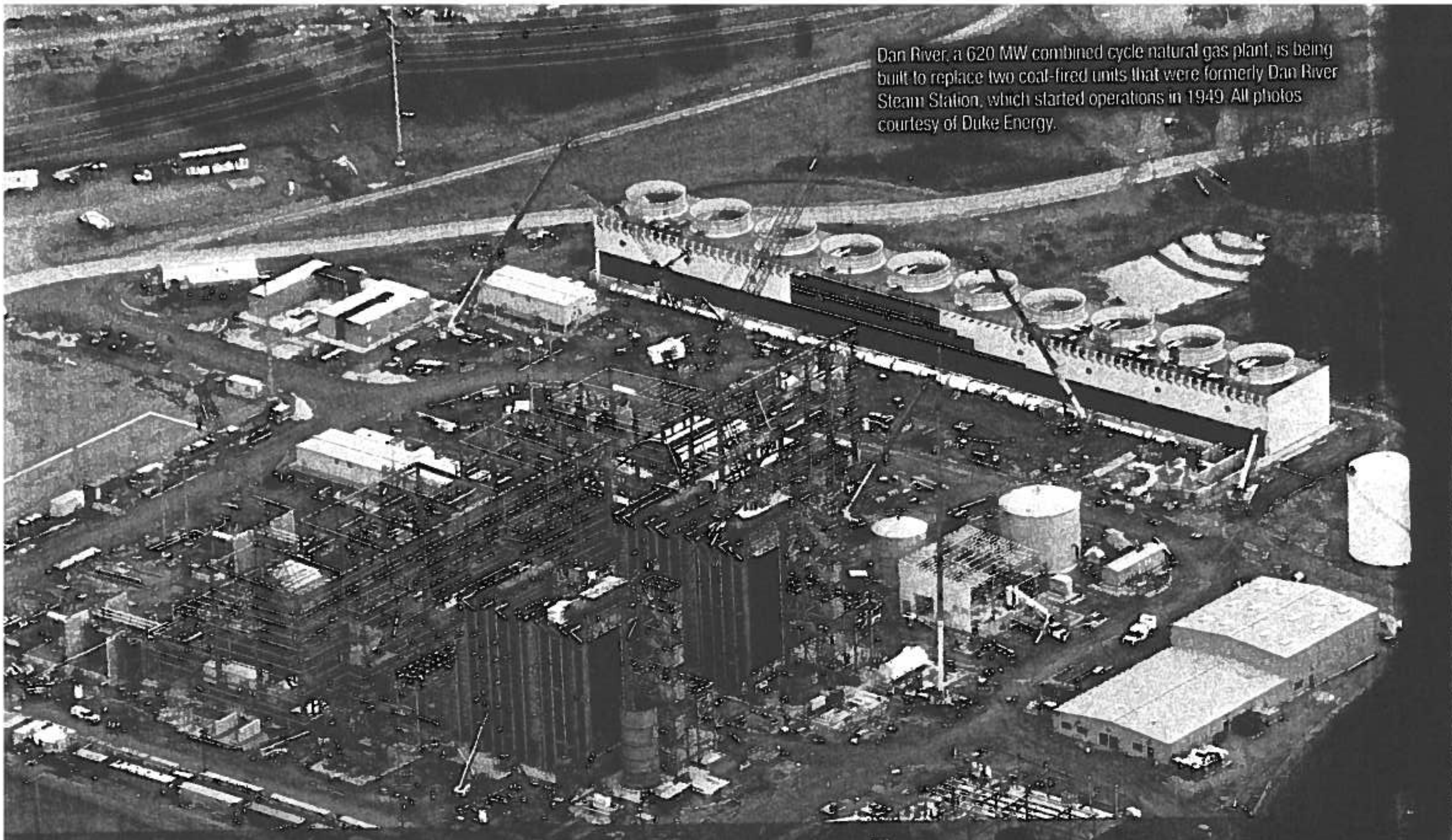
The second volume is focused on privacy issues within personal dwellings. This volume provides awareness and discussion of such topics as evolving smart grid technologies and associated new types of information related to individuals, groups of individuals, and their behavior within their premises. The second volume provides recommendations, based on widely accepted privacy principles, for entities that participate within the smart grid.

The third volume is a compilation of supporting analyses and references used to develop the high-level security requirements. These include classes of vulnerabilities defined by the working group and a discussion of the bottom-up security analysis that it conducted while developing the guidelines.

Research Continues

A number of research efforts related to cybersecurity issues are taking place throughout the industry. At the Electric Power Research Institute, research focuses on collaborative approaches to addressing emerging threats to an interconnected electric system. The initiative is also assessing technologies for data privacy. For example, EPRI is conducting a project to develop standard security objects for automated metering infrastructure (AMI) systems. This would allow third-party vendors to develop security applications to use and display the alerts generated by the meters to provide better situational awareness to AMI operators. EPRI is also developing a "how-to" for NISTIR 7628, to provide practical guidance for utilities that are addressing cybersecurity issues related to grid modernization. ■

*—**Annabelle Lee** (alee@epri.com) is EPRI's technical executive for cybersecurity.*



Dan River, a 620 MW combined cycle natural gas plant, is being built to replace two coal-fired units that were formerly Dan River Steam Station, which started operations in 1949. All photos courtesy of Duke Energy.

Duke Energy Learns the Value of Diversity

By Lindsay Morris, Associate Editor

If any electric utility is playing the "diversity card" at this point in time, it seems to be Duke Energy. The utility, which serves four million customers in the Southeast and Midwest, is in the largest build-out phase in the company's history.

The company is dipping into several forms of power generation. Duke's new coal project, two new combined-cycle natural gas projects, and 770 MW of wind under construction all came online in 2011, or will do so in 2012.

"We're in a build-out we haven't been in since the '80s," said Richard Haviland, senior vice president of construction and major projects. "There was a lot of need from a megawatt standpoint."

Some of this need for new generation comes as Duke, like many other utilities in the U.S., seeks to replace energy lost from coal plants which have been or will be retired. As of April, Duke has announced the planned retirement of more than 1,600 MW of coal-fired generation.

Gas, Of Course

With gas prices as low as they are, it comes as no surprise that two of Duke's new projects are combined cycle natural gas plants. But Haviland said that Duke's two new combined cycle natural gas plants started construction at a time when gas prices "weren't cheap" – 2008. Duke's original intention was to run these plants as intermediate load plants, but due to low gas prices, they will likely play a more prominent role in Duke's generation mix.

The two new plants are Dan River, a 620 MW combined-cycle station in Rockingham, N.C., and Buck Natural Gas Combined Cycle Station, a 620 MW plant in Rowan County, N.C.

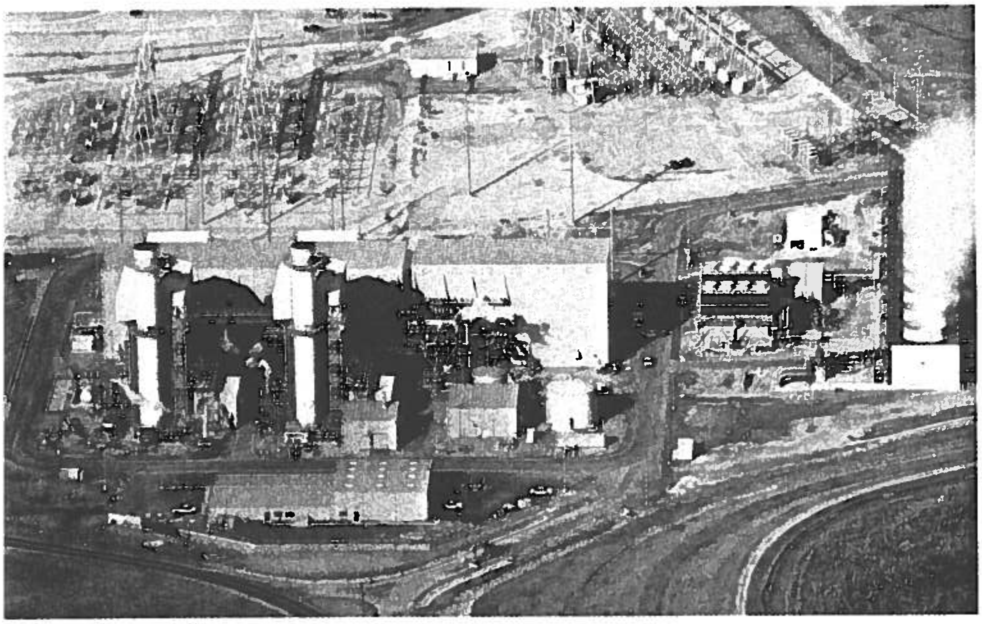
Haviland said that Duke's philosophy is not necessarily to bring more gas online, but to have a diversified portfolio that incorporates all fuel types. "Industry is going to find it harder to justify new nuclear and coal when gas is low."

At the same time, Duke remains cautious about gas. "Shale gas will probably keep prices low for a long time, but it may not, so you've got to be prepared. Diversification is the key."

Duke strategically planned these new gas builds. Buck came online in November 2011, and its construction started in 2008, about one year before construction on Dan River began. Both plants have the same design, and Duke was able to use the same vendors at both sites. Once crews were finished at one location, they moved on to the next site. Shaw served as the primary Engineering, Procurement and Construction (EPC) firm on both projects.

The Buck combined cycle natural gas plant was constructed to replace two coal-fired units, formerly Buck units 3 and 4. The two remaining coal-fired units at Buck 5 and 6, are scheduled to be retired by 2015. Once all of the coal units are retired, the new facility will generate approximately 250 MW more than the coal plant did with a 97 percent reduction in NO_x and more than a 99 percent reduction in SO_2.

Dan River, which is expected to be complete this November, is being built to replace the two coal-fired units that were formerly Dan River Steam Station, which started operations in 1949. Not only does the new combined-cycle plant result in a reduction of nitrogen oxide (NO_x) and sulfur dioxide (SO_2), but the new facility also generates approximately 350 MW more than the original coal plant.



In November 2011, Duke Energy completed construction on Buck Natural Gas Combined Cycle Station, a 620 MW plant in Rowan County, N.C.

New Coal?

The prospect of bringing a new coal plant online in this era of numerous regulations imposed by the U.S. Environmental Protection Agency (EPA) seems unlikely. And while the permitting of coal plants such as LS Power/Dynegy's Sandy Creek has been met with intense opposition in recent years, Duke Energy is discovering that new coal is not unfathomable. Duke realizes that the coal of the future looks different and cleaner than the coal power that came online during the '60s and '70s, due to the enforcement of regulations like the Mercury and Air Toxics Standard (MATS), the Cross State Air Pollution Rule (CSAPR) and proposed greenhouse gas regulations.

The Cliffside Steam Unit 6, which is finishing testing and will come online later this year, has achieved a permit that designates the unit as a minor source of hazardous air pollutants (HAPs) – a permit that is unique for a coal plant to obtain. The permit was granted as a result of the unit's achievement of remarkably low emissions levels for SO_2, NO_x and mercury. On the Rutherford/Cleveland County line in North Carolina, Cliffside has undergone the installation of numerous control technologies, including a wet scrubber, a dry scrubber and a baghouse. Shaw is the primary EPC firm working on Buck.

"A lot of other new coal plants have had problems running over their budget and costs," Haviland said, "but we're going to make our budget and be on time."

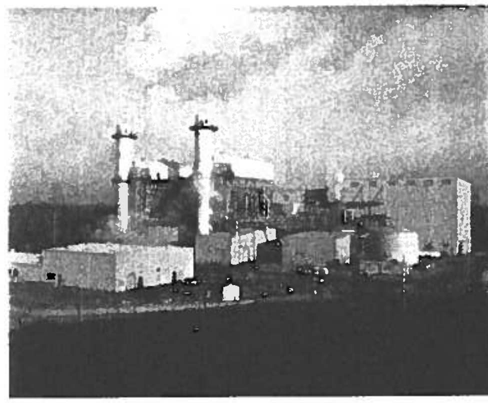
The budget for the 825 MW plant isn't small – Duke will have invested $1.8 billion by the time the project is finished.

Many new coal projects have been cancelled over the last few years because of budget overruns. The completed Cliffside Unit 6 will replace Units 1, 2, 3 and 4 when it comes online. The emission control systems will remove 99 percent of SO_2, 90 percent of NO_x, and 90 percent of mercury. The plant is also supercritical, which results in a better heat rate.

The new Cliffside unit has been met with its share of opposition. After the plant received its permit as a minor source of HAPs, environmental groups sued the state of North Carolina for granting Cliffside the permit. While the lawsuits have already been defeated, Haviland said that anyone who tries to build a new coal plant is going to be challenged due to environmental issues. Another current challenge to choosing coal, he said, is low natural gas prices. "You have to show that coal is the best option from a cost standpoint."

Yet another potential hurdle for new coal generation is potential carbon regulations. On March 27, the EPA proposed the first Clean Air Act standard for carbon emissions from new power plants, known as the New Source Performance Standard (NSPS). The proposal does not apply to plants currently operating or new permitted plants that begin construction by March 2013. Since Cliffside has already received permitting, it will not be subject to the NSPS.

The proposed rule does have the potential of prohibiting future coal developments from Duke and other generators, however. The NSPS would require any new power plant to emit no more than 1,000 pounds of carbon dioxide (CO_2) per megawatt of electricity produced. The average U.S. natural gas plant, which emits 800 to 850 pounds of CO_2 per megawatt, meets that standard; coal plants, however, emit an average of 1,768 pounds of carbon dioxide per megawatt.



The Cliffside Steam Unit 6 is finishing testing and will come online later this year. Duke will have invested $1.8 billion by the time this coal-fired project is finished.

"If carbon legislation came back, that would conclude coal. But without carbon regulations, it's a very competitive energy source," Haviland said.

EPA Administrator Lisa P. Jackson said the proposed rule is not an effort to terminate coal generation. "We believe that coal will remain an important part of America's electric generating mix; (it will) remain the largest single source of electricity in our nation's future."

Under the proposed regulation, new coal plant operators will have two options for compliance: Using carbon capture and sequestration (CCS) technology to limit carbon emissions, or averaging carbon emissions over a 30-year period.

However, some in the industry, such as Scott Segal, executive director of the Electric Reliability Coordinating Council, say that CCS is "still highly speculative, likely expensive, and EPA has provided no assurance that it will help with inevitable permit delays."

EPA is expected to release a final ruling on the proposal after the November presidential election. The outcome of the final rule could play a big role in determining whether Duke and other utilities invest in new coal projects in the future.

In addition to bringing new coal online, Duke, like most other North American utilities, will be retrofitting a number of facilities over the next few years. Haviland said that because MATS and CSAPR requirements are less stringent than the proposed versions of the rules, Duke is planning on retiring "less than half" the coal the company originally planned shuttering. Duke is in a better position than many utilities, Haviland said, because its coal plants already have good scrubbers installed.

The Wind Rush

Duke has also demonstrated a commitment to renewable energy development over the last few years. Duke plans to complete 770 MW of new wind projects in 2012 alone. This will add to the 630 MW of wind projects the company finished in 2010. Additionally Duke has purchased more than 1,000 MW of wind assets in recent years. Part of these assets include the acquisitions of Tierra Energy and Catamount Energy, as well as a 50 percent stake in the Sweetwater project in Nolan County, Texas – one of the largest wind projects in the nation. These investments total a $2.5 billion investment in wind power since 2007.

Duke currently owns and operates a total of 10 wind farms: four in Wyoming, three in Texas, one in Colorado, one in Pennsylvania and one in Wisconsin. In 2012, the 770 MW of new wind Duke Energy Renewables plans to bring online will be at five new wind farms – two in Kansas, two in Texas and one in Pennsylvania.

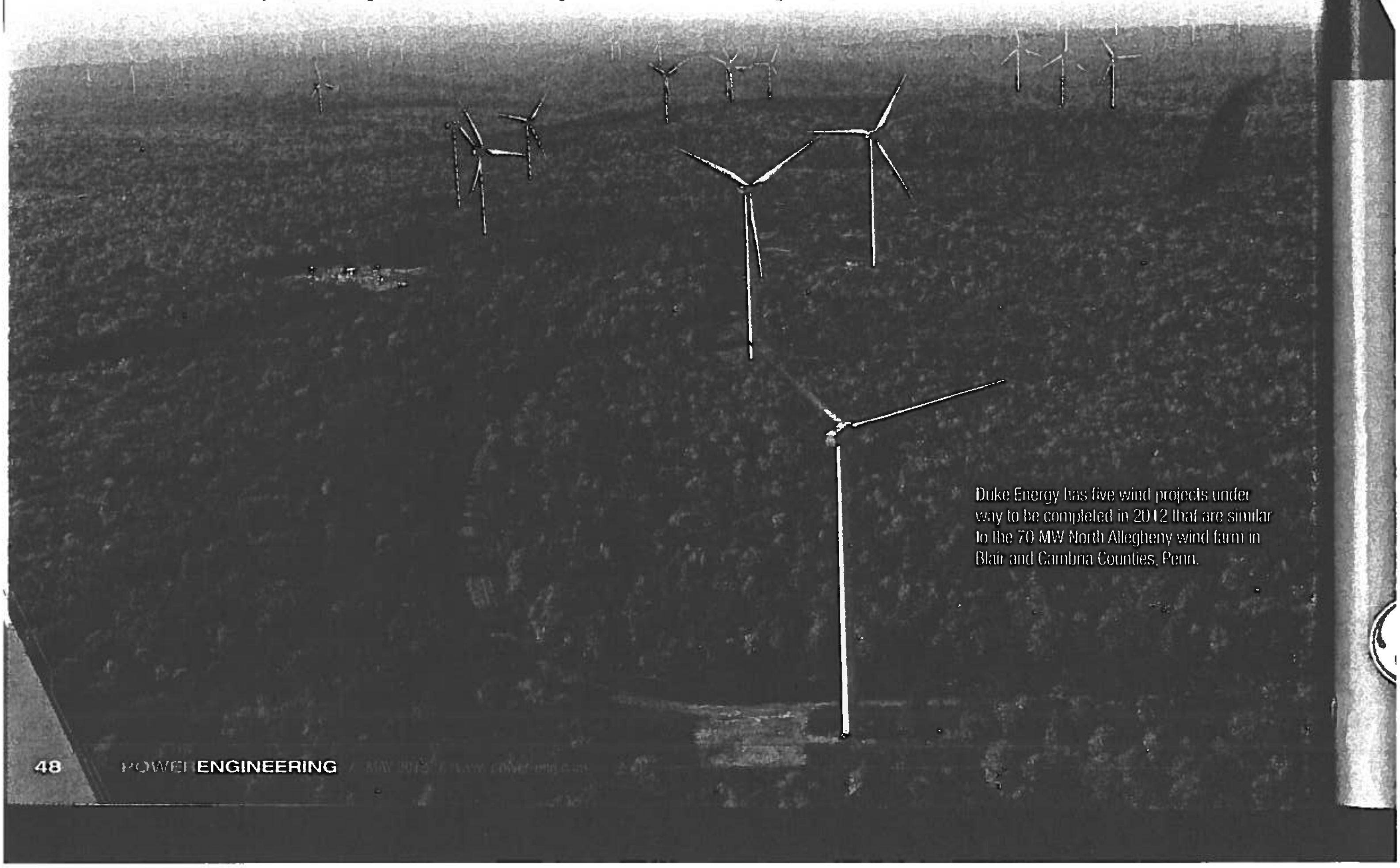
Surprisingly, Duke had no experience in wind energy prior to 2007. "We started from scratch," Haviland said. "Using the Duke engineering and construction resource, we put together a standardized wind execution strategy, and we've been inside our budget on all schedules and finances."

Part of Duke's rush to complete 770 MW by the end of the year is due to the scheduled expiration of the federal Production Tax Credit (PTC) on Dec. 31. The PTC provides an income tax credit of 2.2 cents per kilowatt-hour for the production of electricity from utility-scale turbines. Haviland said Duke expects to complete all 770 MW by the end of the year in order to take advantage of the PTC.

Duke's wind projects scheduled to come online this year include Cimarron II in Gray County, Kan., a 131 MW wind farm run by 57 Siemens 2.3 MW turbines; Ironwood in Ford County, Kan., a 168 MW wind farm operated by 73 Siemens 2.3 MW turbines; Laurel Hill in Lycoming County, Penn., a 69 MW wind project operated by 30 Siemens 2.3 MW turbines; Los Vientos I in Willacy County, Texas, a 200 MW run by 87 Siemens 2.3 MW turbines; and its neighboring Los Vientos II, a 202 MW facility operated by 84 Mitsubishi Heavy Industries 2.4 MW turbines.

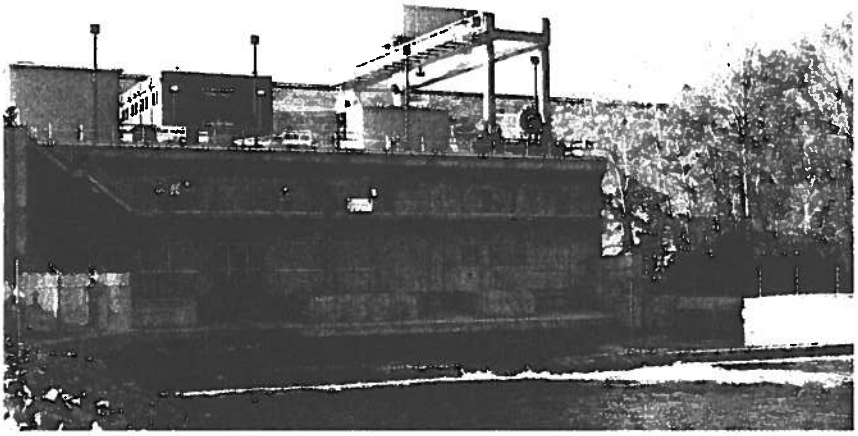
More Megawatts

While coal, gas and wind make up the bulk of Duke's new fleet, nuclear is still on Duke's agenda, Haviland said. Duke expects that Lee Nuclear will receive its Combined Construction and Operating License (COL) from the Nuclear Regulatory Commission in 2013. The William States Lee III Nuclear Station is a planned two-1,117 MW unit nuclear power plant that will be adjacent to the Cherokee Nuclear Power Plant site, which was never completed and abandoned in the early 1980s. Duke estimates the plant will cost approximately $12 billion and will be online in 2021.



Duke Energy has five wind projects under way to be completed in 2012 that are similar to the 70 MW North Allegheny wind farm in Blair and Cambria Counties, Penn.

In addition, Duke continues to operate a number of hydroelectric projects. Due to new guidelines from the Federal Energy Regulatory Commission (FERC), Duke is currently undergoing the reconstruction of three dams near Nebo, N.C.: Linville, Paddy Creek and Catawba, collectively known as the Bridgewater Project. FERC guidelines being used to assess the physical condition in the event of a large earthquake have required the remediation of these three dams, which Duke started in 2005. The new engineering design includes the construction of large earth and/or concrete structures along the downstream slope of the dams, which have been on Lake James since 1919.



Duke is currently undergoing the reconstruction of three dams near Nebo, N.C.: Linville, Paddy Creek and Catawba, collectively known as the Bridgewater Project.

"It's a one-of-a-kind project because you're moving a 100-year old powerhouse downstream," Haviland said.

Shaw is serving as the primary EPC firm on the project. Duke Energy hired HDR Engineering Inc. of the Carolinas (HDR|DTA) to conduct feasibility studies and determine various options that could meet current FERC seismic stability requirements. Voith Hydro designed the turbine equipment to employ a combination of peripheral and central aeration technology. HDR|DTA defined the air flow rate and level of low dissolved oxygen (DO) uptake necessary to achieve tailrace DO goals, and Voith Hydro designed the air intake systems to provide the air flow to the machines. The entire project is expected to be completed by the end of this year and cost approximately $300 million.

In a recent interview, Keith Trent, group executive for Duke Energy, summed up the company's philosophy with this statement: "Play a diversity card; don't put all your eggs in one basket."

While not all utilities are in a build out phase, it's likely that more new projects will be launched over the next few years in an effort to fill the void of the 10 to 75 GW of coal-fired capacity expected to be retired between now and 2030. And it's likely that other utilities will follow Duke's example and play the diversity card. pe