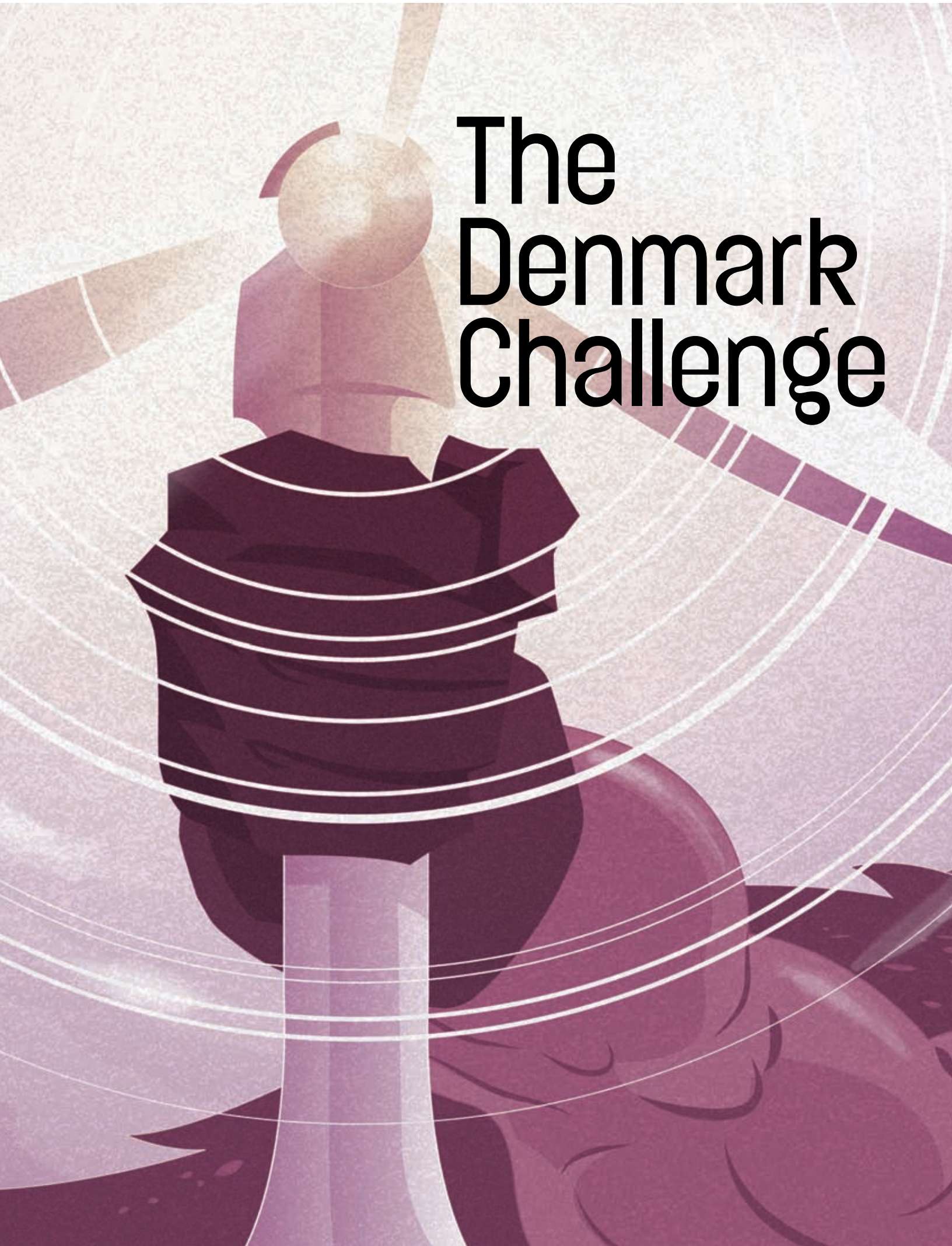
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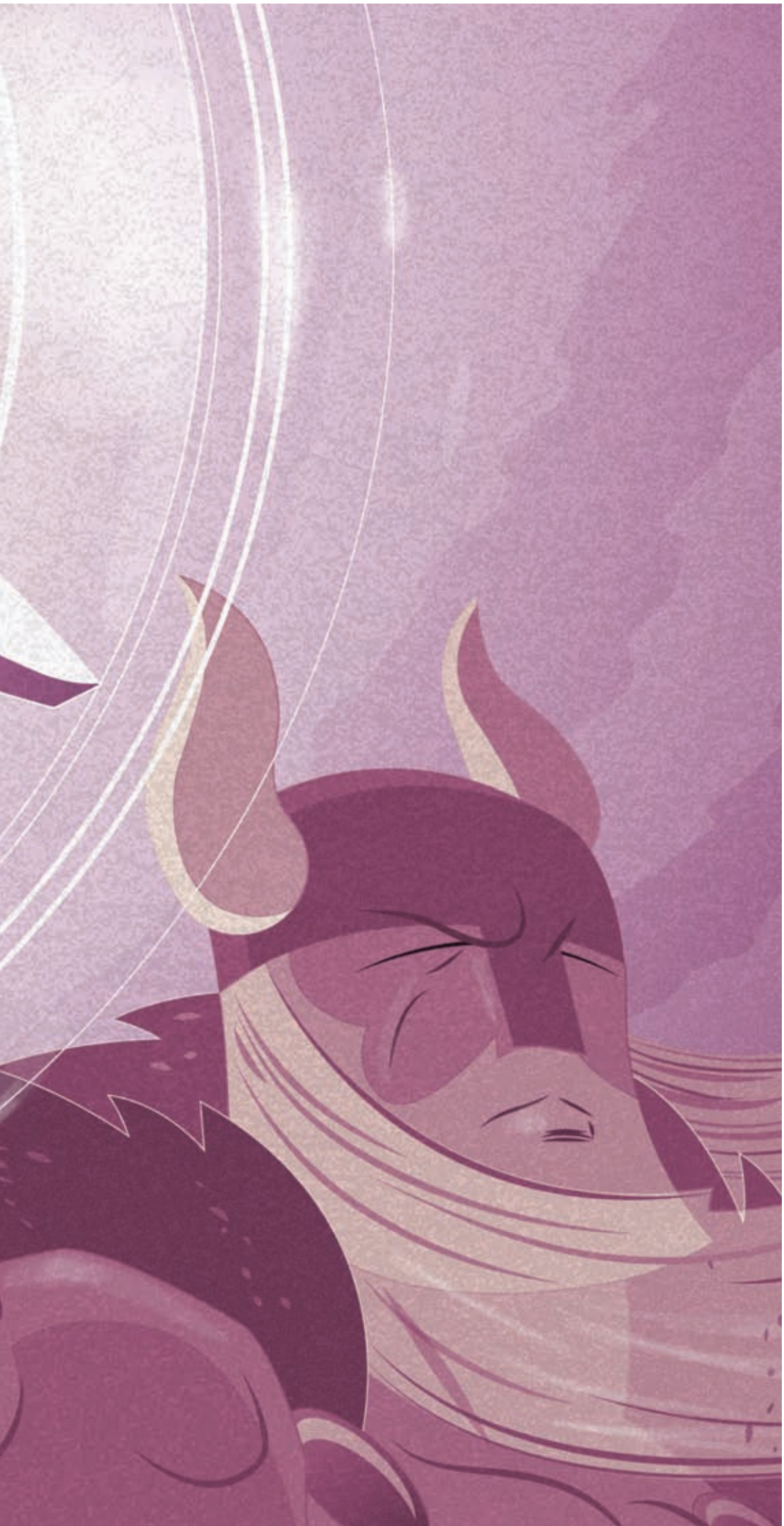

LESSONS FROM AN EMERGING WIND POWER

BY MARTIN ROSENBERG

ILLUSTRATION BY STAN SHAW

The people of Denmark have a story to tell in their own Nordic unassuming way. You hear it from quietly proud Per Volund, an engineer, as he takes a group of Americans out on a small boat to tour the Middlegrunden wind farm in Copenhagen harbor. Volund, the vice-chairman of the cooperative that runs the 20 turbines, pointed out at the arc of units standing in the tides one recent wintry day, providing the Danish capital with 4 percent of its electricity since 2000. "We solved all the problems to make it happen and proved that this is possible and not too complicated," he said.

You also hear the story from scientists like Sten Frandsen of the Risoe National Laboratory, who are helping to nurture the country's fast-evolving wind technology. He envisions the eventual erection of a 20-megawatt wind generator whose whooshing blades would define a 250-meters diameter circle. That would be about the height of the Eiffel Tower or almost the length of three football

EDITOR'S NOTE Research for this article was conducted with the assistance of New Energy Denmark, a group of Danish citizens organizations interested in promoting cooperation between Danes and Americans developing renewable energy resources.

RELATED STORY p. 72, Vestas Commands the Skies

fields. "Diameter is the most important factor," the bearded scientist said. "It takes energy out of the air as it rotates."

You are told the story by earnest, idealistic officials like Michel Schilling, who explained how and why the Danes intend to create a generating system that uses wind turbines to generate half of the country's electricity. "We in Denmark have shown that wind energy can be part of a modern, highly industrialized society – that it can meet the demands for electricity," said Schilling, who is in charge of the government's wind initiatives.

Denmark, with a population about equal to Wisconsin's, has emerged a global superpower in wind energy, led by homegrown companies like Vestas and LM Glasfiber. Vestas started out more than a century ago as a farm implement manufacturer. LM made furniture. Now Vestas has a commanding market share of worldwide wind turbine production and LM is a world leader in manufacturing wind blades. Both operate sprawling facilities not far apart in western Denmark. Today, 21,000 Danes work in the wind industry, giving it proportionally about as significant a role in Denmark's thriving, near full-employment economy as the troubled automobile sector plays in the United States.

To gain a deeper understanding of Denmark's wind power successes and their possible implications for the United States, *EnergyBiz* recently spent a week in the country meeting with government officials, business executives and scientists and touring wind installations, factories and research facilities.

Denmark has been developing wind generation ever since the oil price rise shocks of three decades ago. Even though modest amounts of oil were found near its shores, Denmark continued to work on wind power. Drive Denmark's back roads and you will see wind turbines planted on many hilltops and in valleys that look cutting edge to an untrained eye. Wind turbine experts, however, refer to these older units as museum pieces. The country is eager to continue to ramp up its wind technology.

Some credit northern Europe's culture of frugality and a strong commitment to the environment. Others cite a Nordic ethic. Government has a role to play in directing society. Citizens have a responsibility to shoulder the taxes and support the subsidies that make it possible to pursue renewable technologies while they are in their in early, startup phases. Carol Gold, a historian at the University of Alaska who has studied and lived in Denmark, said the country has benefited from "a sense that the government is more 'us' than 'them.'" Couple that with a sense of pride shared by many Europeans, "a sense of 'we can show the Americans how to do it,'" Gold said. Then you will better understand the continent's current passion about renewables.

The argument against massive wind power development in the United States has centered on the intermittency of the resource. Wind power generation works at maximum efficiency about one-third of the time. Thus, a heavy reliance on wind would necessitate development of other generation that could be tapped when wind is not available. Danish energy planners neatly sidestep that issue because their nation has major transmission line connections to Sweden and Norway, where hydroelectric power resources are about triple Denmark's annual electricity consumption, and to Germany, which has diverse generation resources.

The 20-turbine Middelgrunden wind farm, installed in 2000, produces 90 megawatt-hours of electricity a year.
PHOTO BY BENJAMIN K SOVACOOL

In the United States, the most abundant wind resources are in the middle of the country relatively far from coastal population centers. A major reliance on wind generation would require a significant investment in upgrading the power grid.

Denmark declared a year ago that it intends to double its wind generation capacity to 6,000 megawatts. The United States has 15,000 megawatts of wind power installed meeting almost 1 percent of national electricity demand. The Danes intend to deploy 500 to 1,000 offshore wind turbines to generate enough electricity to meet its residential customers' needs.

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DENMARK CONQUERS WIND

"This isn't an impossible vision," said Randall Swisher, executive director of the American Wind Energy Association. "The Danes really look at wind as a critical technology for the future."

The Danish rush to wind is not unique, at least for Europe. Germany and Spain are noted for wind turbine deployments. One of the world's largest wind turbines, a 5-megawatt unit, now spins near Hamburg. As for seeding the European coast with wind generation, some wind backers are calling for up to 40,000 megawatts of offshore wind generation by 2020, which would satisfy 4 percent of the continent's electricity needs.

American officials are taking note. In an interview with *EnergyBiz* to discuss the implications of Denmark's wind program, Joseph T. Kelliher, chairman of the U.S. Federal Energy Regulatory Commission, said wind is ready to assume a much greater role in American power planning. Too many of us, when we envision wind power "picture a lonely windmill from the Wizard of Oz," Kelliher said. "Really, it is a major program with 150-foot blades and thousands of megawatts of potential."

The Denmark challenge, many Danes suggest, is whether the United States can replicate, perhaps more modestly, what is being attempted in Denmark. Kelliher said it would require strong regional power grids. Today, there are more than 500 transmission owners, "500 sets of hands pulling the levers for those 500 machines," he said. Coordinating an array of relatively small generators spread over a vast expanse for the benefit of far off urban centers will require complex coordination, something made difficult by today's balkanized grid. Furthermore, while annual investment in transmission has doubled since 2002, Kelliher said, it is "still not adequate."

Swisher said that an investment of $60 billion in 19,000 miles of 765-kilovolt transmission lines would spur development of massive arrays of wind generation in the United States. "The U.S. wind industry is focused on 20 percent wind penetration by 2030," Swisher said. Accomplishing that would represent a revolution in the industry. It would take 320,000 megawatts of new wind generation to get to that 20 percent objective, he said. "The potential for wind technology is almost unlimited. The resource isn't the limitation. The economics are in the competitive range. It is a question of constructing an electric system that can use that amount of wind."

We see urban wind as a new niche.

How have the Danes addressed concerns Americans have about wind power?

Consider the esthetic question. Some prominent clam chowder state denizens have fought placement of a proposed offshore wind farm in Cape Cod waters saying it would ruin the view. That attitude mystifies Beate Bentzen, chief development officer with

Changing Society

GOVERNMENT POLICY BOLSTERS WIND GENERATION
BY MARTIN ROSENBERG

MICHEL SCHILLING, LAWYER, slight of frame, 42, father of four, plays a key role in the Danish government when it comes to implementing a grand vision for bolstering the northern European nation's wind generation resources.

As point man in the Danish Energy Authority, he is a central figure in implementing an ambitious national plan unveiled by political leaders a year ago. It calls for a doubling of wind power capacity in the country to 6,000 megawatts by 2025, aided by installation of upward of 1,000 offshore wind turbines around a nation roughly the size of West Virginia. That would represent an astounding 50 percent of the country's electricity demand.

EnergyBiz recently sat down with Schilling outside a European wind energy conference in Roskilde, near a rugged fjord, to discuss where Denmark is with wind power today, and where it hopes to take the technology. His comments, edited for style and length, follow.

ENERGYBIZ Describe Denmark's energy success story.
SCHILLING We have had economic growth every year for almost 25 years. It's one of the only countries in the world where you have decoupled completely economic growth from the energy consumption.

ENERGYBIZ How do you do that?
SCHILLING Energy savings and energy savings

(CONTINUED ON PAGE 26)

Michel Schilling
PHOTO BY MARTIN ROSENBERG

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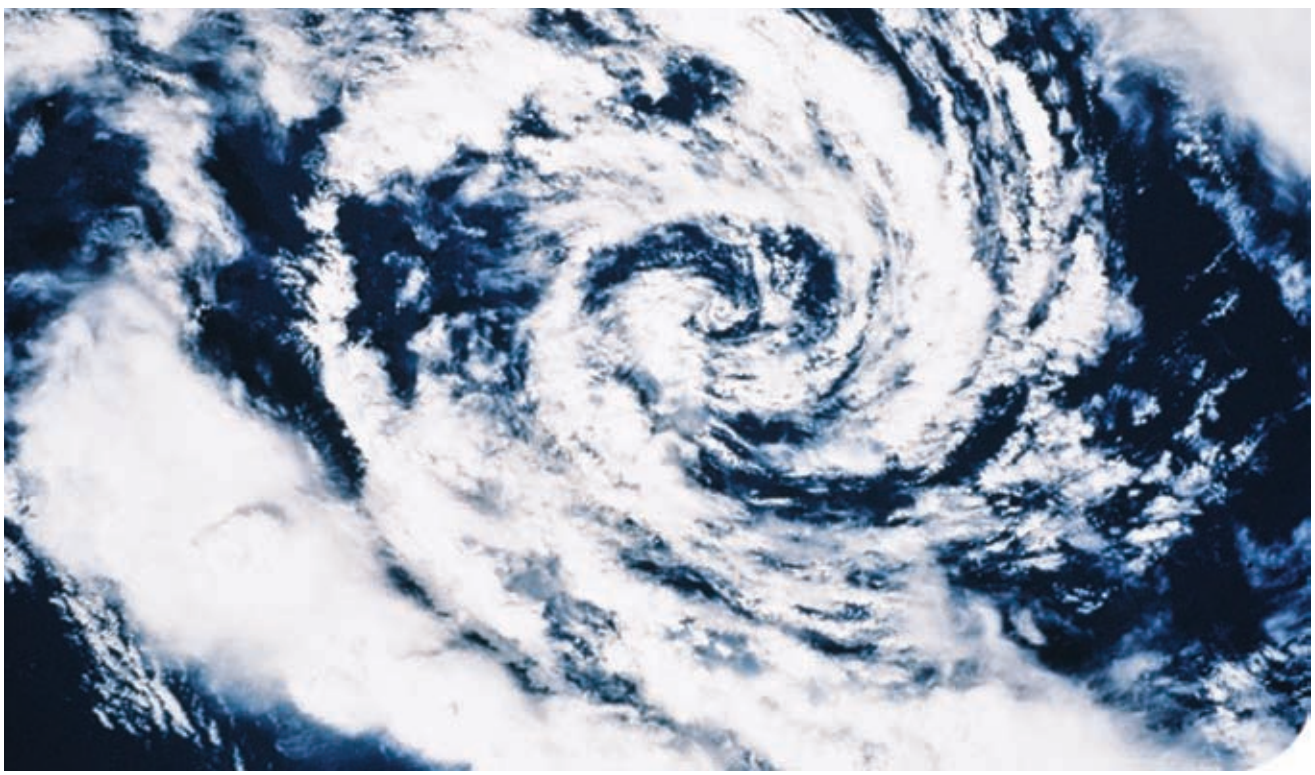

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the Ramboll engineering firm. The modern wind turbine, she said, "is a spectacular piece of art."

Such zealous enthusiasm explains why foreign developers turn to Denmark to develop wind projects. Consider the stunning new Bahrain World Trade Center, which has three wind turbines that will generate 15 percent of the twin-tower's electricity needs, making it the first such building of its kind in the world. The turbines were made by Norwin, a small Danish manufacturer, and the project was overseen by Ramboll. Soren Juel Petersen, Ramboll director of wind energy, said, "We see urban wind as a new niche."

As for those Americans who say the design of the current power grid is an impediment to widespread wind generation, Danes say America must make needed investments in the grid to make it more reliable. Peter Wenzel Kruse, Vestas vice president, forthrightly declared, "The U.S. grid is worn down. You're just walking a thin line of collapsing the economy." Investing in the grid would allow wind generation to go forward. "There is tons of cheap wind power in the Midwest," he said.

Denmark has invested heavily in its power grid, viewing its as a necessary resource, according to Lise Nielson, program coordinator for Energinet, which develops and owns Denmark's electricity and natural gas transmission lines. "Utilities and grids in Denmark have always worked on a nonprofit basis," she said. The grid operators are dedicated to spurring development of all viable generation resources. "We will build grid out to any generation." Furthermore, Energinet has long sought the highest levels of reliability, building its power grid in a robust circular design similar to fiber-optic telecommunications networks in the United States. Costly, perhaps, "but what is the cost of a blackout?" Nielson asked.

The new Bahrain World Trade Center sports three wind turbines made by Norwin and engineered by Ramboll, both of Denmark, that will generate up to 15 percent of the building's electricity. PHOTO COURTESY OF RAMBOLL

(CONTINUED FROM PAGE 24)

and energy savings. Renewable energy and energy savings are not show stoppers when it comes to economic growth.

ENERGYBIZ Denmark has made a commitment to lessen its dependence on all fossil fuels.

SCHILLING Yes.

ENERGYBIZ Does that include natural gas?

SCHILLING Yes. All fossil fuels on a very, very long term.

ENERGYBIZ How can a modern industrial society make that commitment?

SCHILLING How can a modern society have 20 or 50 percent wind energy in its electricity production? Many people still see a wind turbine as a little turbine next to the farm and that the only production it can supply is for the use for this farm and maybe three or four houses. Some say that wind energy is only there when the wind blows, so of course what good is a day when you don't have any wind? We in Denmark have shown that wind energy can be part of a modern, highly industrialized society – that it can meet the demands for electricity. If people said 20 years ago that the wind turbines would be at 1 megawatt or 4.5 megawatts, it was unimaginable.

ENERGYBIZ Now they are planning for up to 8 to 10 megawatts?

SCHILLING Exactly. Right now four wind turbines can provide electricity to a very big city in Denmark.

ENERGYBIZ Does wind still require government subsidies?

SCHILLING Some say that you can only have wind energy if you pay three or four times the market price. It is true that it's still necessary to provide a subsidy for wind energy. On the other hand, the production cost of wind energy today is one-third or one-fourth of what it was 15 years ago. The wind turbines are big and expensive, but they produce more than a hundred times more than just 15 years ago.

ENERGYBIZ Denmark is a small country of 5 million people. What lessons could the United States, with 300 million people, draw from Denmark's experience developing wind power? Is your success exportable to the United States?

(CONTINUED ON PAGE 28)

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A modern transmission grid is more efficient than old technology. Grid line losses are about 4 percent in Denmark, compared to 10 percent in the United States. Nielson acknowledged that part of that difference is explained by the vast distances that must be covered by transmission in the United States. Still, modernization will limit power line losses, she said, and result in less greenhouse gas emissions.

While the Danes feel they have a superior grid – the power network's nervous system – they are intent on developing its intelligence as well. Power systems have for ages relied on a handful of large central generating stations. With the advent of wind and other renewable energy forms, more small sites will go on and off line depending on a variety of factors. These resources must be integrated and used in the most efficient ways. To meet these complex requirements, Danish scientists have launched Syslab, a research facility for distributed power systems in Roskilde, located on a fjord west of Copenhagen. The development of a futuristic intelligent power system is a daunting task, said Henrik Bindner, at the Riso National Laboratory, where Syslab is located. "The challenge is to have millions of inputs," he said. "It's up in the air how to control such a system."

Bindner and his colleagues have defined the challenge and are hard at work meeting it. If successful, Denmark will play a commanding role in not only exporting wind turbines, but also the software and network intelligence that will make it all operate seamlessly.

The Danes have a fix on the possibilities. Sten Frensen pulled out some back-of-the-envelope calculations. An area about the size of Texas and New Mexico contains enough wind energy to meet all of the world's electricity needs if fully captured, he said.

Or you could place turbines in the deep waters of the North Sea and generate an amount of electricity equal to half the world's consumption, he said.

Given rugged ocean conditions, the cost of wind turbines offshore is about double the cost of onshore. Even so, many will tell you that the future of wind power may be in the oceans, which can readily accommodate new, large turbines. Bo Morup, Vestas vice president of offshore sales, said, "Wind hits shore and loses 30 to 50 percent of its energy in the first 100 yards." The trick is to capture that energy before it dissipates.

A new generation of Vikings is heading to sea in search of opportunities to pull energy from the winds. They are coming ashore in the United States and fast-growing markets around the world, eager to do business.

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Why Denmark?

REASONS FOR EXCELLING IN WIND POWER

BY JESPER TORNBJERG

WIND turbines produce close to 20 percent of the electricity consumed in Denmark and the country is a world leader in wind turbine production.

The transmission system operator claims that it is possible for wind power to serve as much as 50 percent of the electricity demand, and the statement is confirmed both by independent consultants and advisers to the Parliament.

Why this focus on wind? Why this success in a country of 5.3 million citizens?

Strong wind blows often from the North Sea. Denmark provides good wind power opportunities.

Denmark has a long history of harvesting wind. Poul la Cour in the later half of the 19th century pioneered modern electricity-generating wind turbines. He built a wind tunnel for experiments and used electricity from his wind turbines for electrolysis to produce hydrogen for the gaslight in his school in Jutland. The technology did not achieve a breakthrough – but it was not forgotten.

(CONTINUED FROM PAGE 26)

SCHILLING That's a very big question. I think that Denmark has shown that it is possible to have a modern society which will have renewable energy playing a big role. It is technically possible. We had wind generating 41 percent of our electricity in Western Denmark one day in January 2007. We had a storm. If you have too much wind, the wind turbines shut down. For one split second we lost 1,000 megawatts in the system. There was no impact at all on the electricity. Due to our grid connections to the other Nordic countries, there was no breakdown, nothing. So it is possible to manage this.

ENERGYBIZ So Denmark depends on the fact that it is surrounded by countries less tied to renewable power than it is.

SCHILLING In Denmark, we have doubled installed capacity with our decentralized power plant. The installed capacity in Denmark is approximately 13,000 megawatts but we usually use only 6,000. We're not totally dependent on the grid connections to the other countries.

ENERGYBIZ Describe your job.

SCHILLING I am part of the Danish Energy Authority. I have a director. And over him is the Minister for Climate and Energy. I am part of the Danish Ministry of Climate and Energy. I'm in charge of wind power.

ENERGYBIZ Are you pessimistic about the global warming and climate change?

SCHILLING Wind power is one of the solutions to combat climate change. But until now where I am part of a new Ministry for Climate and Energy I have not been focused on climate change.

ENERGYBIZ You are focused on wind generation. Denmark is identifying potential sites for additional wind generation and planning for the day when it will provide 50 percent of its electricity.

SCHILLING If there's a desire to develop more offshore wind, we have facilitated this decision through our strategic planning. The government just decided for a new offshore wind park to be grid connected by 2012.

ENERGYBIZ Does anyone complain that offshore wind turbines are a visual blight?

(CONTINUED ON PAGE 30)

The interest in renewables was boosted in Europe in the 1970s by the two oil price crises. The 55-kilowatt generation of wind turbines developed in 1980–1981 became the industrial and technological breakthrough for modern wind turbines. Although large U.S. companies tried and failed to build big turbines, the Danish bottom-up approach had success.

Electricity's cost per kilowatt-hour dropped about 50 percent with the appearance of the 55-kilowatt generation. The wind industry became much more professional. Parallel development of the European Wind Atlas Method by Risoe National Laboratory was important in lowering kilowatt-hour costs.

The government supported wind power development with subsidies paid by consumers, safety regulation and technical assistance from one laboratory: Risoe's Department of Wind Energy and Atmospheric Physics, with a staff of about 100.

Projects in Denmark were driven by both professional utilities and common people, which gave rise to local understanding, awareness and spirit. As a small country, Denmark often requires little time to move from a decision to action.

The local market grew at the same time as a boom in California in the 1980s. Although the Great California Wind Rush seems small now, thousands of machines were delivered to Palm Springs and other destinations. About half of the wind turbines placed in California are of Danish origin.

The market for wind energy in the United States disappeared overnight when California's support schemes evaporated around 1985. The report of the Bruntland Commission in 1987 advanced the idea of sustainable development that meets the needs of the present without compromising the ability of future generations to meet their own needs. A new global agenda involving climate change emerged. Germany, just to the south of Denmark, became the world's foremost market. In 1990, Denmark developed an energy plan together with a strong political will and an ambitious goal of a 20 percent CO_2 reduction in 2005. One of the cheapest ways to reach the goal was with wind power.

The total installed power and the numbers of turbines used in the home market continually increased and demonstrated dramatic technological improvement until 2002. At that time, political power passed to a new center-right administration with less ambitious plans for the use of renewables.

Two replacement agreements have been carried out whereby smaller and badly placed turbines were replaced with bigger turbines. So far 1,300 old turbines with a combined power of 100 megawatts have been replaced by 300 new turbines with a combined power of 300 megawatts.

Besides the replacement agreements, two offshore farms, Horns Rev II and Rødsand II, each for 200 megawatts, have been approved. These farms with 3- to 5-megawatt turbines are expected to be connected to the grid in 2009–2010. By the end of January 2007, Denmark had 5,267 turbines operating with a combined power of 3,135 megawatts.

Without wind, turbines deliver no power. A lesson learned is that a solid backup system with hydropower is a key element to the power system. Thanks to grid connections with the hydro-based systems in Norway and Sweden and a Nordic market for electricity, it is possible to integrate even more wind power.

The center-right administration has changed its attitude toward renewables and has established new goals. Prime Minister Anders Fogh Rasmussen has a vision of a society free of using fossil fuels, owing to concerns about security of supply, the economy and climate change. The task is now in the hands of a new minister for climate change and energy, Connie Hedegaard.

Denmark is preparing for the next rush.

Jesper Tornbjerg is editor of El & Energi, a biweekly published by the Danish Energy Association that reaches 3,571 readers in the power industry in Denmark.

(CONTINUED FROM PAGE 28)

SCHILLING The people who live near the coast would prefer to have the wind turbines where they cannot see them. On the other hand, the technology right now does not permit offshore wind turbines at very deep depths. You cannot construct them in 50 meters of water.

ENERGYBIZ How did Denmark become a world leader in wind power?

SCHILLING How? It wasn't a difficult decision. We wanted to be there starting about 20 years ago. The wind turbines came in here in the mid-'90s.

ENERGYBIZ One of the world's largest turbine makers and one of the world's largest wind blade manufacturers are a short distance apart in western Denmark. Does it ever amaze you that this little country has done so much?

SCHILLING Of course it does. It more or less came out of nothing.

ENERGYBIZ Why can a relatively small country be more successful than a large country such as the United States in deploying renewable energy?

SCHILLING I don't know the United States enough to give you an answer. When it comes to wind energy, big countries like Germany and Spain have succeeded in having a very high share of renewable energy, and especially wind-generated electricity. So I'm not sure that the size of the country is relevant.

ENERGYBIZ What's the most frustrating part of your job? The politics?

SCHILLING I love my job. When it comes to energy we have had a long tradition in Denmark for vast political agreements going from left wing to right wing. Actually all initiatives when it comes to wind energy are a result of vast agreements.

ENERGYBIZ What do you like most about what you're doing?

SCHILLING The results. Recently, we gave a permit for the construction of an offshore wind park. It's maybe funny for some people. I find it interesting to be part of the process that changes society.

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