

# New Technologies in Spain



## Wind Power

As one of the largest wind energy producers in the world, Spanish companies lead the global wind market.

## Innovation in Motion

Spain is now the world's eighth-largest economy and the fastest growing in the European Union. It represents more than 2.5% of the world's total GDP and a third of all new jobs created in the Eurozone last year. Spain is fast becoming a leader in innovation and generating advanced solutions in the industries of aerospace, renewable energies, water treatment, rail, biotechnology, industrial machinery and civil engineering. Spanish firms are innovators in the field of public-works finance and management, where six of the world's top ten companies are from Spain. Where innovation thrives, so will the successful global enterprises of the 21st century.

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Canary Islands Wind Farm

# Wind Power in Spain

**Spain's installed wind-power capacity makes it the second-largest wind-energy producer in the world, and Spanish companies lead the global wind-power market. This is the first in an eight-part series highlighting new technologies in Spain and is produced by *Technology Review's* custom-publishing division in partnership with the Trade Commission of Spain.**

For governments and companies committed to the idea of powering our technological age with clean, renewable energy, wind power is a natural fit. Wind-powered technology has matured over the past two decades, driving down costs and driving up efficiency.

Today, countries like Denmark and Germany have demonstrated that integrating a power source such as wind into the grid can easily provide more than 20 percent—sometimes significantly more—of the power needs of a given region.

Now, Spain has joined them as a wind-energy powerhouse. With 9,000 megawatts of installed capacity, Spain ranked second in the world in 2005 in total installed capacity, behind Germany (16,000 megawatts) and ahead of the United States (6,500 megawatts).

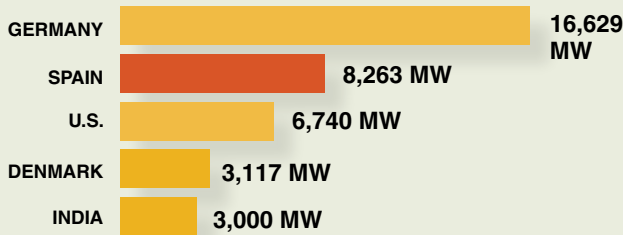
Furthermore, Spanish companies, both turbine manufacturers and wind-farm operators, are among the leaders in the global wind-power market. Some examples are Gamesa Eólica (world's second largest turbine manufacturer), Iberdrola (world's largest wind-farm owner and operator) and Acciona Energía (world's largest wind-farm builder and developer).

What's more, from the dense industrial base already present in Spain, many companies have sprung up to develop technologies befitting the needs of the wind industry, in fields such as composites, steel, electrical components, and wind-data loggers.

With 30 percent annual growth in the sector, and a clear commitment from the Spanish government to encourage private investment, technological advances, and grid development, Spain is poised to continue this trend toward powering its

## Top Five Countries with Highest Total Installed Wind Capacity

The top five countries listed below account for over 67 percent of total wind energy installation worldwide.



Source: 2004 American Wind Energy Association

economic and technological growth with the strong winds that sweep over the country's mountains and plains.

### Wind Power Is an Economic Winner in Spain

One reason Spain stands out from other European leaders in wind power, according to Corin Millais, head of the European Wind Energy Association, is that environmental issues have not been the major driving force behind this expansion.

"It's much more a story about regional growth, economic deployment, driving an economy that requires increasing amounts of energy," said Millais. "There's more of a fundamental value of wind power to an economy in Spain than in northern Europe."

And the figures in Spain support this claim. When the first renewable energy plan was enacted in the late 1990s, energy demand was predicted to increase by 1.2 percent per year. Instead, demand has grown by around 3 to 4 percent. In addition, wind power has grown much more rapidly than expected, with installed capacity increasing by about 30 percent per year. Currently, the government estimates that 300 to 400 Spanish companies are involved in wind power, supporting about 30,000 jobs, with that number expected to double by 2010. This healthy job growth experienced as well in other industries has been crucial: a decade ago, the unemployment rate in Spain was more than 20 percent; it has since fallen to 8.5 percent in 2005.

In addition to economic and technological development, wind power in Spain has transformed the countryside. All along northern Spain's famous Camino de Santiago (St. James' Way), an ancient Christian pilgrimage route through the Pyrenees, plains, and along the coastline, ending at the burial site of the martyr St. James in Santiago, pilgrims travel past modern-day windmills. But the transformation has been more than visual, for the income that wind farms bring to poorer rural areas has literally saved some communities.

The goals of the Spanish government in promoting wind are twofold. First, to reduce dependency on imported oil. "In relation

to other countries in the OECD and the European Union, Spain is much more dependent on foreign oil," said Javier Garcia Brea, until fall 2005 director general of the Spanish Institute for Energy Diversification and Saving (IDAE), part of the Spanish government. "The country is very vulnerable to variations in the oil market. So, at the first analysis, the renewable energy plan has focused on increasing energy independence in Spain."

The second goal, according to Garcia, is equally important: reducing carbon dioxide emissions in line with the goals of the European Union. According to IDAE figures, if Spain meets its goal of generating 30 percent of its electricity needs from renewable power by 2010, with half of that amount coming from wind power, it will reduce emissions of carbon dioxide by 77 million tons.

### A Global Trend

The rapid growth in wind-generated power in Spain reflects a global trend. According to the Global Wind Energy Council (GWEC), wind-power capacity has been increasing at least 20 percent each year between 2000 and 2005, and wind turbines today can produce 200 times more power than equivalent turbines two decades ago.

The wind-power sector is coming of age. Its energy is relatively cheap to produce, some of its technologies have matured—even though there are several breakthrough technologies being developed in Spain—and more countries and communities are turning to wind to reduce both their dependency on foreign fuel and their contribution to global warming. The GWEC expects the costs of power from wind to be competitive with those from conventional fuel within a decade.

In many areas, wind power is still more expensive than other conventional fuels, though costs have plummeted since the 1980s (when wind power was in its infancy). Today, according to the American Wind Energy Association (AWEA), in the windiest sites, wind power may sell for around 4 to 5 cents per kilowatt hour, which compares well with energy prices in new coal or gas-fired plants. Recent fluctuations in steel prices have kept wind power prices steady, rather than continuing this downward trend; but natural gas costs have risen in the same period, making wind increasingly attractive.

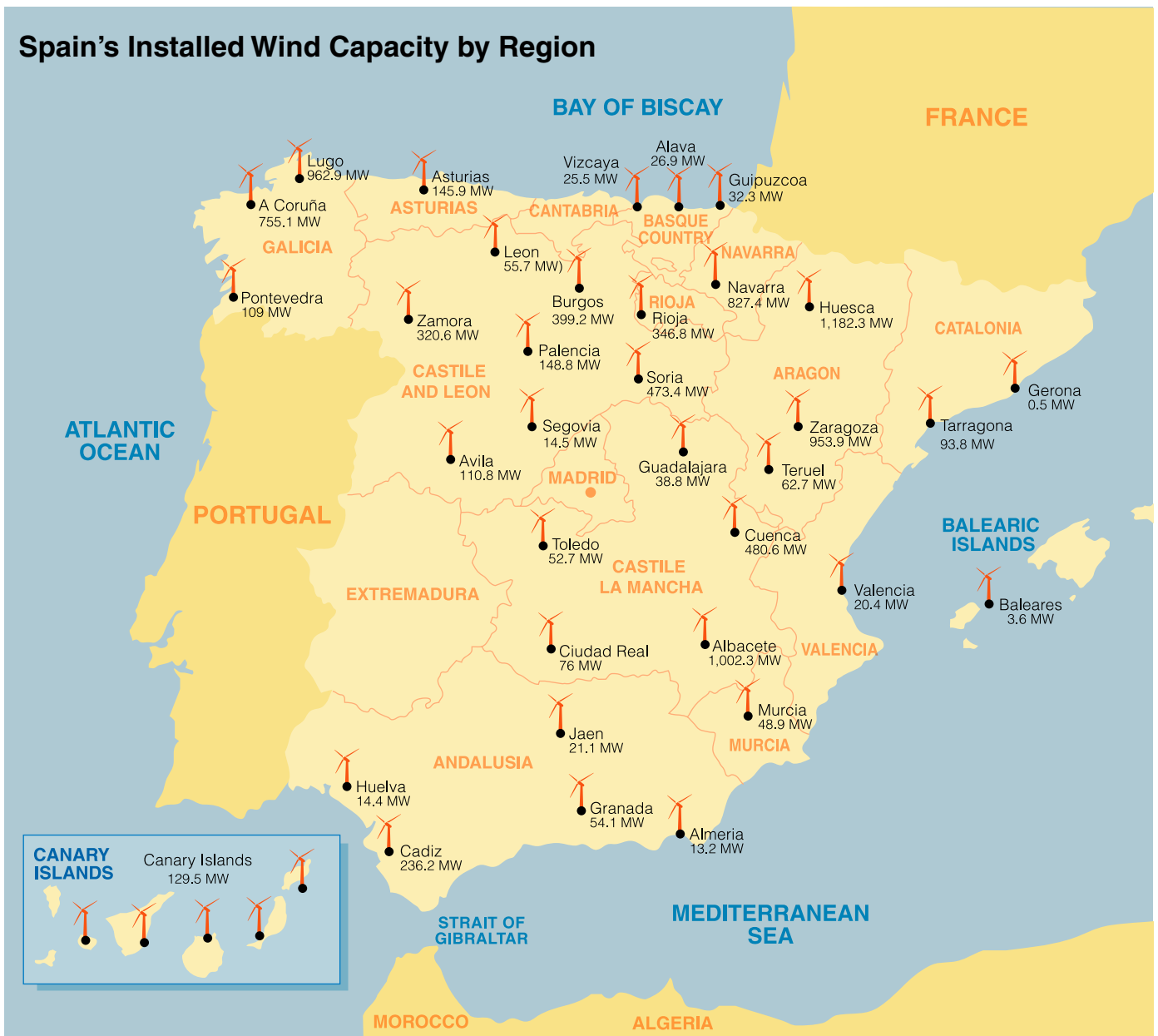
Today there are more than 50,000 megawatts of installed wind-power capacity around the world, up from only 17,000 megawatts a decade ago.

### Surpassing Goals in Spain

The Spanish story reflects those dramatic changes. In 1999, the government set a goal for wind power at 9,000 megawatts of capacity by 2011. By midway through 2005, however, more than that amount of wind power had already fed into the Spanish grid, compared with only 800 megawatts in 1999–2000.

In response, in August 2005, the Spanish government once

# Spain's Installed Wind Capacity by Region



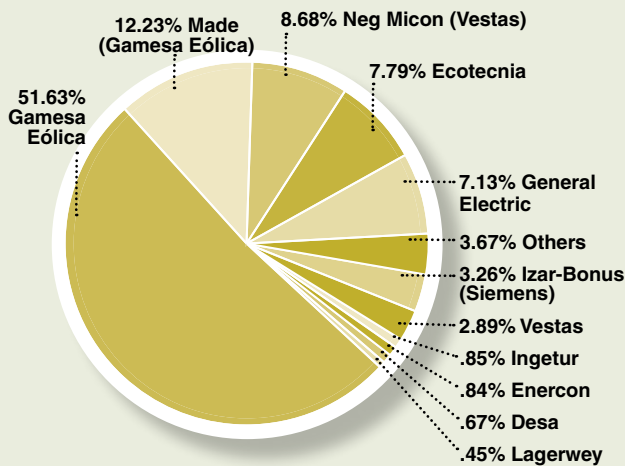
## Wind Power in Spain

Market Snapshot	Economic Growth
<ul style="list-style-type: none"> <li>Total capacity by end of 2005* ..... <b>9,500 MW</b></li> <li>Total capacity target for 2011 ..... <b>20,000 MW</b></li> <li>Growth rate 2003–2004 ..... <b>33%</b></li> <li>Contribution to national power supply ..... <b>6.5%</b></li> <li>Peak contribution to Spanish electricity supply ..... <b>24%</b></li> <li>Equivalent number of households supplied ..... <b>4 million+</b></li> <li>Peak generation in 2004 ..... <b>86,775 MW</b></li> </ul>	<p><b>Employment</b></p> <ul style="list-style-type: none"> <li>Total jobs in wind industry in 2004 ..... <b>30,000</b></li> <li>Jobs projected for 2011 ..... <b>60,000</b></li> </ul> <p><b>Top Growth Regions</b></p> <ul style="list-style-type: none"> <li>Castile La Mancha ..... <b>731.5 MW</b></li> <li>Castile and Leon ..... <b>576.9 MW</b></li> <li>Galicia ..... <b>511.5 MW</b></li> <li>Aragon ..... <b>178.3 MW</b></li> </ul>

Source: AEE/IDAE/REE \*Trade Commission of Spain

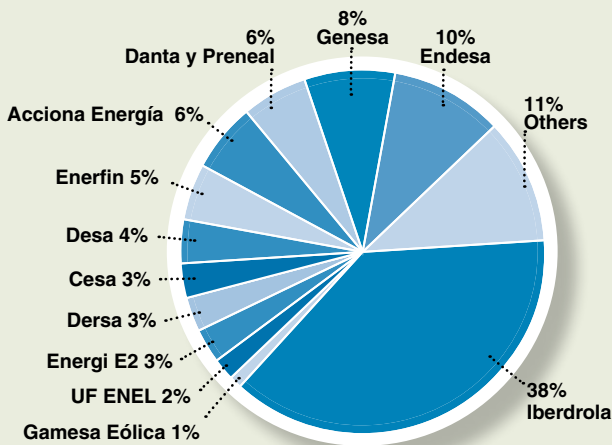
## Spanish Market Share

### Turbine Suppliers



Source: 2004 AEE

### Wind-Farm Developers



Source: 2004 AEE

again reconsidered its goals. More ambitious numbers were needed to reflect the reality of the sector and to assure businesses that the government remained committed to this growth. As a result, a new goal of approximately 20,000 megawatts was set, a leap of almost 50 percent.

“I believe this is achievable for a very fundamental reason,” said Garcia. “In Spain right now there is social and political consensus in favor of wind power. And that, together with the private-sector initiative, makes us very optimistic regarding the future of wind power.”

Today, wind power fulfills about 6 percent of the country’s electricity needs (in the United States, for instance, the AWEA’s goal is to reach the 6 percent level by 2020). In Navarra, one of the autonomous regions that hosts a great deal of wind-power development, wind can fulfill nearly half of the region’s

power needs. “We’re talking about a sector today that is one of the most dynamic parts of Spanish industry,” said Garcia.

### Creating and Developing the Wind-Power Market in Spain

Spain has created some of the world leaders in this industry. In the early 1980s, turbine manufacturer Ecotecnia was one of the first companies to install a wind-power generator in Spain. The company began in the renewable energies sector, then focused on wind generation when Director Antoni Martinez decided to follow the examples of Denmark and California.

According to Martinez, interest and business in wind-power began to pick up in 1992 and took off in 1997, when the Spanish government instituted a new electricity act. With the act, the government set a fixed premium every year according to the baseline cost of power from electric utilities, with a premium to ensure profitability for wind farms. In addition, utilities are obligated to buy any wind power produced and integrate it into the national grid.

Ecotecnia is still a major player in the Spanish wind-power market, selling turbines in Spain and around the world. What’s more, the market has expanded to create international power-houses like Gamesa Eólica, major national energy companies such as Iberdrola, and Acciona Energía, the renewable energies subsidiary of the Acciona Group, a major Spanish business group with thousands of employees.

Iberdrola set up its first wind farm in 2000; already by 2005, it had become the largest owner of wind farms in the world.

Meanwhile, Acciona Energía is the largest wind-park constructor and developer in the world. The company credits its success to its beginnings in the region of Navarra in 1994. “We were pioneers with a plan of implementing wind power in Navarra when wind wasn’t yet looked on as an important economic sector,” said the company’s director of marketing, Jose Arrieta.

“This is giving real corporate credence to the industry. It’s bringing in capital and financial sophistication,” said Godfrey Chua, principal analyst of Emerging Energy Research, an independent organization that provides market research about wind power. “It’s also bringing a level of scale to the industry that it has never seen before.”

Most helpful in Spain, according to companies and the government, has been the stable environment created by government laws first passed in 1997 and updated as needed. The Spanish government sets the cost of wind power each year, based on the costs of power from conventional sources, with an added premium for wind to ensure a return on their investment.

Wind-power operators have two options: to sell electricity at a fixed rate that includes a tariff, or to sell freely in the market and receive a special premium on top of the market price. Each year, this premium is adjusted appropriately.

## The Spanish Model

Similar to other pricing models in Europe, the Spanish model is different from the one pursued by the U.S. government. In the U.S., a national production tax credit provides a tax break for companies for 10 years after a wind farm is established. This production tax credit must be renewed in Congress—and often expires before it can be renewed. Thus, the market in the United States is subject to fluctuations, as developers and manufacturers, on renewal years, wait to see what Congress will decide.

This dynamic played out in 2004, when only about 400 megawatts came on line in the United States. The U.S. market has since picked up speed once again, and projected U.S. wind developments for 2006 are at about 2,500 megawatts. The tax credit is set to come up for renewal again at the end of 2007.

“The Spanish model guarantees the profitability of Spanish companies investing in wind power,” said Garcia. “Because of this, major companies in Spain have bet on wind power. Those two factors together—the premiums and the investment from major companies—have contributed to what I would describe as the spectacular development of wind power.”

## Evolution of the Turbine

Over the past two decades, turbine manufacturers have experimented with different ways of transforming the energy from wind into power. Although models produced have ranged widely in size and shape, the one that has caught on and proved most

effective and reliable is the three-bladed vertical model.

Improvements in design and efficiency have allowed manufacturers to construct larger, more powerful models, so that from a few hundred kilowatts of power years ago, turbines can now generate several megawatts.

“The fact that you have much taller wind turbines allows you to put the blades where the wind speeds are higher and more stable,” explained Christine Real de Azua, a spokesperson for AWEA. “A larger blade means you have a larger swept area. These factors mean that, though the cost of a single turbine is higher, the output is so much greater.”

The standardized shape of wind turbines today, and the general trend towards larger and more powerful individual turbines, demonstrates the maturity of the technology, said Chua of Emerging Energy Research. It also means that individual

companies distinguish themselves by incremental developments in technology that allow them to keep costs down, such as reducing the weight of the turbines and increasing their efficiency.

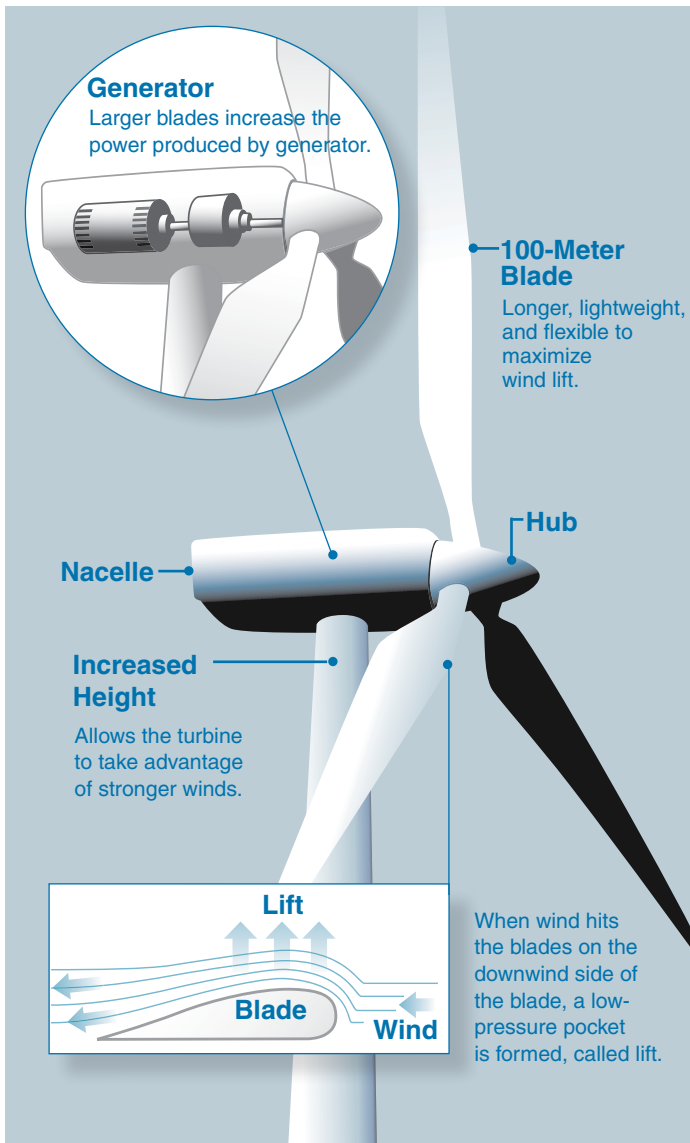
In Spain, Gamesa Eólica has grown to become the country’s largest turbine manufacturer and the second largest in the world. Company sources say that a number of factors have led the company to take the lead. For one, they say, they have vertically integrated within Spain, designing the individual components and overseeing the manufacture of nearly all of them in the country.

To edge ahead of the competition, Gamesa Eólica has focused on pitch technology, in which blades can rotate by fractions of a degree to best take advantage of the wind speed, or to

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## Spanish Companies at the Top of the Global Market

Company	Specialty	Currently Operating in	Expansion Plan
<b>Acciona Energía</b> Largest wind-park constructors in the world <a href="http://www.acciona.es">www.acciona.es</a>	<ul style="list-style-type: none"> <li>• Wind-farm operation</li> <li>• Manufacturing of turbines</li> <li>• Developing wind-power facilities</li> </ul>	Australia, Canada, France, Germany, Morocco, Spain, United States	China, Ireland, United Kingdom
<b>Ecotecnia</b> Second largest manufacturer in Spain <a href="http://www.ecotecnia.es">www.ecotecnia.es</a>	<ul style="list-style-type: none"> <li>• Manufacturing turbines</li> </ul>	Cuba, France, India, Japan, Portugal, Spain	China, Italy
<b>Gamesa Eólica</b> Second-largest turbine manufacturer in the world <a href="http://www.gamesa.es">www.gamesa.es</a>	<ul style="list-style-type: none"> <li>• Manufacturing turbines</li> <li>• Wind-farm operation</li> </ul>	China, Egypt, Germany, Ireland, Italy, Japan, Korea, Portugal, Spain, United States	Greece, Taiwan, United Kingdom
<b>Iberdrola</b> Largest wind-farm operator in the world <a href="http://www.iberdrola.com">www.iberdrola.com</a>	<ul style="list-style-type: none"> <li>• Wind-farm operation</li> </ul>	Brazil, France, Greece, Italy, Mexico, Portugal, Spain, United Kingdom	Continuing to expand in Europe and Latin America



## Innovative Turbines

Spanish companies are leading the way in turbine innovation by increasing the size of turbines while reducing turbine weight. The new longer (100-meter) blades can reach halfway down the length of the tower and help to maximize wind lift. Newer blades are also made of lighter, more flexible material, and in many turbines the blades shift angle, or pitch, either to catch more wind or to angle away in winds that are too strong. Spanish researchers are also developing new technologies to take advantage of wind changes and split-second power outages.

slow down to prevent a power overload. In addition, the company integrates variable speed into all turbines.

Gamesa Eólica believes that Spain's unique geography also provides a benefit to Spanish companies competing in the international market. As one Gamesa Eólica source put it, "Spain is a complex terrain, so our turbines have been reinforced to cope with that. Spain has many more mountains or hilly areas than central Europe, and this has helped us to design robust turbines that we can build anywhere in the world."

Although it is a much smaller company, Ecotecnia, Spain's second-largest turbine manufacturer, is highly competitive, focusing on reducing the weight of its turbines. They are currently developing a three-megawatt turbine with 100-meter blades, the largest of its line, that will be installed in early 2006. This giant turbine is designed for flat plains, where the increased height allows the turbine to take advantage of stronger winds. Like Gamesa Eólica, Ecotecnia is expanding around the Mediterranean region and into Asian and American markets.

Ecotecnia director Martinez says they're also researching new technologies that take advantage of minute changes in the wind and can cope with split-second outages in power. In the past, such dips in voltage, caused by brief failures in a traditional power plant or a disturbance such as a tree falling on a power line, would cause a wind turbine to disconnect from the grid.

Among the other manufacturers, MTorres stands out for its innovative technology. Its gearless and pitch-controlled windmills claim to increase performance and reliability, reducing maintenance costs. Furthermore, their offshore projects merge clean power resources with seawater desalination.

## Challenges Ahead

Hurdles remain in the effort to make wind power even more successful in four main areas: variability, grid issues, centralized control center, and meteorological prediction.

Critics of wind power point to the inherent variability of the energy source as one of the main stumbling blocks to integrating it into the existing system. Yet the integration of wind in Spain has proven that variability is not such an impossible challenge.

"It's something of a red herring," said Real de Azua of AWEA. "No matter what new technology you bring on, a new nuclear plant or anything else, there's always the possibility that it's going to break down at some point, or be taken off the line for repairs and maintenance. No matter what, you have to have some margin of safety, of different types of plants that can meet the supply."

Godfrey Chua of Emerging Energy Research acknowledges that variability is a hurdle that wind power must overcome around the world. "The point is that wind power was never presented as the one power source, replacing all nuclear or coal. It's really meant to be complementary," said Chua.

In fact, while Spain has already reached 6 percent of energy



needs supplied by wind power, on certain windy days the sector can meet almost one-quarter of the country's power demand.

Former IDAE director general Garcia said: "The whole system has improved a great deal, including how it deals with peaks in the winter and the summer. In the peaks of the summer, wind energy has represented sometimes up to 15 to 16 percent of the energy distributed on the grid. And the stability of the system has improved a great deal as well."

Beyond the variability of the resource, grid issues remain. Traditional power sources are large power plants, sited relatively close to the demand. Current transmission lines reflect this reality. Wind turbines, however, may incorporate a number of smaller generators (an entire wind farm may have a few hundred megawatts of power, while a new nuclear plant may contribute a thousand megawatts). In addition, wind turbines may be farther from population centers (such as proposed wind farms in the midwestern United States) that necessitate upgrades and changes to the transmission lines.

In Spain, this issue has presented challenges as well. The Spanish grid has had problems absorbing the amount of wind power generated, according to Garcia. Upgrades to the transmission system are a top priority, according to the Spanish government, in reaching the stated goal of 20,000 megawatts by 2011. In particular, reinforcing and strengthening the power-sharing mechanism between Spain and France—and thus Spain and the rest of Europe—is of primary importance. When there is an energy need

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in France, Spain exports power to meet that need, and vice versa. But the transmission lines between the two countries are not yet adequately reinforced to support this two-way movement to its full capacity.

Because a great amount of wind power is generated in northern Spain, a stronger connection to France and the rest of Europe to better manage power surges and dips is paramount.

"It's similar to the situation of Denmark and Germany," said Garcia. "When wind is blowing in Denmark, they export it to Germany. And when wind doesn't blow in Denmark, Germany exports energy to Denmark. The European energy systems have to be interconnected."

Another challenge that needs to be addressed before the country can reach these ambitious goals, said Garcia, is creating a control center for all the wind farms around the nation, similar to the control center that exists for conventional power plants. Also, the technological challenges addressed by the turbine companies, such as technologies that deal with minute dips in voltage from the grid, will further the ability to meet the 20,000 megawatt goal.

Another factor that could increase efficiency is more-detailed prediction. Meteorological information allows electric companies and wind-farm operators to predict with a high level of accuracy when wind will pick up and slow down. With this hourly information, electric companies know when to expect more power from wind farms, and when to pick up the slack from other sources.

To reduce the inaccuracy in wind-power predictions, Spanish

wind farm operators are joining with system operators to determine the best practices for implementing improvements in predictions. According to Alberto Ceña, director of the Spanish Wind Energy Association (AEE), “Every day wind farms are offering power to the market. They need to reduce deviations—the difference between forecast and the real production.”

Using seven different models, statistical and physical, the companies are refining prediction techniques. So far, in the first year since the project began, the accuracy has improved. “If we can reduce the deviation,” said Ceña, “then we don’t have to have conventional power plants on standby for producing power when we don’t produce the power with wind. This also reduces penalties on the market.”

With all these advances in place, Garcia believes that the goals of supplying 15 percent of Spain’s energy needs via wind power and reducing the nation’s dependence on fossil fuels by 2010 is achievable. “We wouldn’t have proposed these goals if we didn’t believe they could be met,” he said.

### Expanding Global Markets

According to the AEE, Spain has enough wind potential to meet 30,000 megawatts installed capacity—even without offshore wind farms, although a number of offshore projects are in the planning stage.

Of course no one expects wind power to replace all other forms of energy, but rather to be part of a diverse group of energy options. If Spanish wind-power developers and turbine manufacturers meet the government’s goal of 20,000 megawatts by 2010, wind would supply around 15 percent of the country’s energy needs. Even that figure is somewhat misleading, however, since natural fluctuations in wind mean that when wind is plentiful, it could

supply half of Spain’s needs.

Spanish companies are seeing steady demand and markets in Spain, and they look forward to supplying the power to meet the country’s ambitious goals. At the same time, the rest of the world offers a much wider market for these companies, many of whom are already at the forefront of the industry. Gamesa Eólica, for instance, opened a wind farm in Illinois (Mendota Hills) in 2004 and recently opened its new North American office in Philadelphia. Today, it also sells its largest share of turbines in China, a market all companies are eyeing as that country’s rapid industrialization demands more energy. Meanwhile, Iberdrola is already operating

or plans to operate wind farms around Europe and Latin America, and Acciona Energía is working on an industrial project in China. Overall, Spanish wind-power companies are present in the United States, Portugal, France, Italy, India, Australia, Japan, Cuba, and China.

Financial analysts are also recognizing the strength of the Spanish industry. In the United States, Ernst and Young this year placed the Spanish wind market at the top of its index of long-term “country attractiveness,” as assessed by their Renewable Energy Group.

Corin Millais, head of the European Wind Energy Association, says that Spain has not only influenced the current growth of wind power in neighboring countries—France, Portugal, and Italy, which have all increased wind-power targets—but Spain provides a model for countries around the world looking to implement stronger legislation and encourage the development of wind power. “Wind power is a dynamic market, and it is rapidly growing into a mainstream power,” said Millais. “Spain shows how it can be done in a sustained fashion.”

**Financial analysts are recognizing the strength of the Spanish industry. In the U.S., Ernst and Young in 2005 placed the Spanish wind market at the top of its index of long-term “country attractiveness.”**

## Resources

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**AEH2** (Spanish Hydrogen Association)  
[www.aeh2.org](http://www.aeh2.org)

**APPA** (Association of Producers of Renewable Energies)  
[www.appa.es](http://www.appa.es)

**APPICE** (Spanish Fuel Cells Association)  
[www.appice.es](http://www.appice.es)

**ASIF** (Spanish Association of the Photovoltaics Industry)  
[www.asif.org](http://www.asif.org) (in Spanish only)

**CIEMAT** (Center for Research in Energy, the Environment, and Technology)  
[www.ciemat.es](http://www.ciemat.es)

**IDAE** (Institute for Energy Diversification and Savings)  
[www.idae.es](http://www.idae.es)

**PSA** (Almeria Solar Platform)  
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## New Technologies in Spain Series

Spain is a technologically and industrially advanced country committed to innovation, research and development, both through its government and through its private sector. The country is determined to deepen and intensify its productive specialization in industries that depend on technology and innovation. The Ministry of Industry, Tourism and Commerce has launched an ambitious plan combining its available human and financial resources and setting out specific lines of action with the goal of strengthening the international outlook of the most technologically advanced companies in Spain.

As part of this initiative, *Technology Review's* custom-publishing division has produced the New Technologies in Spain Series, which will appear as a special advertising supplement in MIT's *Technology Review* magazine. This powerful eight-part series showcases the technological development and excellence of Spanish companies in several important industries, such as wind energy, water desalination, infrastructures, high-speed rail, aerospace, industrial machinery, biotechnology and renewable energy.

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