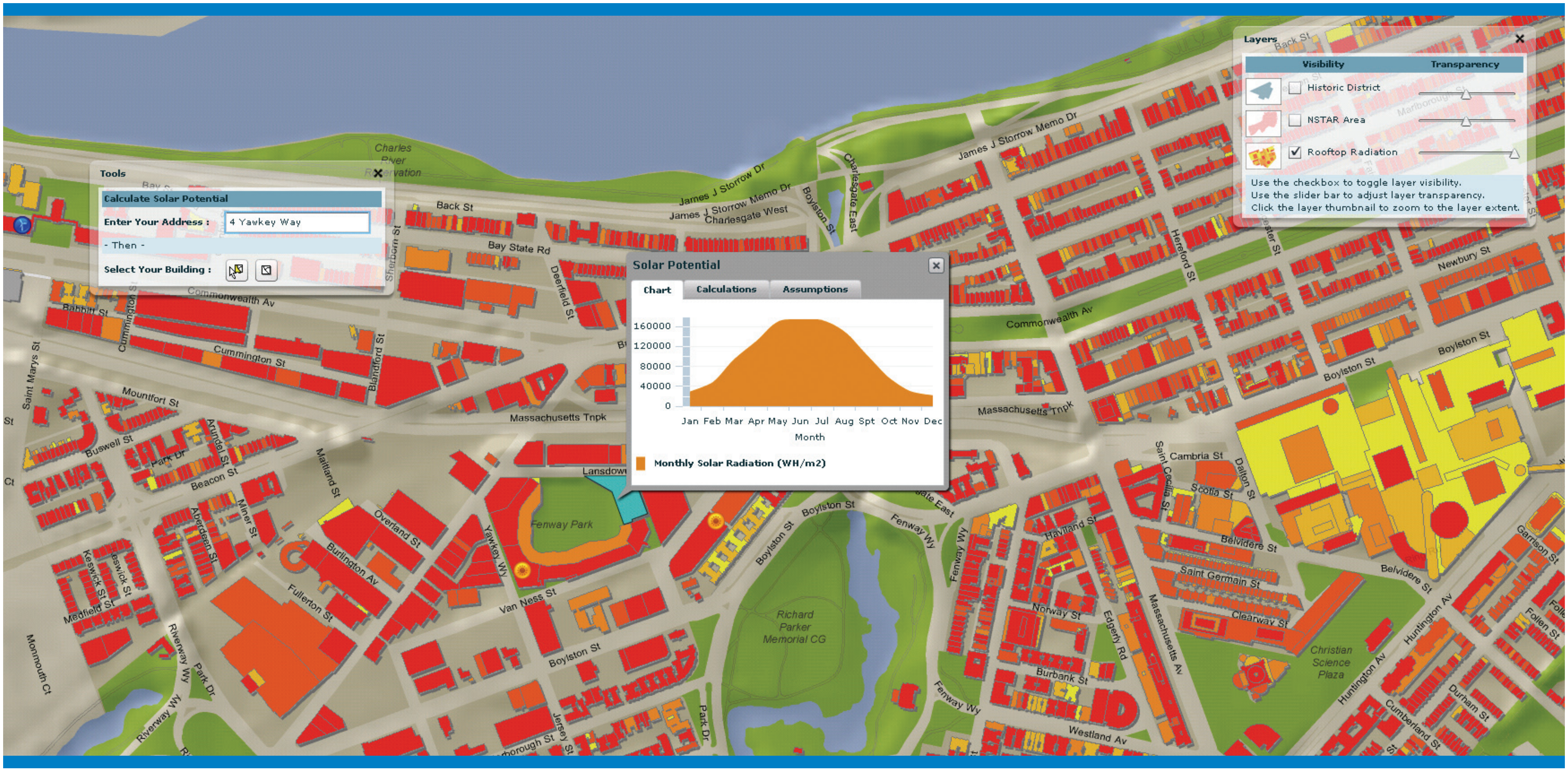
GIS Best Practices

GIS for Renewable Energy



January 2010

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What Is GIS?

Making decisions based on geography is basic to human thinking. Where shall we go, what will it be like, and what shall we do when we get there are applied to the simple event of going to the store or to the major event of launching a bathysphere into the ocean's depths. By understanding geography and people's relationship to location, we can make informed decisions about the way we live on our planet. A geographic information system (GIS) is a technological tool for comprehending geography and making intelligent decisions.

GIS organizes geographic data so that a person reading a map can select data necessary for a specific project or task. A thematic map has a table of contents that allows the reader to add layers of information to a basemap of real-world locations. For example, a social analyst might use the basemap of Eugene, Oregon, and select datasets from the U.S. Census Bureau to add data layers to a map that shows residents' education levels, ages, and employment status. With an ability to combine a variety of datasets in an infinite number of ways, GIS is a useful tool for nearly every field of knowledge from archaeology to zoology.

A good GIS program is able to process geographic data from a variety of sources and integrate it into a map project. Many countries have an abundance of geographic data for analysis, and governments often make GIS datasets publicly available. Map file databases often come included with GIS packages; others can be obtained from both commercial vendors and government agencies. Some data is gathered in the field by global positioning units that attach a location coordinate (latitude and longitude) to a feature such as a pump station.

GIS maps are interactive. On the computer screen, map users can scan a GIS map in any direction, zoom in or out, and change the nature of the information contained in the map. They can choose whether to see the roads, how many roads to see, and how roads should be depicted. Then they can select what other items they wish to view alongside these roads such as storm drains, gas lines, rare plants, or hospitals. Some GIS programs are designed to perform sophisticated calculations for tracking storms or predicting erosion patterns. GIS applications can be embedded into common activities such as verifying an address.

From routinely performing work-related tasks to scientifically exploring the complexities of our world, GIS gives people the geographic advantage to become more productive, more aware, and more responsive citizens of planet Earth.

GIS for Renewable Energy

Faced with grim predictions of energy supply and consumption, humankind is responding with tremendous efforts to capture and cultivate renewable resources. We are looking to help sustain ourselves using wind, solar, geothermal, and biomass energy. We are also searching for cleaner, smarter, and more conscientious methods of energy production, transmission, and distribution.

GIS technology is supporting and underlying the progress of this monumental change. GIS is not only improving the way we produce and deliver energy, it is changing the way we view our earth's resources.

U.S. DOE's Renewable Energy Lab Maps Wind Resources with GIS

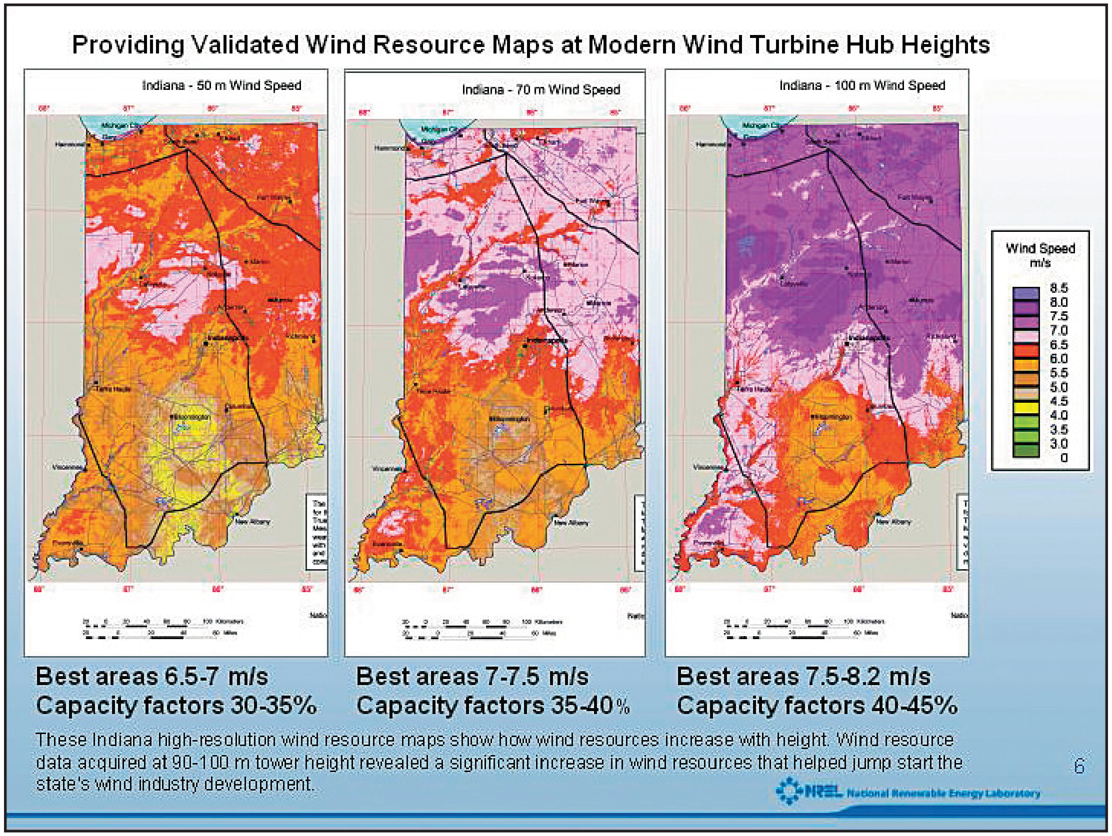
Highlights

- Using ArcGIS Desktop software, the NREL team can determine the most favorable locations for wind farms.
- GIS-based modeling enables analysis of terrain, which significantly impacts the quality of wind at a particular site.
- The primary audience for these maps is government decision makers.

During the 1970s, the United States experienced a significant energy crisis as oil consumption grew and supply fell. Soon after President Jimmy Carter came into office in 1977, he addressed the nation and said, "We must balance our demand for energy with our rapidly shrinking resources. By acting now, we can control our future instead of the future controlling us." His energy policy included maintaining healthy economic growth; protecting the environment; and developing the new, unconventional energy sources that the nation would rely on in the following century.

Several months later, Carter established the U.S. Department of Energy (DOE), and the Solar Energy Research Institute (SERI) was opened in Golden, Colorado. In September 1991, SERI was designated a DOE national laboratory, and its name was changed to the National Renewable Energy Laboratory (NREL). NREL is the primary laboratory for renewable energy and energy efficiency research and development in the United States.

NREL works to advance many renewable resources, including solar, hydrogen and fuel cells, biomass, and geothermal, but wind is currently the most developed renewable energy market. Windmills appeared on the American landscape in the early 20th century and evolved into wind turbines that increasingly capture more energy and become more cost-effective. In 2006, President George W. Bush spoke about the nation's need for a more diversified energy portfolio and how wind energy might provide 20 percent of the nation's energy by 2030.



These Indiana high-resolution wind resource maps show how wind resources increase with height.

In May 2008, DOE released a groundbreaking report, *20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply.* The report provides a road map to reaching this important goal, including identifying steps and challenges.

As part of the research behind having 20 percent wind energy by 2030, NREL team members were tasked with updating wind resource maps. The updated maps were a critical component of the wind deployment model used to develop the 20 percent scenario. Using ArcGIS Desktop software (through a U.S. government license agreement), the NREL team can determine the most favorable locations for wind farms based on the cost of transmission, locations of load centers and wind resources, and the layout of the electrical grid. GIS-based modeling enables analysis of terrain, which significantly impacts the quality of wind at a particular site.

The NREL team also examines economic development potential based on strong manufacturing centers and filters the data to exclude sites such as national parks and wilderness areas. "We use GIS for policy analysis and implementation analysis," says Marguerite Kelly, senior project manager at NREL. "We use it to help decision makers at all levels understand what their resource is."

For utility developers, NREL creates forecasting models. "A utility wants to know not only what the average wind speed is at a location," Kelly adds, "but also what's going to happen in 10 minutes, and then in an hour—that's how they buy and sell electricity."

The collaborative that produced the road map report includes the American Wind Energy Association, engineering consultants from Black and Veatch Corporation, DOE, Lawrence Berkeley National Laboratory, NREL, Sandia National Laboratories, and more than 50 energy organizations and corporations.

Maps include details such as voltage of transmission lines and classes of wind speed and wind power. Forecasts include projected wind capacity by state in 2030 and the expansion of transmission lines that would be required.

"The wind maps consistently amaze people," Kelly notes. "Often, the wind resource is much bigger than people expect, since a wind farm requires a strong steady breeze, not gusts." The primary audience for these maps is government decision makers who are thinking about how renewable energy can be used in their counties and states. The secondary audience is developers looking for renewable energy installations.

As of September 2008, 35 states were generating wind power. Texas, California, Iowa, Minnesota, and Washington (respectively) made the Top 5 list of total wind power capacities. According to the American Wind Energy Association, as of December 3, 2008, U.S. wind capacity was just over 21 gigawatts (GW) (awea.org/projects). The United States must reach 305 GW by 2030 to meet the 20 percent goal.

(Reprinted from the Spring 2009 issue of *ArcNews* magazine)

The Big Sky State Taps Wind Resources

Cascade County, Montana, Visualizes and Maps Data with GIS

Highlights

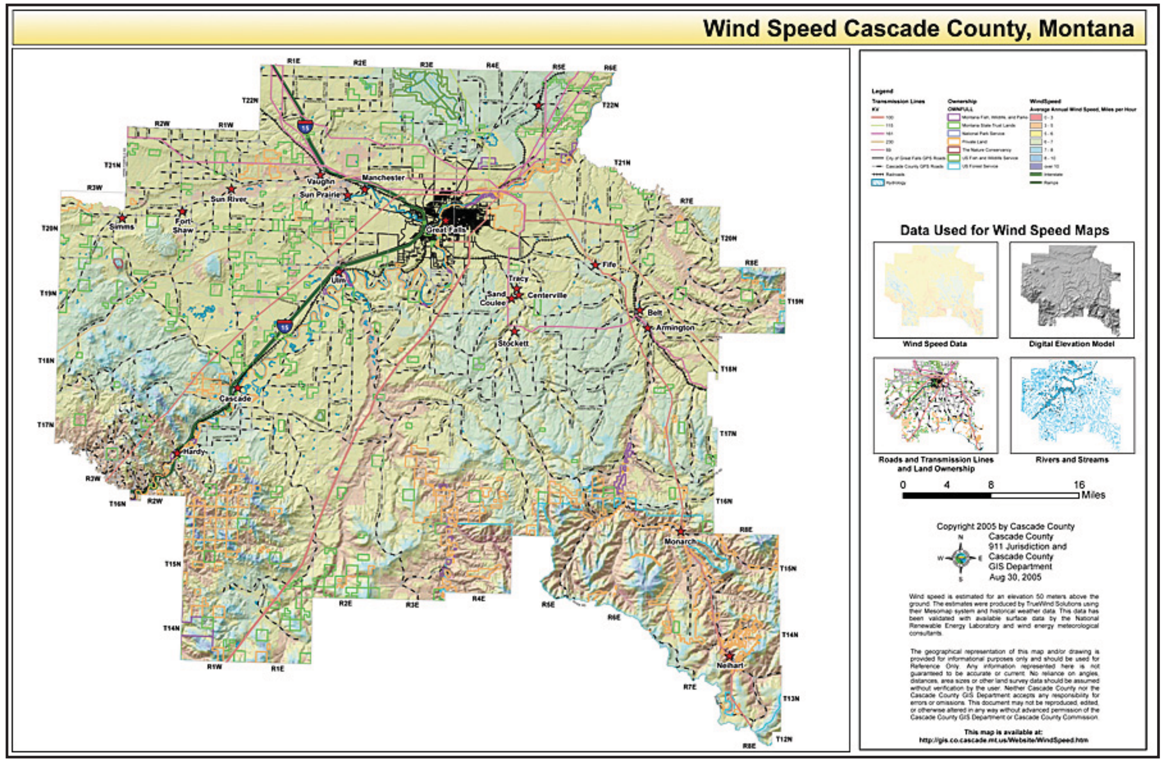
- ArcGIS Desktop is used to create a wind map book combining wind, transmission, parcel, and road data.
- GIS data helps investors and developers locate best wind power resource areas.
- The county can visualize wind speeds and transmission lines with the functionality in ArcGIS.

Cascade County, Montana, has its county seat in Great Falls and lies in an area on the eastern slope of the Rocky Mountains known for its powerful chinook winds. Cascade County commissioner Peggy Beltrone has coined the area south of the Canadian border the Don Quixote Canyon after the fictional character who had notable encounters with windmills. Beltrone, who also serves on the Department of Energy (DOE) Wind Powering America steering committee, has been the force behind a unique wind marketing program for the county that is receiving attention around the globe.

"There is a tremendous wind resource in Montana," Beltrone says, "but wind is generic, and the way to differentiate the wind that crosses through your county and the next county is to draw attention to it and make it easier for developers to explore your wind resource and see its value over wind in other areas."

Cascade County is using GIS to help developers interested in investing in wind power easily research parcels available for lease and the wind resources that exist on those parcels. In addition to regional developers, interest has come from business people as far away as Japan and Ireland internationally and Florida in the United States.

"We have a lot of people coming into our office looking for data on wind," notes Tom Mital, GIS manager for Cascade County. To better serve these interested parties, Mital used his county's ArcGIS Desktop software to create a wind map book that combines wind, transmission, parcel, and road data. The wind speed estimates for an elevation of 50 meters above the ground were produced by TrueWind Solutions LLC (Albany, New York) using its Mesomap system and historical weather data. The data was then validated with surface data from the National Renewable Energy Laboratory and wind energy meteorological consultants.



A wind speed map created with GIS.

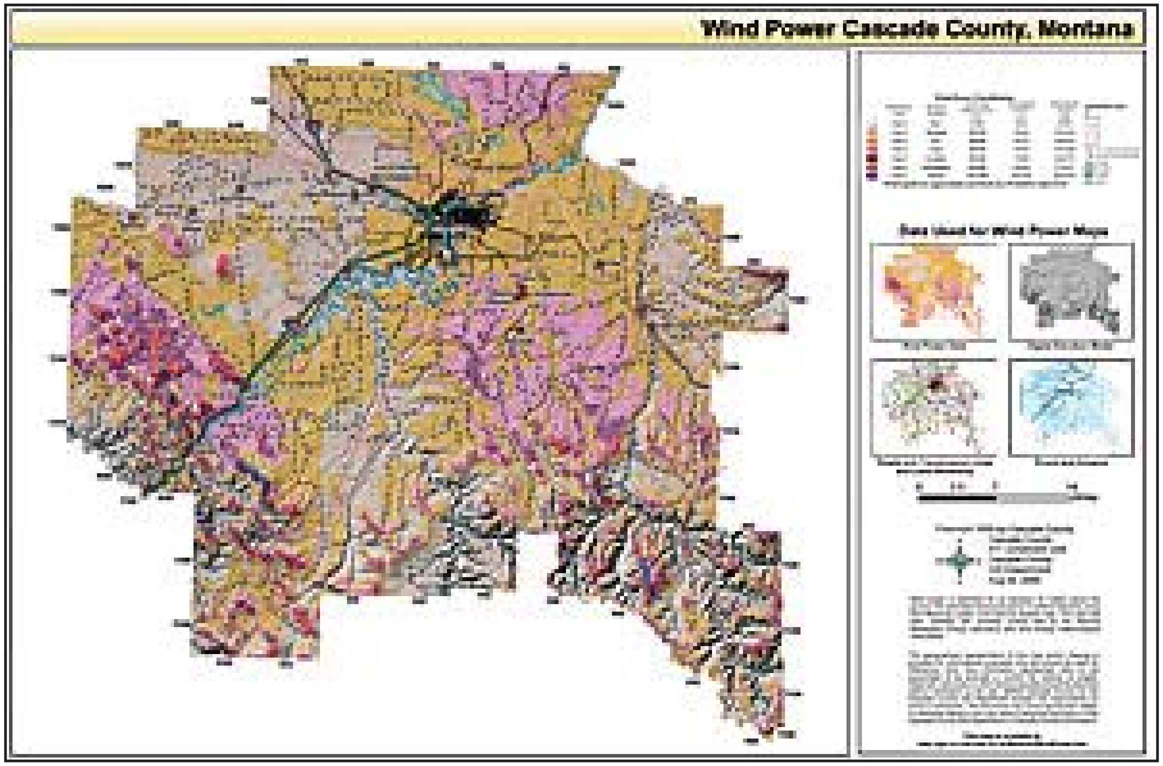
A PDF version of the map book is available on the Cascade County GIS Department Web page at www.co.cascade.mt.us. The Web page also includes links to a Wind Power Map and Wind Speed Map that visitors can download in PDF format. When someone requires more detail about a specific area, Mital creates a custom map.

ArcGIS allows the county to show developers wind speeds across the county and locations of transmission lines. "Along with that, we have data such as topography, so it's very easy for someone to see that a wind farm would not be on the top of a pristine mountain," Beltrone notes. "This saves developers from having to fly in and be on the ground to see these things for themselves, and it saves them from having to go to the courthouse to search for landownership documents. Instead, they can access all of this information in one place on a computer anywhere in the world."

Horseshoe Bend Wind Farm in Cascade County, Montana (source: John Godwin).

Once a developer leases property from a landowner, typically a farmer, the investor installs a commercial-grade anemometer to measure the wind speed at 50 meters. Measurements are taken for approximately 18 months to verify the wind speed before installing wind turbines and connecting to a transmission line.

"The nation is thirsty for wind power," Beltrone says. "Today, wind power supplies 1 percent of the nation's electricity. Under a plan by DOE's Wind Powering America, that number could climb to 20 percent by 2030."



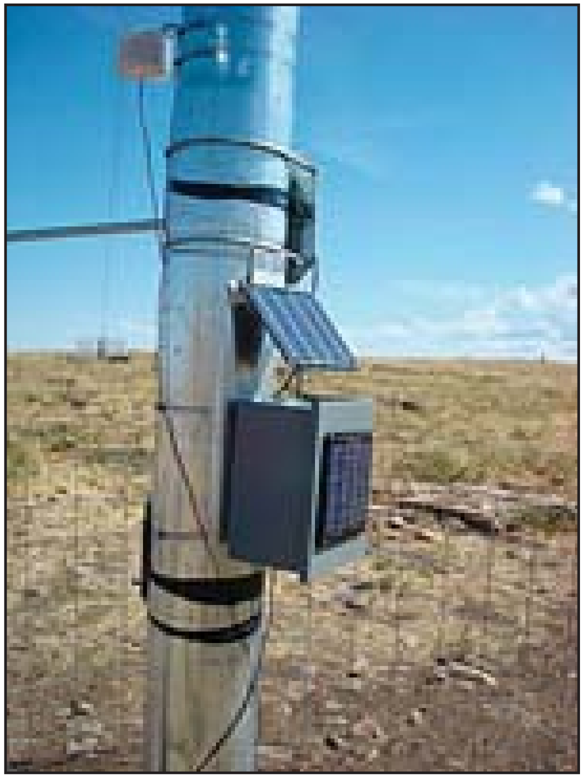
A wind power map.

In Cascade County, anemometers are showing up on land throughout the area, and there is currently one wind farm, Horseshoe Bend, that has six wind turbines producing nine megawatts of energy.

In addition to the positive environmental impact of generating green energy, wind farms allow the county to expand its tax base. During the first year of taxation, Beltrone estimates that each commercial wind turbine brings $25,000 into the community.

For the investors, the wind farms generate revenue when they sell the energy the turbines generate. Additionally, investing in green energy helps states meet renewable energy portfolio standards. Twenty-nine states have adopted renewable energy portfolio standards.

"The advantage of using GIS in the marketing of wind is that it gives developers a lot of information that they need to decide whether or not placing a wind turbine in this area is going to work for their power needs and their budgets," Beltrone adds. "One executive told me that the information we provided saved his staff months of work, since we did all the work for them. If he can take a look at our resources without having to invest time and money in preliminary research, it's a big draw."



Wind data from sensors on this rural anemometer is sent to remote computers for analysis.

(Reprinted from the Summer 2008 issue of *ArcNews* magazine)

Boston Showcases Solar Power Potential with Web GIS

Highlights

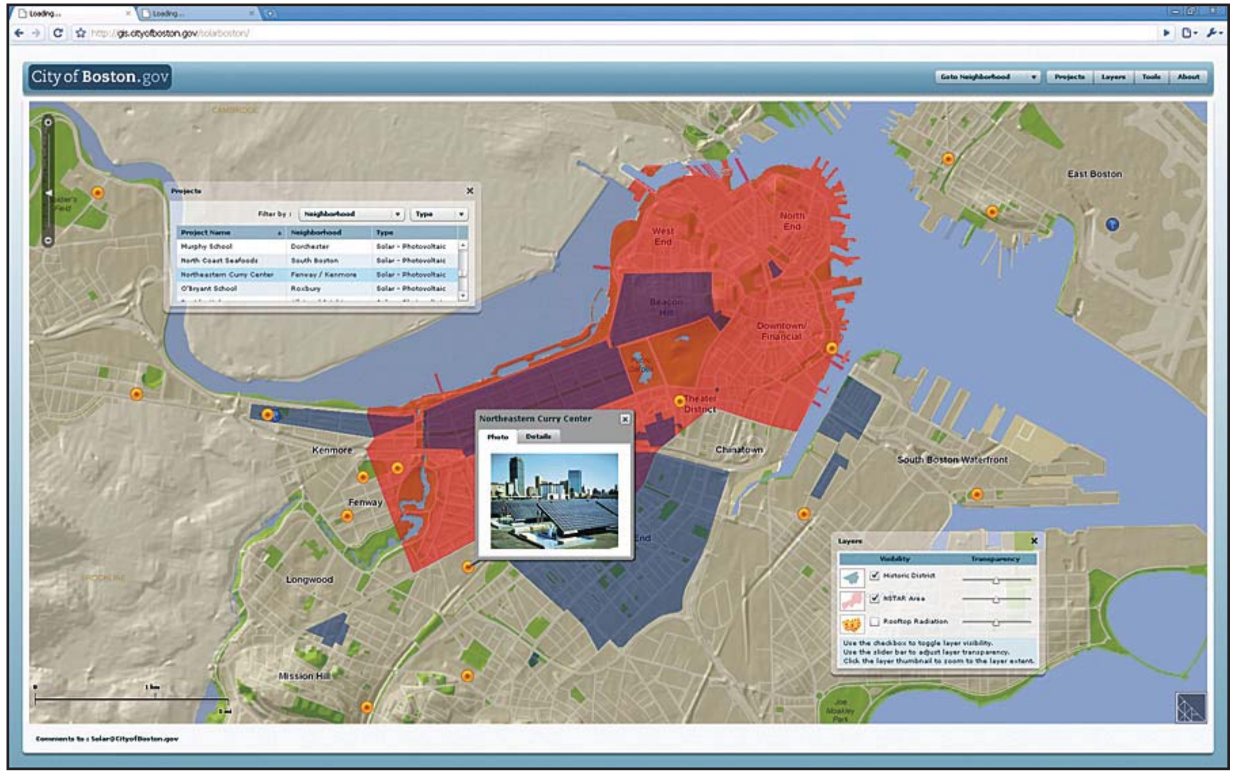
- Web GIS helps track the progress of citywide solar installations.
- Solar radiation tools in ArcGIS Spatial Analyst calculate the solar energy potential of building rooftops.
- The ArcGIS API for Flex wraps the application in a user-friendly format.

In 2007, Boston mayor Thomas Menino issued an executive order on climate change that set greenhouse gas reduction goals and outlined city strategies for recycling and renewable energy. That order was decisive in the formation of Solar Boston, a two-year $550,000 project designed to expand the use of solar power throughout the city. Solar Boston is part of the Solar America Initiative, a campaign launched by the U.S. Department of Energy (DOE), to make solar electricity cost-competitive with traditional electricity production by 2015. To help meet the city's greenhouse gas reduction targets and support the goals of DOE, Mayor Menino set a target of 25 megawatts of solar power installed by 2015. To support the Solar Boston program, Boston is using Web GIS technology to map current solar installations, track progress toward the mayor's goal, and allow Bostonians to analyze their rooftop solar energy potential.

Solar Boston builds on the City of Boston's leadership in promoting green buildings. Green building is the practice of maximizing the use of a building's resources while reducing the environmental impact throughout its life cycle. In 2004, Mayor Menino created a Green Building Task Force, and in 2007, based on the task force's recommendations, Boston became the first major city in the United States to require all large, private-sector buildings to conform to the Leadership in Energy and Environmental Design (LEED) green building standards. Outfitting Boston's largest residential and corporate structures with solar panels is in keeping with the city's green building and energy conservation objectives.

Renewable energy is a solution for reducing the demand on and air pollution from traditional energy systems. As on-site sources of clean power, solar energy systems can reduce greenhouse gas emissions and air pollution, increasing energy security and creating local jobs.

Solar electricity systems (also called photovoltaics [PV]) also have the potential to generate power when it is needed most—on hot summer days—thereby relieving strain on the electricity system and reducing the risk of blackouts. By encouraging solar energy, Boston hopes to not only capture these benefits but also prepare for the market explosion likely to occur when solar power becomes competitive with fossil fuels.



The ArcGIS Solar Radiation tool gives users the ability to research solar power capacity.

To promote the use of PV to investors, the Boston Redevelopment Authority (BRA) needed a system to showcase solar energy potential in a user-friendly format—one that lets users investigate locations of interest and perform preprocessed analysis. GIS was the obvious tool to achieve this end because it started with a visual reference—a map of the entire city showing the buildings that had solar installation potential. Says Wilson Rickerson, Solar Boston coordinator, "We needed a baseline, because you can't really get anywhere if you don't know where you are. Without GIS, we'd have no concept of the size of the city's solar industry, how fast had it grown, and what potential it had."

GIS analysts at BRA started on the project by using ArcGIS Desktop software's ArcGIS Spatial Analyst extension to calculate the solar radiation available on building rooftops. To do this, they built a digital elevation model (DEM) of the city. "We took the bare earth DEM and 'burned' into that the building heights using attributes available in the building footprints, which resulted in a three-dimensional surface model of the city," says Greg Knight, senior GIS applications developer with the Boston Redevelopment Authority. "We proceeded with this prepared surface and utilized the solar radiation tools available in Spatial Analyst to calculate what the solar radiation availability would be for each rooftop." The solar radiation tools allowed the analysts to model incoming solar radiation and take into account numerous factors, including variation in elevation, orientation (slope and aspect), the shadows cast by topographic features, and changes with time of day or year.

After completing the analysis in ArcGIS Desktop, the solar radiation map was published, along with a basemap, other layers of interest (e.g., historic and local electric utility districts), an address locator, and geoprocessing tools, to ArcGIS Server for use by the Solar Boston Web application. "The application was originally built using a geoprocessing service, which calculated the solar radiation on the fly," continues Knight. "Because the calculations took about 30 seconds to complete, we preprocessed the analysis in order to deliver a more responsive Web application."

Wrapping the analytics in an easy-to-use Web GIS application was the next step. GIS developers at BRA saw great potential in ESRI's new ArcGIS API for Flex, which is a client-side technology rendered by Flash Player 9 or Adobe AIR. Flex gives developers the capability to combine GIS-based Web services from ArcGIS Server with other Web content and display it in a fast, visually rich mapping application that can be deployed over the Web or to the desktop. It was the ideal medium to show investors the logistics of solar energy investment. "We gathered market data to get a baseline, but we knew it was equally important to publicize the information via the Web," says Bradford Swing, director of energy policy for Boston. "We knew Solar Boston needed a map, and this map is a simple, powerful tool to chart what we've accomplished and where we want it to go in the future."

Thanks to Boston Solar's Web application, Boston's real estate sector can easily start learning about the feasibility of its solar projects.

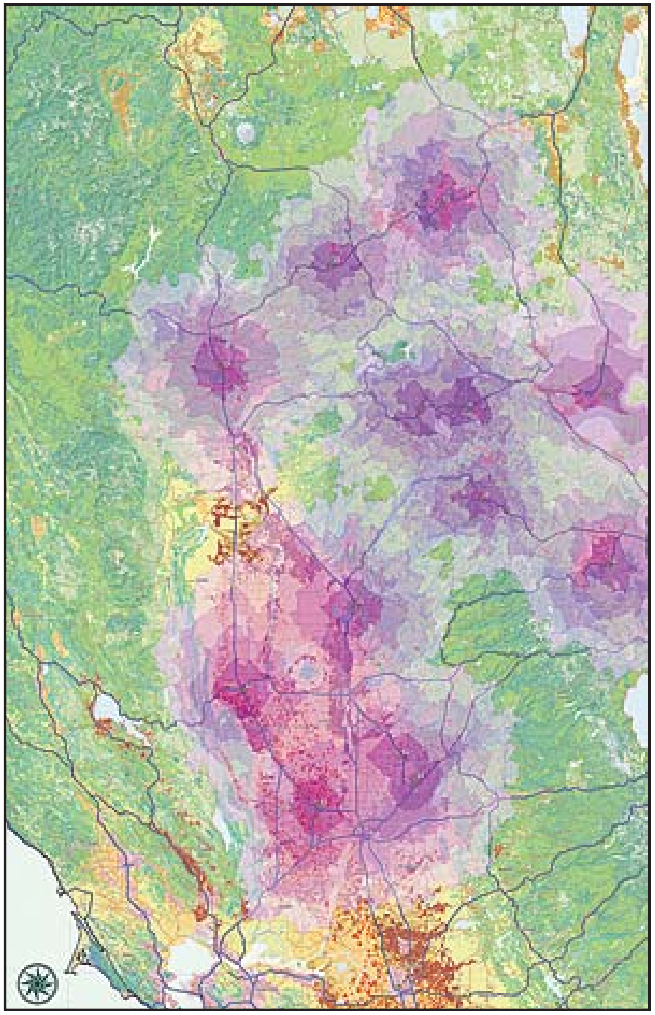
(Reprinted from the Fall 2008 issue of *ArcNews* magazine)

Assessing Economic Biomass Resources in California with GIS

California has a large and diverse biomass resource base that could potentially provide the state with renewable energy, according to research from the California Biomass Collaborative. Feedstock for biomass energy production in California comes from forestry and forest products; agriculture; and urban sources, such as municipal wastes. Biomass may also emerge in the form of new crops as the state moves to reduce consumption of fossil fuels and petrochemical feedstock and use more sustainable and renewable resources for energy and products.

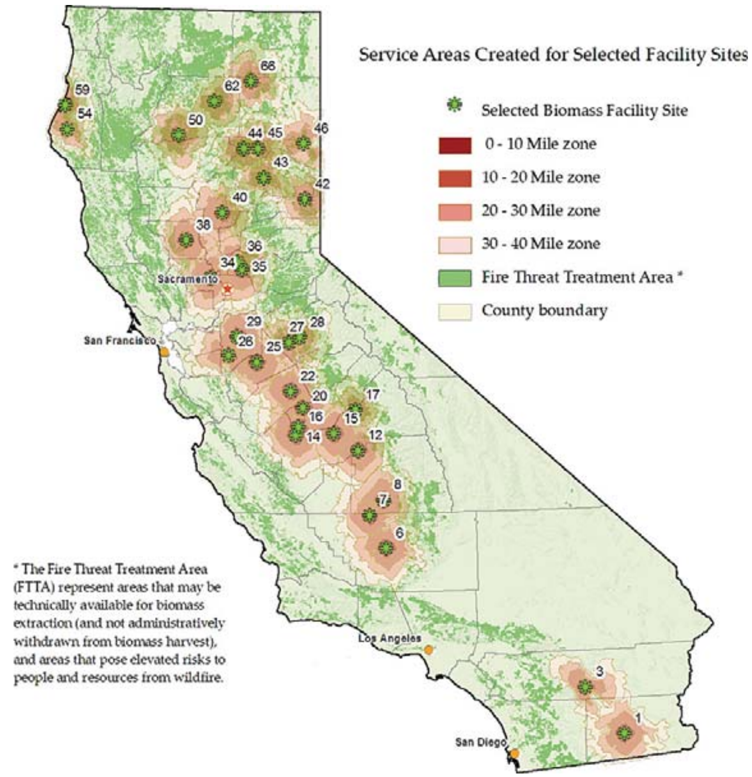
In a recent report, the California Energy Commission asserted that dedicated biomass crops for energy, fuels, chemicals, and other bioproducts may develop given sufficient market incentives or in association with new agronomic practices.

The California Biomass Collaborative used ArcGIS Desktop software to examine the economic feasibility of biomass supply for different types of manufacturing facilities of future bioenergy, biofuel, and bio-based products. The collaborative is made up of researchers from the California Energy Commission and the University of California (UC), Davis. The data used for the study was provided by the California Biomass Collaborative, California Department of Forestry and Fire Protection, California Department of Water Resources, California Energy Commission, UC Davis, and ESRI and included previously assessed data about gross and technically feasible feedstock supplies.



This project examines the economically feasible biomass supply for different types of future bioenergy, biofuel, and bio-based product manufacturing facilities sited across the landscape. This assessment extends that work by identifying supply curves (cost of supply by quantity delivered) (courtesy of California Biomass Collaborative).

Using the ArcGIS Network Analyst extension, researchers identified feedstock supply zones within fixed distances of each facility site. The actual distance along the road network was determined, as contrasted with simpler analyses employing a fixed radius and tortuosity factor. Researchers accumulated area in acres for each resource polygon to yield the total area within the supply region based on transportation distance. By adding cost information per road and feedstock type, the team was able to determine total delivered feedstock cost.



The team identified supply curves—the cost of supply by quantity delivered—and added cost information by road class and feedstock type. The resulting data allows optimization of facility scale or size by satisfying different requirements such as the minimization of delivery cost and the maximization of facility profit.

Facility size optimization was evaluated by combining feedstock delivered costs with economies of scale for capital and operating costs. Using the ArcGIS Spatial Analyst extension, the team was able to provide future developers with a map of supply overlap to assess potential competition for feedstock among facilities.

The GIS work of the California Biomass Collaborative may support statewide efforts to attract developers and include biomass as a viable renewable resource to meet state energy demands.

(Reprinted from the Fall 2009 issue of *ArcNews* magazine)

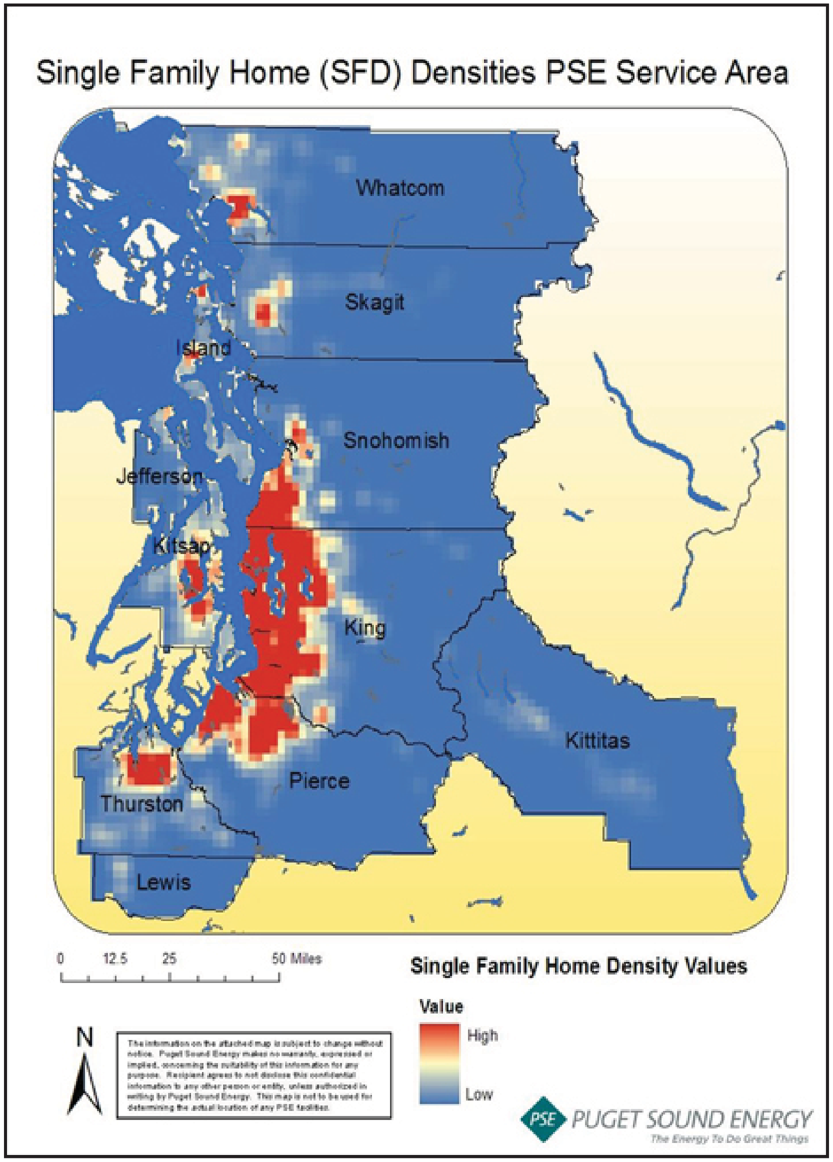
A Bright Future at Puget Sound Energy

Washington has always been forward thinking. When the state passed some of the most progressive renewable energy legislation in the United States in 2005—Bills 5101 and 5111—it was par for the course. The bill passing was prompted by a severe energy crisis in 2001, when the Columbia River experienced its lowest water levels in 60 years. The state decided it was time to diversify and become a leader in energy efficiency. The Energy Freedom Program was set up in 2006, committing $25 million in low interest loans and grants to provide the capital necessary to support production of green energy.

Washington State's oldest local energy utility, Puget Sound Energy (PSE), adapted quickly with a program that rewards customers with qualifying renewable energy systems. PSE continues to push the envelope for innovative ways of thinking about renewable energy and conservation programs. The utility is recognized by the American Wind Energy Association as the second-largest utility owner of wind energy facilities in the United States and owns two commercial production wind power plants. PSE has garnered national recognition for a variety of energy efficiency achievements recently, including the prestigious platinum-level Energy and Water

Management Award by the Secretary of the Navy and the U.S. Environmental Protection Agency's 2009 ENERGY STAR for its efforts in energy conservation.

PSE has been supplying energy to customers for more than 100 years and today serves more than 1 million electric and approximately 750,000 natural gas customers around the Puget Sound region. To meet the electrical energy needs of its customers over the next 20 years, PSE implemented a 2009 integrated resource plan that directs the utility to add 1,100 megawatts (MW) of renewable wind generation and 1,064 MW of efficient energy to its existing generation portfolio of hydroelectric, wind, gas, and coal power plants. As energy efficiency becomes a leading resource addition, the utility has to become more innovative in targeting customers with energy savings potential and increasing their engagement with its energy efficiency programs. Geographic information system (GIS) technology is playing an increasing role in refining PSE's understanding of its customers and their potential efficiency gains.



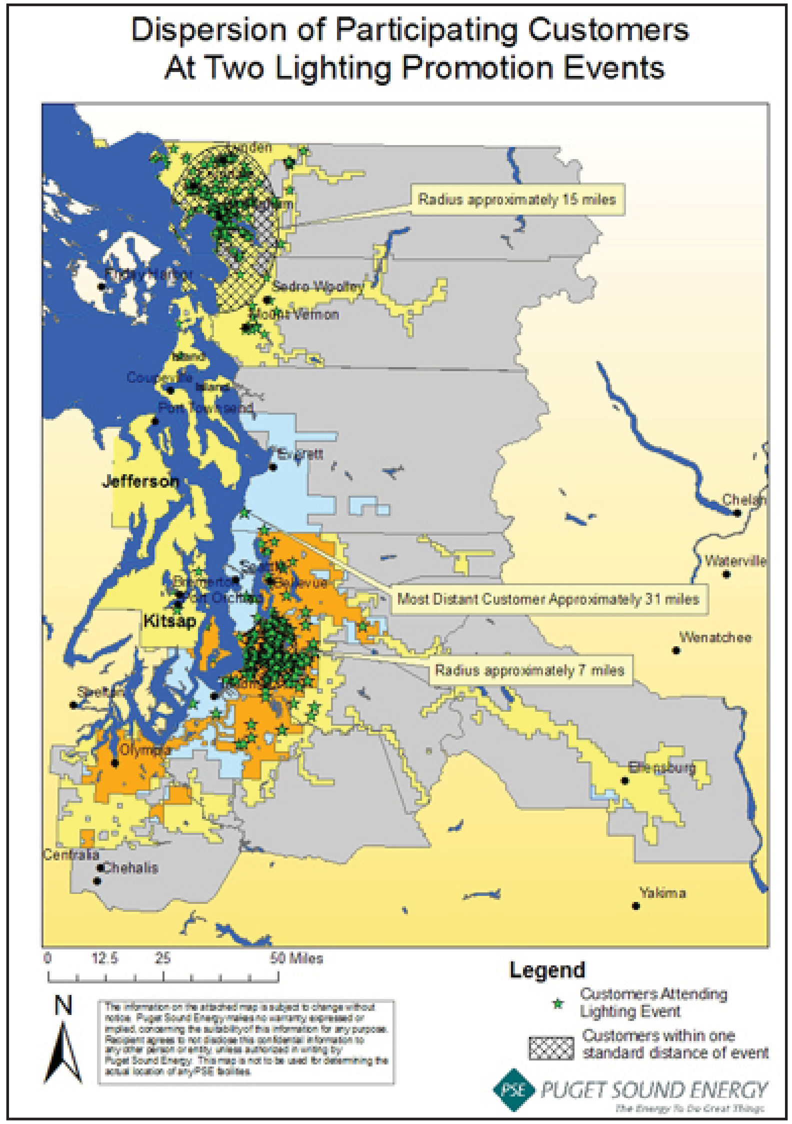
Density of single value homes is easily displayed using ArcGIS and analyzed for various marketing activities at Puget Sound Energy.

A Lightbulb Moment

One of the easiest and most inexpensive ways for people to save energy is to replace incandescent lightbulbs with compact fluorescent light (CFL) bulbs. ENERGY STAR-qualified CFL bulbs use up to 75 percent less energy than conventional incandescent bulbs and can last about 10 times as long. To incent its customers to trade in old incandescent bulbs and try new CFL bulbs, PSE created a Rock the Bulb program and a targeted marketing campaign to drive customers to events in their service areas.

Using ArcGIS, the Energy Efficiency Services (EES) Group looked at hardware stores and the "big-box" home improvement stores and their proximity to customers. Creating a radius, EES selected customer and census-level household information to see if the stores were near service areas that housed a select number of customers who would be interested in turning in old lightbulbs into new ones. Using this data in planning and budgeting, the EEG Group was able to estimate the number of participants that would attend and what ZIP Codes within the radius would respond to a variety of marketing and social marketing applications. "In addition to making use of externally derived datasets, GIS enables PSE's EES division to gain additional value from its existing data by bringing together separate datasets, creating new capabilities to guide marketing and program efforts," says Bill Hopkins, manager for strategic planning, PSE. From the success of this program, GIS is being used to assist in refining other energy efficiency marketing programs. By looking at customers in ArcGIS, EES can find out what type of housing customers reside in and determine which areas have a larger number of homeowners as opposed to high concentrations of renters. Because homeowners typically have more interest in incentive programs for switching out energy-hogging equipment, such as water heaters and furnances, marketing to homeowners is more effective.

GIS also helps EES staff look at the demographic profile of different areas. Understanding who lives in each area helps fine-tune marketing messages by understanding how "green" an area may be as well as finding out whether there might be language barriers. Some locations may require that marketing materials be printed in more than one language to reach the correct people.



Information from the attendance at two different Rock the Bulb events was used for further analysis, in this case looking at demographics of the radii from the events around other potential retail locations.

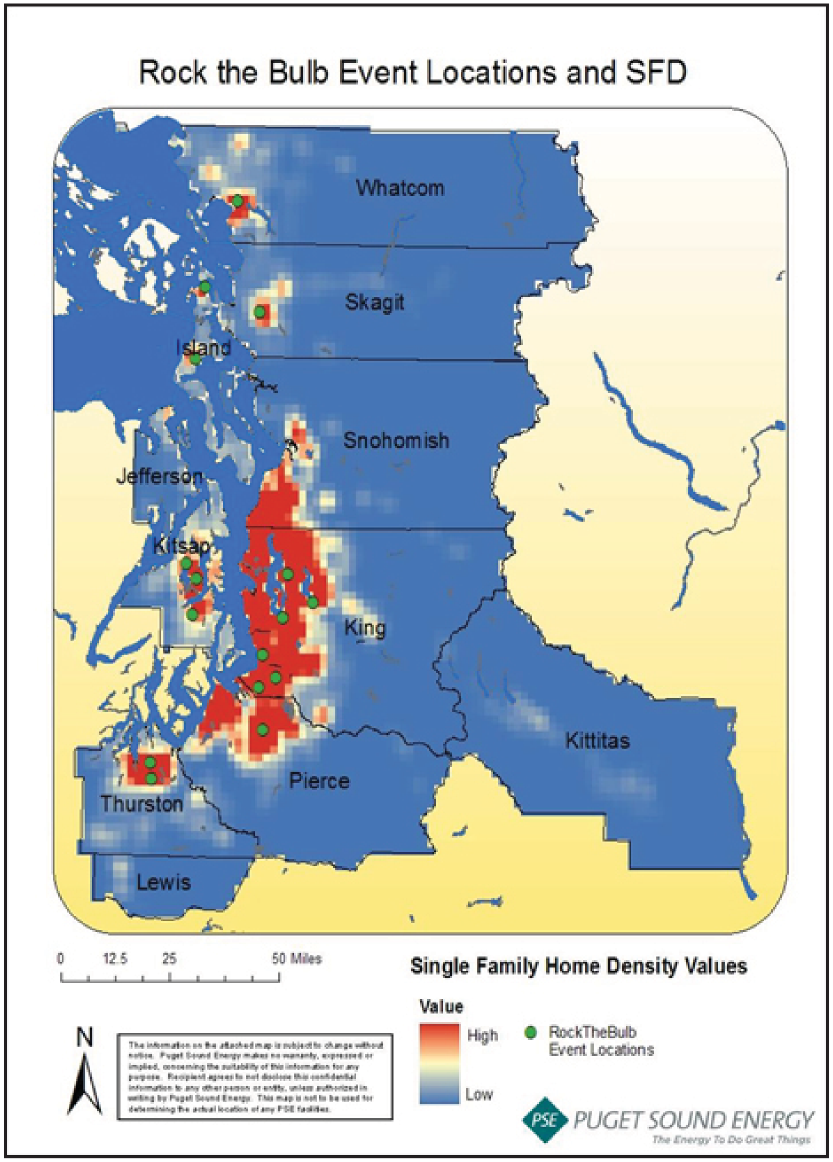
Moving to More Efficient Fuels

The Natural Gas Development Group saw the usefulness of GIS and used the technology as well. The group was interested in contacting households about converting from oil heat to natural gas. To target messaging to the correct people, household information was minded according to geographic area. From the information, labels and maps were created for a campaign to contact households about conversion from oil heating to natural gas. This data-mining effort involved filtering all households in specific geographic areas and eliminating existing PSE gas customers. That filtered list was further reduced using data elements like type of heating fuel and proximity to gas mains. In the end, letters were sent to households having a higher likelihood of becoming new PSE gas customers.

"GIS provides value to PSE by introducing customer and operations data with external data, such as assessor's household information, and creating tools like mainlining lists and maps displaying where future customers live," says Liz Norton, manager, natural gas planning and development, Natural Gas Development Group. The group is currently exploring the integration of systems planning data to further identify loads on the system and areas in which to concentrate future growth.

"GIS is much more than maps to us, because it provides a collaborative decision support tool for visualizing company data," says Norton. "GIS has helped different groups and departments within PSE analyze many different datasets that traditional means cannot equal. GIS is a complementary tool that helps visualize data, improving decision making at all levels."

Groups throughout PSE are hard at work improving how GIS is being used. Efforts so far have helped close the gap between what can be done right now and what could be done in the future. Those collaborative efforts are happening now and will continue moving forward.



Combining different datasets into one common view gives Puget Sound Energy the information needed to increase the success of marketing events.

Next Steps

PSE has come a long way from its first use of GIS, producing maps to communicate projects internally and at community outreach program meetings. PSE hopes to continue realizing more widespread benefits of the technology. GIS allows each business group to have improved management and internal control of information and a means of analyzing and allocating their own resources.

For example, GIS is useful for energy conservation and efficiency programs by finding how surplus power in one geographic area can provide additional power elsewhere, in essence creating an additional energy supply. "GIS can help identify opportunities where combined electric and gas networks exist to reduce load on electric networks by moving customers to natural gas for heating when it's available in their area and there is enough capacity," says Hopkins. "This helps reduce electrical demand and can avoid costly upgrades to circuits."

Because GIS has the ability to link datasets by geography, the technology facilitates interdepartmental information sharing and communication. By creating a shared database, one department benefits from the work of another—data is collected once and used again and again. As communication increases between individuals and departments, redundancy is reduced, productivity is enhanced, and overall organizational efficiency is positively impacted. This represents a shift from project-driven GIS to what is traditionally known as enterprise GIS. This shift would help PSE leverage operations and customer data for additional projects like those described above.

(Reprinted from *V1* Magazine, September 28, 2009)

Building an Oasis in the Desert

GIS Helps Ensure that Masdar City Meets Its Carbon-Neutral, Zero-Waste Goals

Highlights

- Every facet of designing and building the city will be analyzed with ArcGIS.
- Asset management using ArcGIS means all systems can be visualized, maintained, and tracked efficiently.
- An enterprise geodatabase will be used throughout the city's life cycle.

Many of us are interested in decreasing our carbon footprint, whether one individual, one family, or one organization at a time. Imagine living in an entire city specifically designed to meet the ambitious goals of zero waste; sustainable living; and, ultimately, carbon neutrality. This is the vision of Masdar City, which is being designed and constructed in Abu Dhabi, the capital of the United Arab Emirates (UAE), by Masdar, Abu Dhabi's multifaceted initiative advancing the development, commercialization, and deployment of renewable and alternative energy technologies and solutions. *Masdar,* which means "the source" in Arabic, integrates the full technology life cycle—from research to commercial deployment. The Masdar company aims to create renewable energy solutions.

Masdar City is a prime example of how GIS can be used to design our future. This shimmering oasis of 6 square kilometers, located 30 kilometers from Abu Dhabi city, is committed to sustainable living. To reach its carbon-neutral ambitions, Masdar City will use only renewable energy sources. A photovoltaic power plant will generate most of the electricity, while the city's cooling will be provided via concentrated solar power. The zero-waste targets of Masdar City will be achieved through a combination of recycling, reuse, and some breakthrough waste-to-energy technologies. Landscaping within the city and crops grown outside will be irrigated with gray water and treated wastewater produced by the city's water treatment plant.

This artist's conception shows an aerial view of Masdar City as it will look when completed.

Through this innovative design, residents in Masdar City will consume far less energy. Peak demand at Masdar City is currently predicted to be only 200 megawatts instead of the

800 megawatts normally required by a conventional city of the same size and climate zone. Desalinated water consumption will drop from 20,000 cubic meters per day to only 8,000. And Masdar City will eliminate the need for millions of square meters of landfill.

The first residents of Masdar City will be the students and faculty of the Masdar Institute of Science and Technology (MI). MI is a graduate-level university specializing in alternative energy and environmental technologies and is a collaboration between Masdar and the Massachusetts Institute of Technology. MI will ensure a ready supply of highly skilled graduates to meet the growing demand within the clean technology and sustainable energy sectors.

Shifting from Oil to Renewable Energy

UAE is a federation of seven emirates, or federal states, located in the southeast Arabian Peninsula. Abu Dhabi, the capital of UAE, has a rapidly growing economy, due largely to the emirate's vast oil reserves: Abu Dhabi is estimated to hold approximately 9 percent of the world's crude oil reserves.

Despite its vast hydrocarbon resources, Abu Dhabi has adopted a progressive approach to its economic growth. The emirate is committed to diversifying its economy away from oil, ensuring the long-term development and prosperity of the country. As a worldwide leader in the energy markets, the emirate believes it is well placed to invest its knowledge and financial resources in the world's future energy markets—renewable energy. So in April 2006, the Abu Dhabi government established Masdar. Through its portfolio of projects that includes carbon monetization, clean technology investments, and renewable utilities projects—both in Abu Dhabi and abroad—the company is contributing to the global effort of mitigating climate change. In this way, Masdar plays a key role in the development of Abu Dhabi's renewable energy sector, driving continual innovation and commercialization of clean and sustainable energy technologies.

Masdar's progress since its development has been significant. The company has established partnerships and large-scale renewable energy programs around the world. And as a further sign of Abu Dhabi's advancement in the alternative energy space, UAE was recently successful in its bid to host the headquarters of the International Renewable Energy Association, against strong European competition, in Masdar City.

CH2M HILL, an ESRI Business Partner and a leader in full-service engineering and consulting based in Colorado, was chosen as a leading partner for the Masdar City design/build project.

CH2M HILL had used ESRI technology on many projects in the past and knew ArcGIS was the solution necessary to manage and analyze information throughout the city's life cycle.

Lean, Green City Planning

"GIS is imperative in managing the overall spatial information necessary for designing, building, and operating Masdar City," says Derek Gliddon, GIS manager, Property Development Unit, Masdar.

Staff members at the City of Masdar use GIS to model building information throughout the life cycle of the project.

For the city to meet its challenging goals, CH2M HILL carefully considered the geography of the area: sun angles, wind patterns, street widths, and building density and height. The orientation of buildings on a diagonal grid to provide maximum natural shading was modeled in ArcGIS. To understand all the variables and communicate effectively during the project, the company used a geodatabase that enforces use of a single, shared coordinate system across the project. A common basemap was created to support planning, design, and construction of the city, with the foresight that the city would also be maintained and operated using the same data.

"Building a city like this has never been done before. And GIS is proving to be an absolutely critical tool," says Shannon McElvaney, information solutions consultant, CH2M HILL.

Data layers contained in the geodatabase include information such as transportation, vegetation, drainage, structures, boundaries, elevation, biodiversity, buildings, and utilities, as well as terrain elevation, bathymetric data, and remotely sensed imagery. Information from tabular databases is incorporated into the map layers, as well as GPS coordinates and georeferenced photographs. All the construction-related information, including cost, schedule, and carbon tracking data, is tied together by location, making it more accurate and efficient to use.

The resulting information is available company-wide. ArcGIS Server was recently deployed and will enable the more than 100 organizations involved in developing Masdar City to access maps, data, and analytic services, thus reducing problems of multiple data versions in circulation. A sophisticated Web browser-based virtual city visualization and navigation tool uses master plan data from the geodatabase and links to the program scheduling software. This tool is used to visualize the construction of the city over time. Construction managers can navigate anywhere in the city; "play" the project timeline; and identify spatiotemporal clashes, accessibility problems, and other logistical issues. On a fast-paced, high-density development, these issues are very important. Information can be searched using spatial criteria and viewed on easily readable thematic maps. Using GIS to visualize the massive amounts of data makes communicating about the project easier.

Optimized Facility Placement

ArcGIS introduced the spatial analysis and modeling necessary for the most efficient placement of facilities at the city. Water and sewage treatment plants, recycling centers, a solar farm, geothermal wells, and plantations of various tree species were placed using traditional planning principles modeled with ArcGIS. Questions—Is there enough physical space available? How much are the buildings shading each other? How much space is needed between a facility and the residents?—are modeled and the best answer chosen through GIS.

McElvaney cites a problem that was quickly resolved when line work from one building was off by 30 centimeters from the previous line work. Having access to all the data and visualizing it with GIS allowed catching the mistake: "A mistake like that could be very time and cost intensive to fix during the construction stage. GIS is extremely helpful in preventing that kind of thing from happening."

From Models to Real Life

GIS has ensured that the carbon-neutral status of the city translates from a concept to design. CH2M HILL used ArcGIS to even choose where to place construction materials during the building phase. Alternative scenarios for where to place building materials could be modeled so that, in the end, the company could choose the most efficient location for reducing transportation-related carbon emissions.

GIS was able to model water and power usage over a period of 10 years, plotting monthly resource demand across the city like a geographic histogram. The variables appear as different heights, allowing planners to see any issues rapidly. "This exercise immediately revealed a couple of problems with the logic that had not been easy to spot in a massive spreadsheet format," says McElvaney.

Changes happening during construction were tracked and recorded to monitor the effect on carbon neutrality. Masdar City has a team that keeps track of all fuel and material use and reuse during building. This team is also responsible for logging any environmental infractions. Team members found that using a GPS-enabled camera to take photos and transfer them to the GIS to document the location of an infraction allowed them to see what happened where and whether there were underlying trends, all of which contribute to managing the sustainability of the build.

Innovative Transportation

Masdar City will utilize breakthrough transportation technologies that revolutionize and redefine urban transport. A Personal Rapid Transit (PRT) system running on solar-charged batteries will transport residents around the city. There will be 3,000 PRT vehicles, generating 130,000 trips each day across 85 stations. A Freight Rapid Transit system will make up to 5,000 trips per day to transport the city's goods. ArcGIS was instrumental in visualizing all routes for the PRT network and testing predicted walk times between PRT stations. Transportation planners also used ArcGIS to find optimal locations for perimeter parking garages, along with effective road and rail transport routes into the city. Real estate plots were valued using routing GIS.

Beyond Construction

Conventional cities of similar size create approximately 1.1 million tons of CO_2 per year—80 percent from buildings and energy creation, 13 percent from waste, and 7 percent from transportation. Masdar City expects to eliminate the emissions by producing zero carbons. ArcGIS will continue to be used and integrated with a computerized maintenance management system that will include the location of all infrastructure assets; gas pipes; smart grid infrastructure; clean, gray, and black water networks; and the transportation network. Moving forward, GIS will make facilities maintenance easier and enable the tracking of resource use and reuse and the overall carbon balance of the operational city. GIS will be used in city governance, where it will form part of the city's sustainability performance feedback service, which will inform residents about their personal contribution toward overall city performance.

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Mapping the Solar Potential of Rooftops

Germany's SUN-AREA Research Project Uses GIS

Highlights

- Using ArcGIS Desktop tools, researchers identified all necessary rooftop data.
- ArcGIS Desktop ModelBuilder was used to determine the solar potential of all roof areas.
- The ModelBuilder application gave the team an intuitive interface.

The solar age has dawned in Germany. About 20 percent of the country's rooftops are suitable for solar power production, according to recent results from the SUN-AREA Research Project. The project aims to determine how solar energy resources can be optimized by placing photovoltaic panels on rooftops around the country.

The SUN-AREA project is sponsored by the University of Osnabrück and the TOPSCAN topographical information company. It is led by geomatics engineer Martina Klärle and researchers Dorothea Ludwig and Sandra Lanig.

Preliminary findings of the SUN-AREA project estimate that, at full potential, solar power could meet the entire energy needs of homes throughout Germany. The team began its work with an examination of the northern German city of Osnabrück.

"We have proven that 70 percent of the city's total demand for electricity can be covered using only the roofs that are already present in Osnabrück," Klärle says. "In other words, if all the roofs that are especially suitable were now fitted with photovoltaic devices, we could meet 70 percent of the electricity needs of all of Osnabrück."

Germany is very well suited to generate electricity using photovoltaic systems. The majority of the population is not concentrated in urban centers, but spread out over rural areas. That means more space per person, and more roof area.

SUN-AREA researchers used ArcGIS Desktop applications to calculate the possible solar yield per building for the city of Osnabrück.

"My vision is to use all suitable roof surfaces to make solar electricity," Klärle says.

Now Klärle is trying to turn the SUN-AREA vision into reality. She gave city officials a solar power potential map of Osnabrück with an exact catalog of all suitable rooftops. The data has been made public and has already received positive response. The city is stepping up efforts to equip public buildings with solar collectors. Osnabrück has doubled its solar energy installations in the past year alone.

"We're at the point where we can't afford to get our electricity from coal-fired power plants, and we don't want to get it from nuclear power plants," she says. "I just won't accept that we have all this potential on our roofs, and we don't use it."

The SUN-AREA Method

SUN-AREA researchers set out to develop solar power potential maps of each roof area, each city, and each county or district in Germany.

The team started by gathering data, then devised a digital analysis method for identifying high-potential areas. Rooftop data was collected with aerial laser scanners. Klärle spent time flying through the skies over Germany, seeing to the effectiveness of the scanning technology.

Using ArcGIS Desktop tools, including ArcGIS Spatial Analyst, the researchers identified all necessary rooftop data, such as outer form, inclination, orientation, and clouding. The team used an algorithm sequence, created with the ArcGIS Desktop ModelBuilder application, to determine the solar potential of all roof areas. Important data included the angle and alignment of the roof, the sun's path across the sky, shadows cast by a chimney or another rooftop over the course of the day, and the seasonal change in hours of sunlight. The SUN-AREA project also calculated solar suitability, potential power output, CO2 reduction, and investment volume for each subarea of a roof.

The ModelBuilder application gave the team an intuitive interface to implement necessary data and tools to model solar power. The system detects optimal locations for producing solar power based on laser scanner data and plain view data.

The results from the Osnabrück pilot region are available to the public via an interactive online map created with ESRI's Web GIS technology (www.osnabrueck.de/sun-area).

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Renewable Energy—No Longer the Impossible Dream!

GIS and the Science Behind Tapping Wind Power Offer Insight on the Resource's Feasibility

Highlights

- ArcGIS improves the quality and accessibility of data to maximize the efficiency of decision making.
- Nearly all the wind power facility layouts can be done with GIS.
- Locating the right site can be done quickly and accurately with publicly available data and GIS technology.

Just then they came in sight of thirty or forty windmills that rise from that plain. And no sooner did Don Quixote see them that he said to his squire, "Fortune is guiding our affairs better than we ourselves could have wished. Do you see over yonder, friend Sancho, thirty or forty hulking giants? I intend to do battle with them . . . With their spoils we shall begin to be rich . . ."

When Miguel de Cervantes wrote of the impetuous and noble hero Don Quixote 400 years ago, he could not have imagined that one day environmental scientists and energy analysts would "dream the impossible dream" of stocking the electric grid with the power of the wind. Nor could he have envisioned the hulking giants that now line many a horizon, the 400-foot-tall wind turbines each wielding three 130-foot steel blades and weighing 8.5 tons. When he talked of tilting at windmills, the Spanish literary master would not have guessed that public utilities, private companies, and investors would someday look to the wind to "beat the unbeatable foes" of waning fossil fuel supply and deleterious carbon emissions.

Wind energy now accounts for 1 percent of the United States' power supply, and forecasts from the U.S. Department of Energy say that figure could reach 20 percent by 2030. While wind farms crop up across the country's windiest terrain, critics point to the need for new transmission lines and the variability of the wind. Many citizens support the idea as long as it's "not in my backyard."

The Maple Ridge Wind Farm is a 321-megawatt project spanning the New York towns of Martinsburg, Lowville, Watson, and Harrisburg, about 75 miles northeast of Syracuse. The project produces enough electricity to power up to 160,000 average New York homes. Maple Ridge has increased the amount of wind power in New York by 600 percent. New York is a state with a 25 percent Renewable Portfolio Standard, designed to be in full effect by 2013.

Despite criticism, wind power is touted as one of the cleanest, most reliable renewable resources dreamed up so far. But is harnessing wind power on a wide scale as quixotic as dreaming the impossible dream?

In 2008, the United States surpassed Germany as the world's biggest generator by volume of wind energy. The amount of wind power the United States generates has doubled in the last two years, according to the American Wind Energy Association (AWEA), a trade group for wind power developers and equipment manufacturers. An investigation into the solid science of wind power facility development clarifies the potential and reliability of this blustery resource.

Twenty-eight U.S. states have set renewable energy mandates and are determined to woo wind developers. A Nebraska utility brochure boasts, "Nebraska has wind. In fact, the state ranks sixth in America for wind development." An energy company in Minnesota is announcing plans to buy an interstate transmission line and develop wind energy to replace coal-generated electricity. One county in Montana is distributing a wind map book compilation of all necessary data to entice investors.

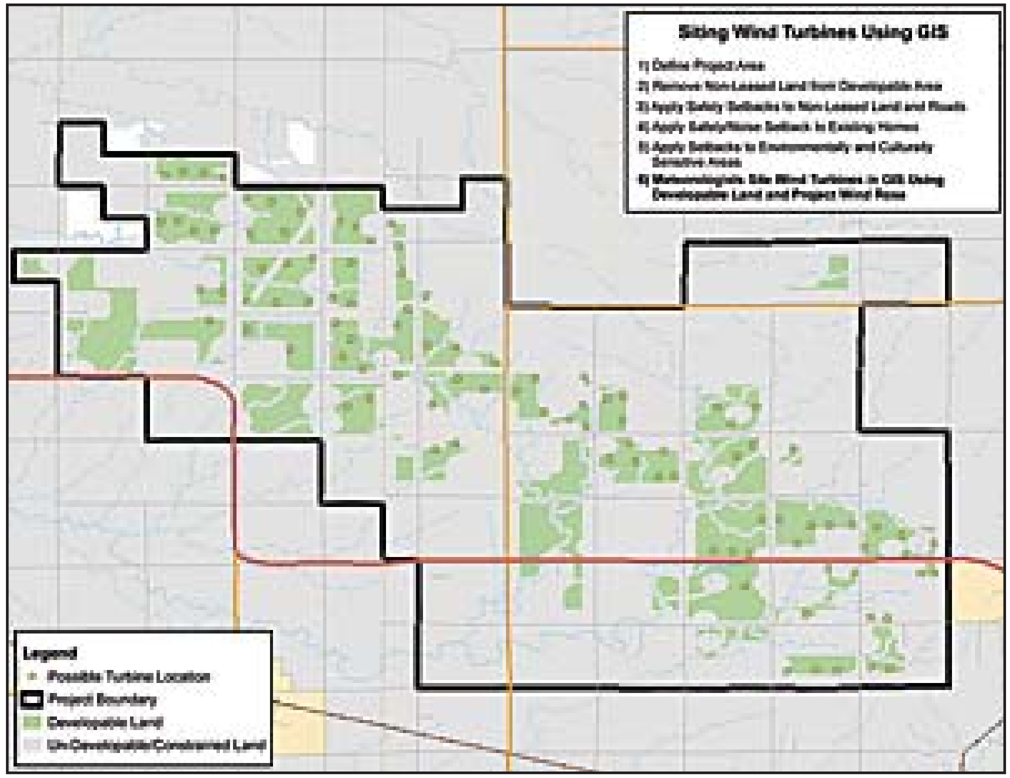
Harnessing the Wind

Wind turbines convert the kinetic energy in moving air into rotational energy, which in turn is converted to electricity. Humans have used wind power for centuries to move boats, grind grain, and pump water. Timeless and simple as it may seem, development of a wind power facility is much more complex than staking a pinwheel in the breeze.

Iberdrola Renewables is the largest developer of wind power in the world. It has a flurry of wind power projects in the works as utilities aim to reduce dependence on nonrenewable energy. Modeling the feasibility of these projects requires studying location, wind speed, environmental concerns, and other variables.

There was a time not long ago when the company's development teams of meteorologists, engineers, environmental permitting staff, and land agents only had paper maps to work from. These paper maps didn't show property ownership, wetlands, county- or state-required safety setbacks, rights-of-way, or environmental and cultural resource sites.

Knowing that there had to be a better way, Iberdrola investigated available technologies that would help it organize and analyze complex data and decided that GIS from ESRI, which was a familiar platform for engineers in the electric and gas industry, would dramatically improve the quality and accessibility of its data and maximize the efficiency of decision making. ArcGIS Desktop and ArcGIS Server became fundamental to the business model of the company.



This example of siting wind turbines with GIS shows six layers of data.

Smart Layers for Smart Maps

The life of a wind farm project starts with a look at potential plots of land. Most developers require land within a prescribed distance of a transmission line to tie in power to the grid. If the wind is strong and steady, developers may decide to build their own transmission line. By loading utility data into the GIS, researchers can quickly see existing transmission routes and estimate the benefits of accessing existing electric lines.

Another important consideration for developers is landownership. State and county land-use data in the GIS identifies areas under development restrictions from the Bureau of Land Management and those requiring right-of-way grants. If land is privately owned, developers will have to obtain consent from individual landowners.

A layer of constraints is added, marking areas that are environmentally protected for migratory flight paths or other animal activity. Other site restrictions are military bases and airports where developers must consider radar interference and Federal Aviation Administration regulations.

Wind data is equally crucial to researchers, who add a resource layer to ArcGIS detailing wind speed and reliability. Meteorological data is continuously collected during a one- to five-year period using tower-based anemometers and vanes mounted at several height levels up to 60 meters aboveground. Wind power can be classified into wind power density classes ranging from one (poor) to seven (excellent). For example, a wind power class of four has an average wind speed of 15.7 to 16.8 mph at a height of 50 meters aboveground. In addition to site research, meteorologists use wind data stored in ArcGIS Server to help design the layout of a wind farm by identifying wind direction, strength, and location.

Site Scouting Field Trip

"Almost all the wind power facility layouts can be done in the GIS, with maybe one or two visits to the field," says Tyler Hoffbuhr, GIS analyst and manager with Iberdrola Renewables. "Now we can stock the GIS with U.S. Geological Survey maps, property lines, aerial photography, and detailed topography data to see how the buildable area matches up with the wind data."

When development teams visit a proposed location, they collect site-based data to compare with digital information and maps within the GIS. Using a mobile device equipped with GPS and GIS, the team is able to update data from the site and make any necessary adjustments to the facility layout.

"GIS enables us to reach our goal of finding the best wind areas while causing as little impact as possible to wildlife and the environment," says Hoffbuhr. "Locating the right site can be done quickly and accurately with publicly available data and GIS technology."

In total, wind power facility development is about a four-year process that involves the site research and data collection, as well as procurement of government permits, landowner permission, funding, and the physical resources. When the plans are ready, developers hand over the project to the construction team.

"Once all the initial research is done, construction of the wind power complex happens quickly, sometimes in four to six months," says Laurie Jodziewicz, manager of siting policy, AWEA. "Projects under construction right now will be online and delivering energy within a year or less."

Once a wind farm is up and running, operators continue to use GIS to help gather inspection and operational data. Since wind energy is variable, utility companies have to figure out what to do when the wind does not blow. With ArcGIS technology, operators can model and predict how well the wind will perform in the next few hours or days and accurately match energy production with demand.

But Will It Work?

Healthy government incentives are driving much of the wind power development in the country. A report led by the Department of Energy's National Renewable Technology Laboratory in Golden, Colorado, reiterated predictions that wind energy will claim a 20 percent share of electricity production in the next 10 years. The report called the forecast "ambitious," but "feasible."

The energy industry is already on board with more than 9,000 new wind farms under construction in the United States and nearly 20,000 existing.

"With sophisticated site development technology and incredible wind resources, wind energy is becoming increasingly valuable," said ESRI's utility industry expert Bill Meehan. "We are now seeing utilities integrate wind power into the electric system to supplement fossil fuels. Wind is a cost-effective, nonpolluting energy source that will continue to be one answer to international energy concerns."

The Elk River Wind Project is a 150-megawatt wind energy project located in Butler County, Kansas.

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