

Germany's Bright Idea

Thirty years ago, a mountain village sparked a national energy revolution. Now, the political and technological movement may face its greatest challenge yet.

By [Osha Gray Davidson](#)

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Solar panels are a common sight in Schönau, the birthplace of Germany's energy revolution.

Sven Eberlein

Schönau im Schwarzwald, Germany — Coming off the twisting mountain road that cuts through the heart of the Black Forest, the village of Schönau looks like something out of Grimm's fairy tales. Small shops and rustic beer gardens line narrow streets built for horses and foot traffic. Dairy cattle, a rare variety bred here centuries ago to be as sure-footed as mountain goats, graze on steep-pitched pastures high above the village. From the highway north of town, Schönau appears much as it did in the 12th century.

Viewed from the south, however, Schönau looks quite different. The sun glints blue off thousands of rooftop photovoltaic (PV) panels — small, grid-connected power plants owned by residents. The panels generate more electricity on sunny days than the village of 2,500 people consumes. If the bucolic view from the north is a reminder of the past, the second

one, says Schönau resident Ursula Sladek, is a hopeful vision of the future, of a society transformed.



Ursula Sladek

ImageBroker/Alamy

“With something new, a few people must always go first,” Sladek says through an interpreter. “The others come afterward.” She leans forward and stage-whispers in English: “But only if it works.”

If you ran into Sladek at the local Aldi grocery store, the word *revolutionary* would probably not come to mind. In her late 60s, with piercing blue eyes and straight gray hair, Sladek looks like the grandmother and former schoolteacher she is. But in the mid-1980s, in the wake of the Chernobyl nuclear power-plant disaster, she spearheaded a local movement to achieve what she considered a reasonable, even modest, goal: that Schönau residents should decide how their electricity is generated.

Sladek and her neighbors didn’t know it at the time, but their battle with the local utility — and their challenge of the conventional wisdom about how an energy system should run — would become part of a nationwide technological and political movement called the *Energiewende*, or Energy Revolution. The *Energiewende* aims to abandon nuclear power and nearly eliminate fossil fuels as an energy source in Germany, the world’s fourth-largest industrial economy, with a population of 80 million. Nearly three decades after Schönau’s energy upset, about a quarter of the country’s power comes from renewable sources like wind, solar and biomass, the highest percentage of any large industrialized nation. By comparison, the United States gets just 13 percent of its electricity from renewables. Almost 25,000 wind turbines dot the German countryside, producing 52 terawatt-hours (TWh) of electricity in 2014, enough to power the entire country of Colombia. (A terawatt-hour equals 1 million megawatt-hours.) More than a million rooftop solar systems, including those in Schönau, add another 30 TWh to the German grid.



Hans-Josef Fell

Courtesy Hans-Josef Fell

The Energiewende also has sparked enough technological innovations to fill a patent office. Thanks to hundreds of improvements in fields from mechanical design to material sciences to electrical engineering, the average wind turbine installed in Germany in 2014 generates six times as much electricity as those from 1990. Building facades made of solar panels are popping up across the country. In many basements, combined heat and power units burn biofuels or natural gas to generate electricity and capture what was once considered waste heat to keep homes warm through the long German winter.

But for all its achievements, the Energiewende is in danger of losing its way, critics say. They point to a slowdown in the reduction of greenhouse gases, a potential decline in industries that still rely on nuclear power and fears about the grid's ability to handle ever higher levels of power from small, decentralized renewable sources. Even some supporters are concerned. Andrea Lindlohr, a rising star in the Green Party, puts the problem this way: "Germany can do it. The technological hurdles can be overcome. But I'm not sure if Germany will do it because that depends on politics."

The Electricity Rebels

To understand the Energiewende's future prospects, it helps to know a bit about its past. In late April 1986, Sladek was hobbling around her home with a broken leg, the result of a skiing accident, when she heard a news report about an explosion at a Soviet nuclear power plant. German officials assured the public there was nothing to worry about. "Chernobyl is 2,000 kilometers away," Germany's interior minister told the nation. "There is no danger." He was wrong. The next day, radioactive particles from the catastrophic explosion at Chernobyl began falling on Schönau. Sladek and the other residents were warned to stay indoors.

In the months after the disaster, Sladek and her neighbors decided that it made no sense to continue relying on power generated by nuclear plants. They asked the regional power company to divest from nuclear. It refused.

"At first we just wanted to make sure this never happened again," Sladek says. "Then we realized that the only way to be sure was to take things into our own hands."



The Chernobyl nuclear plant explosion in 1986 sparked a backlash against nuclear power in Germany.

Vladimir Repik/Reuters/Corbis

At the time, what Sladek knew about electricity didn't go much beyond changing a light bulb. Over the next several years, Sladek and her allies learned about power generators and the grid — that mind-numbingly complex web of wires, power substations and transformers. The German grid, like the one in the U.S., was designed more than a century ago around a simple organizing principle: Electricity generated by a few massive power plants needs to be delivered to millions of users, large and small, across an entire region. That centralized system, with power moving in one direction from plant to user, worked well enough as long as there was a dependable amount of electricity to meet demand at any given moment (called baseload). Sladek's proposal would flip this model on its head. Renewable sources — such as rooftop solar panels, which sometimes generate more power than a household uses — required a decentralized system in which electricity flows in *both* directions, from many small generators into the grid, and from the grid to consumers. And the system had to be flexible enough to handle wildly varying power loads.

Solar and wind power generate electricity only when the sun shines or the wind blows — a characteristic that's called "undependable" if you're an opponent of renewables, or "variable" if you're a supporter. Before real change could come, researchers would need to develop new technologies to improve renewable energy's integration into the electricity mix.

Feed-in Tariff (FiT)

Under a FiT system, homeowners with solar panels are paid for the extra power they generate. They can still use power from the grid when the sun isn't shining.



Alison Mackey/Discover, Chombosan/Shutterstock

The Schönau group also would have to navigate an even more complex web: the countless regulations that would need to be revised to allow the shift from a centralized system to a decentralized one. Schönau's push for what's called *BürgerEnergie* — energy produced by citizens — meant challenging the interests of the powerful electrical utilities that were content with the monopolistic and highly lucrative status quo.

“Perhaps it was good we didn't know what we were getting into back then,” Sladek admits with a smile.

The Schönau residents came up with an ambitious plan: to buy their local grid and run it themselves. They began with a campaign to raise \$2.4 million, the amount they believed was required to purchase the system. The owners responded by claiming the grid was worth at least \$5.2 million. (A judge later put the fair market value at \$2.2 million.) By the early 1990s, the David-and-Goliath battle was on and soon drew the attention of the national media. A reporter dubbed the Schönau group the *Stromrebellen*, the electricity rebels. The name stuck.

At the end of it all, the rebels prevailed, and they had a new name: Elektrizitätswerke Schönau (EWS), the Schönau Electric Power Co., with Sladek as its president. By 1996, through a local network of solar panels and small hydroelectric dams, EWS supplied “green” power to the entire village.

The Stromrebellen was a major victory, but it was an isolated one. Not every town could afford to buy its grid even if it wanted to. And generating electricity from solar panels remained wildly expensive, with the solar modules priced at nearly \$7 a watt in 1996 — a victim of what Germans call the “devil's circle.” Without economies of scale, in which mass production drives down cost, few could afford solar panels. But lacking sufficient demand, no solar manufacturer would ramp up production enough to lower prices. Without a new approach, the Energiewende would remain a green fairy tale set deep in the Black Forest.

Bavaria's Big Idea

In 1993, while Sladek was still battling for control of the local grid, some 200 miles to the northeast in Bavaria, Hans-Josef Fell was orchestrating a different kind of energy overhaul as a member of the town council of Hammelburg (population 12,000), his hometown. A physicist by training, a science teacher by vocation and an environmental and peace activist, Fell was intrigued by all facets of renewable power. He was convinced early on that solar and wind power presented an alternative — not just to fossil fuels and nuclear power, but to wars over oil and to the potential for nuclear conflict.



Bavarian rooftops collect the sun's energy with solar panels. Germany leads the world in installed solar capacity.

Stefan Kiefer/imageBroker/Corbis

As a local politician, Fell drafted legislation to encourage the use of renewables in Hammelburg using a feed-in tariff, or FiT. Under the system, residents who installed solar panels received an above-market price for each kilowatt-hour of electricity they supplied to the grid. The amount of the incentive was designed to fully compensate the owners for the cost of their solar installation and, crucially, a little bit more.

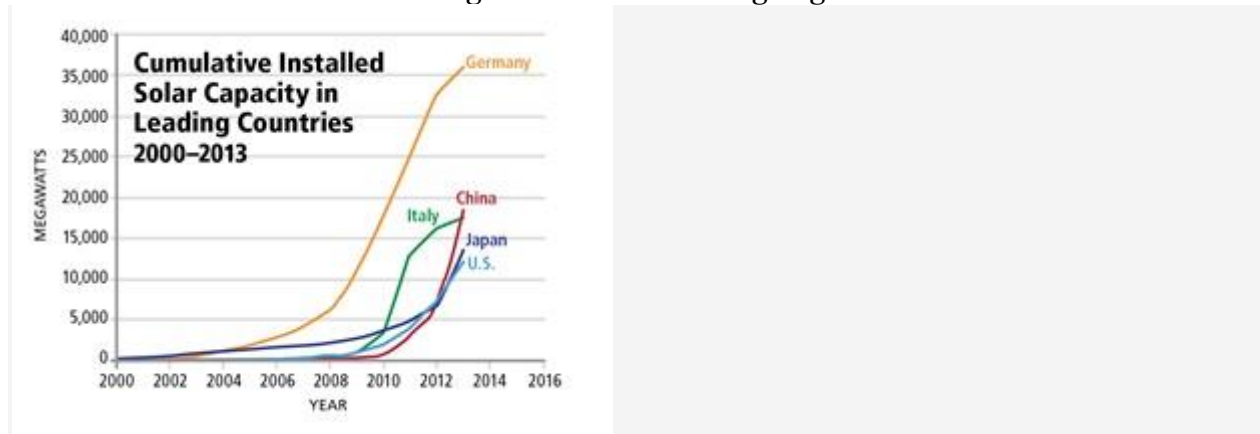
Fell may have been a bearded, longhaired *Ökofreak* (ecofreak), but he understood that most Germans weren't — especially in deeply conservative Bavaria, where the right-wing Christian Social Union (CSU) had governed almost continuously since 1946. Fell knew he couldn't sell an energy revolution to his fellow Bavarians by quoting Gandhi, so he channeled Adam Smith instead.

"You must make the FiT high enough so that the profit is possible," Fell says, explaining his thinking at the time. "And you must guarantee the FiT for 20 years so that it will be a secure investment."

Bavaria and BürgerEnergie went together like sauerbraten und Pilsner. That's partly because Bavarians are equally opposed to market-skewing big government and

monopolistic businesses, on the grounds that both stifle competition. Take Josef Göppel. He's a leader of the conservative CSU, but when he talks about the Energiewende, he sounds more like Michael Moore.

"The reason that so many Germans are interested in pursuing renewable energy is a simple one," Göppel once told a reporter. "It is the desire for independence from big companies." Hammelburg's FiT applied only to the first 15 kilowatts of solar panels installed on local roofs, a size that Fell today calls "ridiculously small." But Fell's law was a test run, the first of its kind in the world. And it succeeded: The 15-kilowatt cap was quickly reached, and residents who didn't act fast enough were left clamoring to get in on the action.



Alison Mackey/Discover after Earth Policy Institute from BP

Other towns followed suit, but like Schönau's Stromrebellin, the impact of the Hammelburg experiment was primarily local. It was time to up the ante. The movement got its chance to go national in 1998, when Bavarians sent Fell to Berlin to represent them in the German national parliament. The very next year, party leaders tapped Fell, a member of the Green Party, to draft a new German energy policy that put renewables front and center. He had his work cut out for him: For years, opponents had questioned the grid's ability to handle large amounts of electricity generated by renewable sources. Above 4 percent of total generation, experts cautioned, the grid would disintegrate, plunging cities into freezing darkness and destroying the bulwark of the German economy — its energy-intensive manufacturing sector.

Fell was eager to prove the naysayers wrong. He knew his first task was breaking the devil's circle. Fell's solution was the Renewable Energy Sources Act (EEG), adopted in 2000. The new law created a national FiT (paid for by a monthly surcharge added to utility bills) to encourage mass deployment of renewables. It also aimed to cut emissions of greenhouse gases. The next year, lawmakers mandated a nuclear phaseout.

The EEG was a major victory, but many supporters wondered if its goals — particularly its renewables target — might be unrealistic. Before the EEG, just 2.6 percent of the country's electricity was generated by renewables — virtually the same meager amount as in the United States. As a top utility executive later put it, "[The Energiewende] is a political wish that is without a realistic view of what is achievable."

To everyone's surprise, however, the Energiewende proceeded according to Fell's plan. Germans jumped at the opportunity to fight climate change, phase out nuclear power, make a profit and free themselves from the "Big Four" utilities. In 2002, after just two years of the EEG law, the share of renewable power on the German grid doubled to 5 percent, far ahead of schedule and without any cities going dark. By 2007, renewables claimed 10 percent of the grid — more than twice the amount predicted to crash it. And even without goals for citizen power, 50 percent of all renewable generation came from ordinary citizens. The Big Four's share was just 6.5 percent.



Stuttgart has become a hotbed of renewables research. Here, a worker checks a solar coating machine at the ZSW facility.

ZSW

While the utilities ignored the Energiewende, the FiT was transforming the devil's circle into a virtuous one. To keep up with German demand, manufacturers around the globe ramped up production of solar panels, causing the price of going solar to plummet worldwide. Solar modules that cost \$3 per watt in 2000 sold for half the price in 2010. The price of a rooftop system in Germany that went for \$23,000 in 1990 had plummeted to \$2,200 by 2013. Market competition spurred researchers to squeeze every last electron they could from the 1,000 watts of solar energy falling on each square meter of the planet's surface. When the EEG was passed in 2000, the most efficient PV cells converted about 30 percent of solar radiation to electricity. Today, PV cells can achieve efficiency rates over 44 percent by combining layers of different elements (gallium, germanium and indium, among others)

that together generate electricity from across the spectrum, from ultraviolet to infrared radiation.

As renewable generation increased, supporters amended the EEG to increase its renewables targets: up to 12 percent by 2010 and 80 percent by 2050. Skeptics merely upped their estimate for when the sky would fall. German Chancellor Angela Merkel cautioned that “the share of renewable energies in electricity consumption to a 20 percent increase is not very realistic.”

Merkel’s 20 percent threshold was reached and then surpassed, however, and new BMWs and little bottles of Bayer aspirin continued rolling off German assembly lines, *eins . . . zwei . . . drei*, without interruption.

But the critics aren’t entirely wrong. The Energiewende does face some hard choices — and they’re coming up fast.

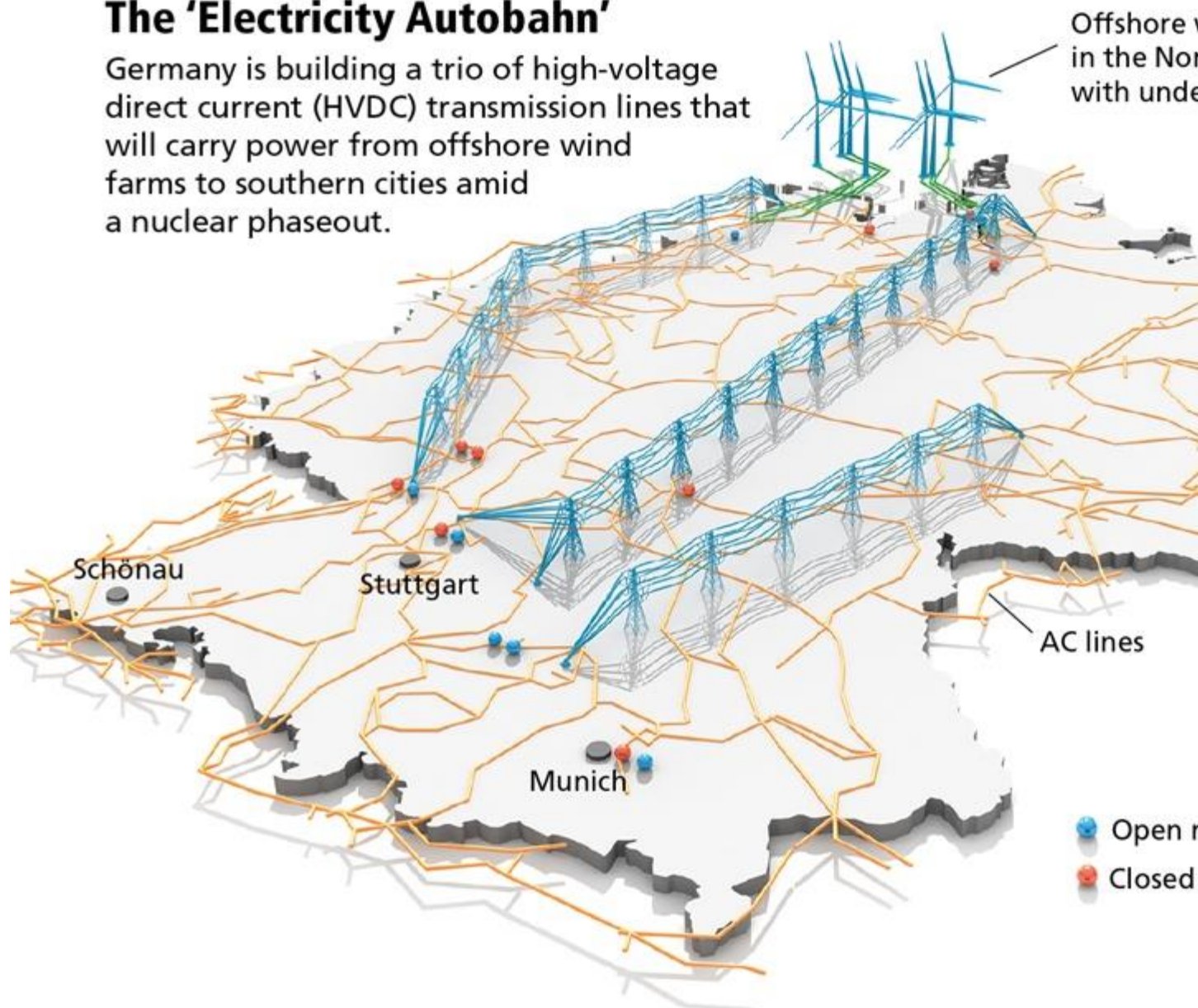
Tech City

Stuttgart, in southwestern Germany, has long been synonymous with industry. Sometimes called the Original Motor City, Stuttgart is the birthplace of the automobile. Many of the area’s 1 million workers are employed by the giant automakers headquartered here, including Mercedes-Benz and Porsche. Despite its deep fossil-fuel roots, Stuttgart is speeding into the energy future. The center of engineering innovation in Europe, the Stuttgart area spends a greater percentage of its gross domestic product on research and development than anywhere in Germany. It leads the nation in patent applications because of the high concentration of high-tech research institutes, including the Center for Solar Energy and Hydrogen Research (ZSW).

ZSW’s managing director, Frithjof Staiss, has spent his adult life studying the promise — and challenges — of a renewable energy economy. For Staiss, the Energiewende marks a historical and technological divide.

The 'Electricity Autobahn'

Germany is building a trio of high-voltage direct current (HVDC) transmission lines that will carry power from offshore wind farms to southern cities amid a nuclear phaseout.



Bryan Christie Design

“In the old world, you delivered power from a big utility to the small user,” Staiss says, sitting in his utilitarian but comfortable third-floor office on Stuttgart’s *Industriestrasse* (Industry Street). “Now the consumer at the end of the line adds PV. That changes things.” Power that flows both to and from homes with solar panels, and that dips and surges depending on cloud cover and wind speed, requires a more flexible system.

One of the most important changes needed, Staiss says, is an overhaul of the German grid. Its 557,000 small transformers were intended for power that flowed in only one direction. As part of the *Energiewende*, German engineers have developed bidirectional transformers to replace the existing ones, as well as a host of other technological innovations to meet the

new demands of an influx of renewable energy, says Maïke Schmidt, head of ZSW's Department of Systems Analysis. Superconducting cables minimize energy loss, and power-to-gas systems store excess electrical generation as hydrogen or methane.

"In a country like Germany, we need these innovative developments to sell to other countries," she says. "That is our core business. The Energiewende is an opportunity to have more innovation and sell it to the world." German businesses are making the most of that opportunity, with exports of renewable energy technologies totaling \$30 billion in 2013. Even industrial giant Siemens, which built Germany's first nuclear power plant, has been transformed by the Energiewende. In September 2011, the company that helped build all 19 of Germany's nuclear power plants announced it was exiting the business completely. Siemens turned its attention to the lucrative global offshore wind-power market, predicted to reach \$142 billion a year by 2020. Three months after its nuclear exit, the company announced plans to install 80 giant wind turbines in the North Sea, enough to power 300,000 households and cut carbon emissions by 815,000 tons a year.

With the last German reactor scheduled to close down in 2022, the south, which has depended on nuclear reactors for nearly half its electricity, desperately needs that power. It stands to benefit greatly from the next phase in the Energiewende, which involves building an "Electricity Autobahn" — a trio of high-voltage direct current transmission lines (HVDC) spanning 2,000 miles to carry huge amounts of electricity from offshore wind farms in the North Sea down to the heart of Germany's manufacturing region.

The undertaking, estimated to cost \$22 billion, is controversial. Economist Claudia Kemfert points out there's plenty of sun and enough wind to greatly expand renewable generation in the south. And two of the three HVDC lines, she adds, will carry electricity from polluting coal-burning plants, which is at odds with the objectives of the Energiewende.



Offshore wind farms, like this new Siemens project, are expanding in the North Sea, off Germany's northwest coast. But the large pulses of intermittent power they generate are not easy to integrate into the grid.

Siemens AG/Tennet

Some also see the Electricity Autobahn as a threat to community energy and democratization. A government-created FiT will pay for power from offshore wind at rates more than double that paid for onshore projects.

Faced with a shrinking market share and dwindling profits, the Big Four utilities are waking up from their fossil fuel-induced slumber. Last November, one of Germany's largest utilities, E.ON, stunned energy watchers by announcing a shift toward clean energy and acknowledging that its old business model "can no longer properly address these new challenges" brought on by the Energiewende. "We are seeing the emergence of two distinct energy worlds," says E.ON CEO Johannes Teysen, echoing Staiss' division of the "old world" and the "now." Three decades after Schönau's Stromrebell, E.ON was choosing renewables.

Energy writer and analyst Craig Morris says many activists see the Big Four as interlopers trying to hijack a revolution they first ignored and then opposed. "The grass-roots

movements see the corporations as saying, ‘Excuse me, but I’ll have that energy sector back,’” now that proponents have made the Energiewende work, he says.

That success is especially evident in Schönau, where Sladek’s EWS is now the primary power provider for 170,000 households in every German state. Customers anywhere in Germany can choose EWS as their utility and pay for power EWS purchases from green energy generators throughout the country. That model could be challenged, however, if the energy landscape is once again dominated by powerful utilities.

A U.S. Energiewende?

As the Energiewende has gained momentum, it has become a model for other countries; more than 50 have copied the FiT alone. But as energy expert John Farrell notes, neither the FiT nor any of the Energiewende’s other elements has been widely adopted in the U.S.

Farrell, with the Minnesota-based Institute for

Local Self-Reliance, has spent years designing and promoting an Energiewende for the United States, earning him a reputation as the “guru of distributed generation” in the U.S.

A host of differences between Germany and the U.S. makes an energy revolution more challenging here, he says. With a population density one-sixth that of Germany, the U.S. grid must traverse tremendous distances to bring electricity to its people and industries.

Most Americans can’t pick power suppliers based on their use of green energy, or anything else for that matter — with a handful of exceptions, utilities operate as legal monopolies.

And while Germany is phasing out nuclear power, five new reactors are under construction in the U.S., adding to its existing fleet of 99 commercial reactors. Unlike Germany, the U.S. has vast deposits of fossil fuels owned by powerful corporations. Partly because of that drive to keep drawing greenhouse gas-producing fuels from the ground, the U.S. lags far behind Germany in the share of electricity generated from renewable sources.

That’s especially unfortunate, Farrell says, because the U.S. has everything it needs for an energy transformation, including a surfeit of untapped solar, wind and other renewable resources that far outstrip Germany’s. A study by the National Renewable Energy Laboratory concluded that fully 80 percent of electricity could come from renewables by 2050.

The U.S. is ahead of Germany in another crucial area: developing low-cost, efficient energy storage. Researchers at Harvard, for example, are perfecting an organic flow battery that can store a full day’s production of electricity from solar or wind farms, a development that could play a key role in integrating variable electrical generating sources into the grid.



Nuclear power has attracted new interests in the U.S. Two reactors under construction near Waynesboro, Ga., will be the first built here in 30 years.

Georgia Power

Given these advantages in resources and technology, Farrell says there's only one thing holding the U.S. back: political will. "We need to design a system for the 21st century," he says. "Germany has given us a great example of what's possible when people have a vision." More specifically, Germany is an example of what's possible when people stick with a vision. The Energiewende has its roots in an American energy revolution that began under President Jimmy Carter. In February 1977, two weeks after taking office, Carter urged Americans to turn down their thermostats and announced a plan to move the U.S. away from fossil fuels and toward a system based on solar and other renewable energy sources. Carter installed solar thermal panels on the White House roof and pumped millions in R&D into alternative energy development.

For a few years, the U.S. led the world in developing renewable energy. But after Ronald Reagan defeated Carter in 1979, America made an abrupt U-turn. In the next few years, the White House's solar panels were removed, fossil fuel prices dropped, and federal support for renewable energy dried up.

The U.S. may have lost its vision of a renewable energy future, but an ocean away, Hans-Josef Fell and others were inspired by America's flirtation with renewable energy.

"There was wind power in California and solar power on the White House," Fell recalls. "I thought, 'Oh, this is wonderful! Why can't we have this in Germany?'" He smiles and adds, "And, of course, now we do."