ZONINGPRACTICE July 2008

AMERICAN PLANNING ASSOCIATION

APA

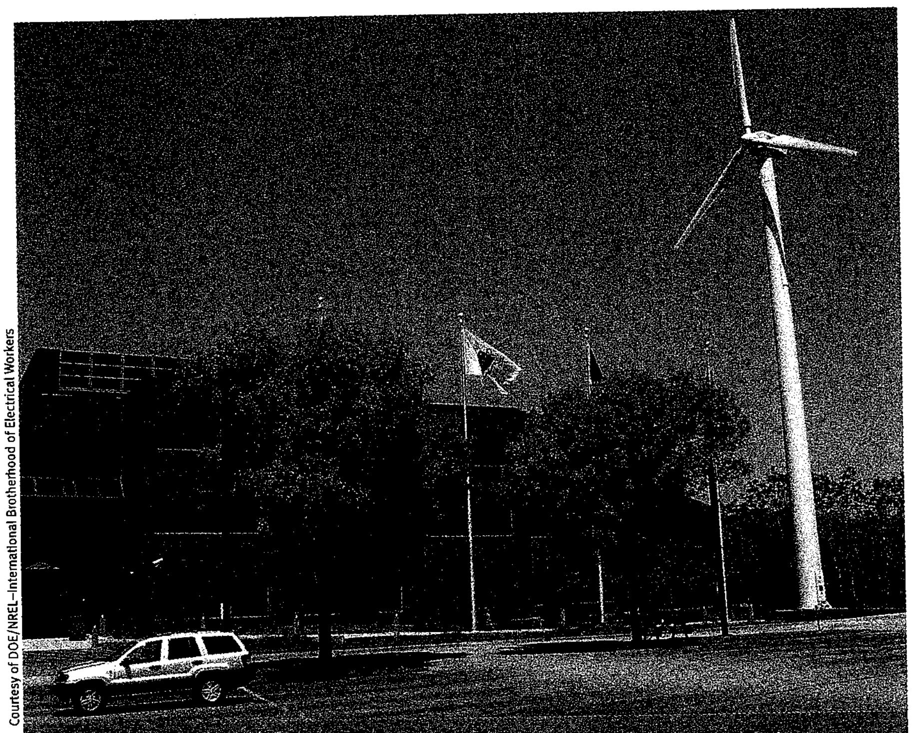
ISSUE NUMBER SEVEN

PRACTICE RENEWABLE ENERGY

Urban Wind Turbines

By Erica Heller

Wind is an abundant renewable resource in much of the U.S.



Courtesy of DOE/NREL–International Brotherhood of Electrical Workers

This turbine at the International Brotherhood of Electrical Workers Local 103 in Dorchester, Massachusetts, represents the upper limit of small wind energy conversion systems.

As wind power development expands, technologies are being developed and improved to increase efficiency and reduce impacts. A range of new turbines (wind energy conversion systems, or WECs) enable wind power to be harnessed in a much wider variety of settings than ever before, including in urban and suburban settings.

Many local governments that have never processed an application for a wind turbine permit may find themselves needing to review one in coming years. In fact, most of these communities are unprepared to review these permits and lack the standards to ensure safe installation in compatible locations. This can result in lengthy, costly public review processes that yield mixed results.

SMALL WIND

"Small wind" refers to turbines rated 100 kW or less that can be used to power farms, homes, or businesses. The vast majority of nonrural applications for wind are small WECs, sited as accessory uses to a primary business or residential use. The photo on the left shows a 100 kW WEC located at the offices of the International Brotherhood of Electrical Workers Local 103 in Dorchester, Massachusetts—this is as big as "small" wind gets. A WEC used at a residence (such as that shown on page 4) is typically smaller—up to 10 kW and about 50 to 80 feet high (depending on a number of factors, as will be discussed). Even smaller WECs may be used for targeted applications, such as the systems shown on page 5, which are mounted on light poles to offset power used by the lights in a shopping center parking lot in Lakewood, Colorado. Rooftop models, often used in rows, are a newer type of small wind that is growing in popularity for commercial applications and urban areas.

URBANIZED SETTINGS

This article focuses on incorporating small WECs in urbanized settings. The science of small wind is the same across urban and rural settings, and the discussion here may also be useful for planners in rural areas. However, this article does not specifically address rural settings. Within urbanized settings, there are a variety of zoning districts in which WECs may be appropriate, including industrial, commercial, and even residential neighborhoods, as the images in this article depict. Successful integration of WECs in densely built environments requires careful examination of potential impacts and thoughtful standards that balance mitigation against the cost effectiveness of installing a turbine.

POWER FROM SMALL WECS

Planners often ask if small WECS produce enough energy to justify both installation

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About the Author
Erica Heller is an associate with Clarion Associates based in Denver, Colorado. She has six years of experience working on community and neighborhood plans, development codes, and airport land use plans. Prior to joining Clarion, she was a long-range planner for Lakewood, Colorado. Heller recently presented at the APA National Conference in Las Vegas on the topic of zoning standards for wind turbines.

costs and potential land-use impacts. Because WECs can be controversial, it is reasonable to ask if they are effective. The answer depends partly on planners and local officials. A small WEC can produce impressive amounts of power, but only with access to good wind, which is largely a function of proper siting and adequate height—factors that zoning regulations impact mightily.

UNDERSTANDING LOCAL WIND RESOURCES

The U.S. Department of Energy (DOE) and National Renewable Energy Laboratory (NREL) provide state-level wind resource maps for nearly every state in the U.S., and some state governments provide more detailed maps. Wind resource maps show the average strength of the wind at 50 meters, with a ranking between 1 (weakest) and 7 (strongest). Most utility wind developers today look for areas with steady Class 4 or 5 winds, but Class 2 or 3 winds, which are found in much of the U.S., can power small WECs.

Large-scale wind maps are a free resource that can help a community understand generally if wind energy potential is likely to exist. To determine the actual wind power generation potential of a given site, a site-specific wind resource assessment by a qualified professional is needed. Site-specific assessments are typically the responsibility of the property owner.

FACTORS THAT INFLUENCE ENERGY PRODUCTION

How much energy a WEC will produce depends primarily on three factors:

(1) The engineered design of the turbine, which determines efficiency of power transfer. Modern WECs are highly engineered and most are very efficient.

(2) The size of the rotor. Capacity increases with "swept area," meaning the total area of the spinning rotor blades. Area, and thus capacity, increases geometrically with blade length.

(3) The speed and consistency of the wind. Power output increases exponentially with wind speed, but gusty or turbulent winds can damage turbines. Variations in topography and obstructions such as buildings and trees slow the wind and add turbulence near the ground. Therefore, adequate height is a critical factor in WEC effectiveness. In order to function well, the lowest part of the rotor blades must be a minimum of 25 to 35 feet higher than surrounding obstructions. Height regulations that do not achieve such separation eliminate the benefits of investing in a WEC.

The National Renewable Energy Laboratory provides estimates of yearly energy generation potential for small wind turbines. Using these figures, it is possible to estimate the power generation potential for various turbine sizes and wind classes and to gauge the number of average U.S. homes that can be powered. The table below illustrates the variation by wind speed and rotor size (assuming good wind access). Depending on such factors, a residential turbine can often supply about one-third to one-half of an average U.S. home's energy demand and a substantially greater percentage if the home is energy efficient. Larger "small" WECs can supply consumers with higher energy demand, such as commercial or public facilities.

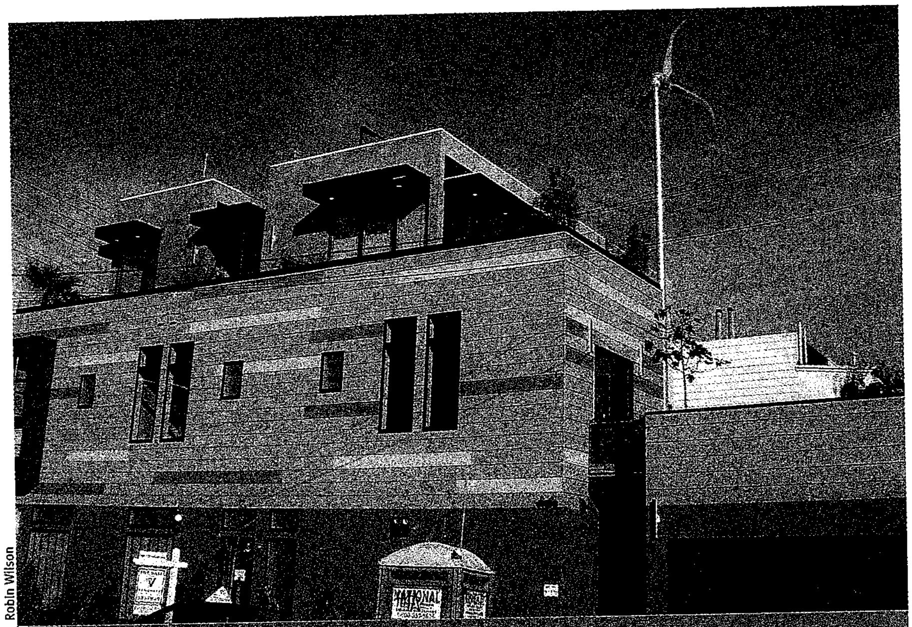
CARBON EMISSION REDUCTIONS FROM WIND-GENERATED ENERGY

Using 100 percent wind-generated energy versus typical utility energy can reduce annual carbon emissions by eight tons for a U.S. home with typical energy demand. This is equivalent to the carbon emissions produced annually by 1.4 typical U.S. passenger cars. Thus, for an average two-car household, converting the

MEDIAN NUMBER OF HOMES POWERED BY SELECTED WECS SIZES AND WIND CLASSIFICATIONS

	Wind Strength					
Rotor Diameter	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7
3 m	0.3	0.3	0.3	0.4	0.4	0.5
5 m	0.7	1.0	1.2	1.3	1.5	1.9
7 m	1.4	2.0	2.3	2.6	3.0	3.7
10 m	2.9	4.1	4.8	5.4	6.1	7.5
12 m	4.1	5.9	6.9	7.7	8.8	10.8

Estimated NREL median yearly energy production figures, expressed as kWh per square meter of swept area, are multiplied by swept area, then divided by U.S. national average annual home energy usage to estimate the number of average homes powered


Robin Wilson

A small 10 kW residential turbine in San Francisco's Mission District.

home to 100 percent wind power reduces carbon emissions as much as driving one car 40 percent less and not using the other car at all! If we take the need to reduce carbon emissions seriously—as many studies and recent global events strongly suggest that we should—then incorporating WECs into our communities may be a more practical approach than radical changes to our driving behavior. Communities should seriously consider how and where to allow WECs to ensure that regulations are not so strict as to eliminate their potential for effective energy production.

THE CASE FOR LOCAL ACTION

In addition to reducing CO_2 emissions, there are several important reasons that local governments should draft reasonable standards for WECs:

(1) *Respond to community desires.* Ultimately, permitting decisions are local decisions. Permitting takes public time and resources, especially when uses must be approved through discretionary approvals. Good zoning standards that address potential impacts can allow WECs to be permitted as by-right uses, at least in some districts, reducing public cost and NIMBY battles.

(2) *Maintain local autonomy.* In several windy states, state legislatures have restricted the ability of local governments to deny permits for WECs. By proactively adopting reasonable, locally appropriate standards, local governments reduce the likelihood that states will override local control.

(3) *Protect local resources.* Many states offer incentives such as rebates or buy-down programs for WECs. Where public funds are used to encourage WECs, standards should ensure that this money is well spent.

(4) *Diversify energy supply.* Small-scale WECs can help diversify energy supply. Many small WECs are less vulnerable to attack than a centralized plant. If a storm, system overload, or terrorism event shuts down energy grids, small WECs can provide dispersed backup power.

One of the least expensive alternatives for small increases in grid energy capacity is to allow small-scale producers, since they, rather than the utility, purchase and maintain the infrastructure. Such investments may delay or reduce the need for major capital investments by the utility.

COMMUNITIES ALLOWING TURBINES IN SUBURBAN AND URBAN SETTINGS

- Brewster, Massachusetts (www.town.brewster.ma.us)
- Centennial, Colorado (www.centennialcolorado.com)
- Chicago (www.cityofchicago.org)
- Duluth, Minnesota (www.duluthmn.gov)
- Fairfield, California (www.ci.fairfield.ca.us)
- Mason City, Iowa (www.masoncity.net)
- Saco, Maine (www.sacomaine.org)
- San Francisco (www.ci.sf.ca.us)

Note: Not all communities fully conform to the recommendations in this article.

LAND-USE IMPACTS AND RESPONSIVE STANDARDS

Wind turbines can have impacts on surrounding property owners and land uses. Permit requests for wind turbines may be controversial—particularly in residential areas—due to both real and perceived impacts. Impacts can be grouped in four categories: noise impacts (normal and storm conditions); safety impacts (electrical and structural safety, potential for climbing, and avian impacts); aesthetic impacts (appearance and visibility); and property value impacts. Each of these categories is discussed below, along with zoning tools and standards to address them.

In this discussion the assumed goal is to adequately address impacts in a way that is responsive to realistic concerns but not onerous to the turbine owner. Time and cost requirements for permitting are among the biggest hurdles for many potential turbine owners and can quite easily determine whether a WEC is cost effective. For this reason, local governments should strive to keep requirements to the minimum necessary to address impacts.

NOISE IMPACTS AND STANDARDS

Although noise is often a first concern of neighbors, small WECs are less noisy than most people expect and rather easy to regulate. The noise from a modern small WEC that would be used in a residential setting (up to about 10 kW) can be compared to a flag flapping in the wind. To further illustrate, the noise level measured 50 feet away from a WEC on an 80-foot tower is approximately 45 decibels—quieter than standing next to a kitchen refrigerator. When operating in extremely

> Due to variation in noise performance of different turbine models, standards to address noise that specify turbine size may produce varied results, and local governments should adopt a standard for noise measured at the property line.

windy conditions, noise levels may be slightly higher, but so will ambient wind-related noise, such as that made by wind in trees. Noise levels are reduced by a factor of four for each doubling of distance (as measured from the turbine to the listener). Thus, off-property noise intrusion from a residential WEC is typically very limited.

Due to variation in noise performance of different turbine models, standards to address noise that specify turbine size may produce varied results, so local governments should adopt a standard for noise measured at the property line. In general, it is appropriate to use the same standard for "nuisance noise" that the community applies to all other activities in the zoning district. Adding the caveat "or 10 decibels above ambient noise levels" gives some leeway to turbine owners during very windy conditions when ambient noise levels rise and neighbors are less likely to be outdoors. This caveat also helps if the neighborhood is already impacted by another noise source, such as a freeway. By measuring noise at the property line, the turbine owner can limit it by using a quieter model, increasing setbacks, adding a fence or hedge along the property line, or other techniques.

SAFETY IMPACTS AND STANDARDS

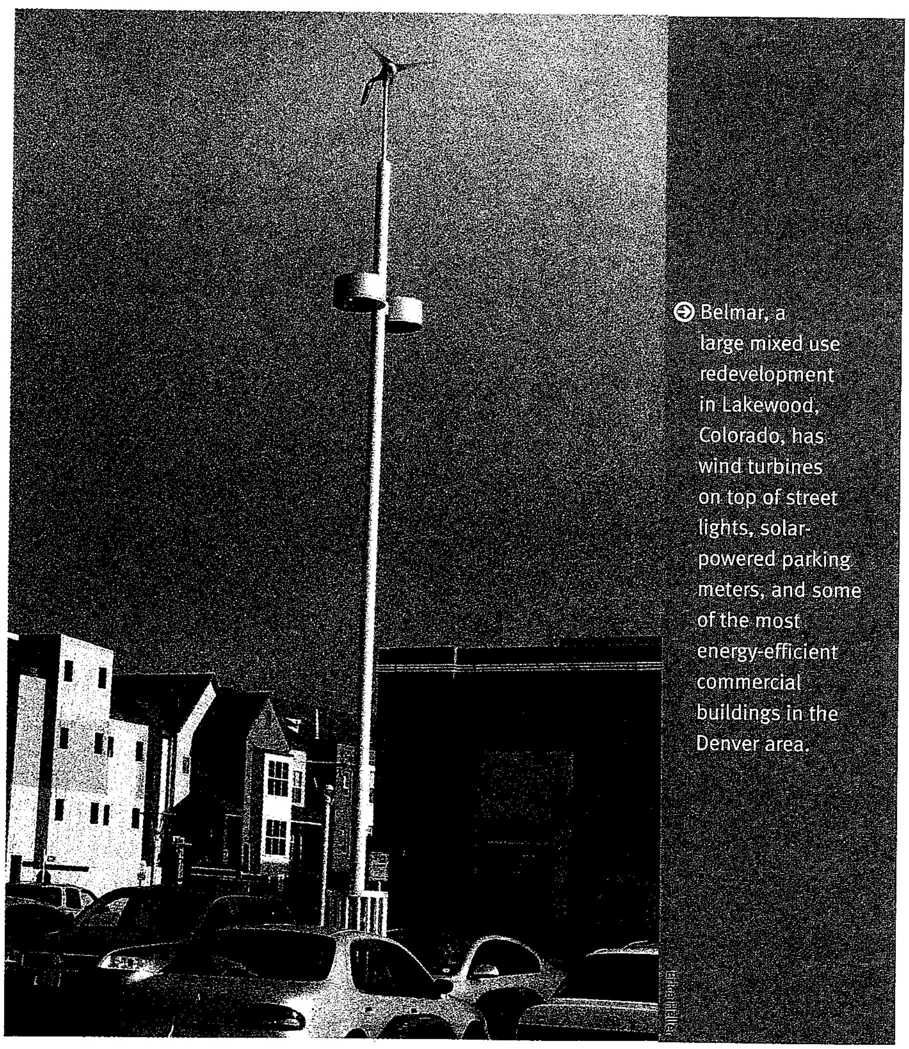
Safety is, of course, an important concern. Local governments should address three main issues when writing zoning and permitting standards for WECs: structural failure, electrical failure, and climbing potential. This section concludes with a brief discussion of safety-related issues associated with windfarms. Although risks for small wind are minimal, opponents often raise safety concerns, and planners should be aware of these concerns and be prepared to respond.

Structural Failure

One concern with wind turbines near property boundaries is that the supporting pole or tower could fall down. However, structural failure in a WEC is extremely unlikely. A turbine is a significant investment, as are the engineered towers and poles on which they are installed. WECs are not sold as do-it-yourself appliances. Rooftop models must be installed on structures that are engineered to accommodate the additional weight and stress. The likelihood of structural failure in a properly installed WEC is not more likely than for a flag pole, and is much less likely than for trees. Even so, a setback requirement of 1.1 to 1.5 times the total height of the WEC (i.e., tower or pole height plus rotor radius) is a reasonable requirement. Such setbacks address a range of potential impacts including safety, noise, and aesthetics, and can give neighbors peace of mind.

In most cases the local building inspector can verify that installation conforms to approved plans. It is not necessary to require an engineer to certify installation, except in cases where a reduced setback is to be approved with recorded consent of the adjacent property owner.

Because WECs are installed by professionals, additional certifications add unnecessary expense for a small WEC owner. Soil testing is generally unnecessary and is often cost prohibitive; it should only be required if soils are so weak as to merit testing for



Belmar, a large mixed use redevelopment in Lakewood, Colorado, has wind turbines on top of street lights, solar-powered parking meters, and some of the most energy-efficient commercial buildings in the Denver area.

AeroVironment, Inc.

The Adventure Aquarium in Camden, New Jersey, uses a modular, rooftop-mounted turbine system that eliminates the need for stand-alone support towers.

similar structures, such as flag poles or cell towers.

Finally, it is reasonable that, as for billboards and cell towers, local regulations require an owner of an abandoned WEC to remove it from the property. Over time, an abandoned system might become a structural hazard.

Electrical Failure

Electrical failure is highly unlikely in a modern WEC. Like individual furnace units, these systems are factory certified by engineers for electrical integrity, and thus third-party inspection for an individual turbine is unnecessary. Modern systems also come equipped with manual override brakes so that in the event of an electrical outage the turbine may be shut down. To make sure that the property owner installs a WEC that meets modern standards, local governments should require a permit applicant to submit the manufacturer's electrical drawings and require that the system is equipped with manual braking.

Climbing Potential

WECs on towers may raise the concern that children will try to climb supporting structures and fall, causing injury or death. Many pole-mounted turbines lack climbable features (they are designed to be lowered to the ground for servicing) or have removable climbing features below 12 feet. Local governments should only require fences around WECs if equivalent regulations apply to similar uses; designs that lack climbing features should be exempt.

Safety and Nuisance Issues of Large WECs

Neighbors may express the following concerns that are associated with large, utility WECs. Planners should be ready to respond.

- *Effects on birds.* The effects of WECs on birds has received much attention due to documented bird kills at a windfarm in Altamont Ridge, California, which is located in a major raptor migration corridor. A small WEC kills fewer birds than a single domestic cat or sliding glass door. Except perhaps in critical endangered bird species habitats, where even very small population losses are unacceptable, WECs should not be restricted based on avian impacts.
- *Acoustical interference.* The slow-spinning blades on large WECs can cause thumping vibro-acoustical effects or cast flickering shadows. Faster rotating, smaller WECs do not cause the same effects. Radio signal interference is also associated with some large turbines. Modern small-scale wind turbine blades are not metal, so they are "invisible" to radio frequency transmissions.
- *Ice buildup.* A concern about turbines in northern climates is that they can accumulate and then throw off ice. This has been observed occasionally in windfarms. However, chunks of ice on the surface of the lightweight blades of small WECs alter aerodynamics so much as to slow or stop the blades from turning until most ice has melted. English and German scholars in a 1998 study used physics to calculate that the risk of personal or property damage from flying ice from a small WEC is lower than the risk of being hit by lightning.

AESTHETIC IMPACTS AND STANDARDS

The appearance of wind turbines is a serious issue in many communities. Opinions vary widely about whether WECs are attractive, based largely on personal taste. Urban environments are not visually pristine, and many of the concerns about aesthetics may sound familiar to planners who have already dealt with aesthetic opposition to satellite dishes, cell towers, and even modern archi-

RESOURCES

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tecture. Visibility and appearance are two major issues related to wind turbine aesthetics.

Visibility

WECs are usually quite visible because they must be placed high enough to access good wind. Sometimes, height can actually decrease their visibility from the street. More often, though, a community has to decide if the aesthetic impact is serious enough to enforce height standards that would compromise a system's functionality. Small WECs must be mounted at least 25 to 35 feet above surrounding objects—between 50 to 120 feet (the higher the better) in order to perform well. At lower heights, even if there is a lot of wind, it will be so turbulent that the turbine will wear out quickly, before installation costs can be recouped. In densely built environments, where there are many objects at varying heights creating turbulence, height becomes even more important. A local jurisdiction with standards that allow WECs but severely restrict heights can inadvertently undermine the effectiveness of the system, its potential sustainability benefits, and the substantial investment of the turbine owner.

Appearance

The appearance of a turbine is an aesthetic issue, and one that is readily and easily controlled without impacting effectiveness. Sound responses to appearance issues include the following:

- *Color.* Do not require special colors to blend with trees. Studies show that the light gray factory color of most turbines is the best for blending into a range of sky conditions.
- *Signs.* Clarify that WECs cannot be used as, or used to support, signage that is not otherwise approved through the sign ordinance.
- *Removal.* Require removal of abandoned WECs. If a system is not productive, the visual impact should be eliminated.
- *Lighting.* Do not require special lighting except in airport districts. Structures less than 500 feet in height are not considered flight hazards unless located in close proximity to an airport.
- *Restrictions.* Consider restricting WECs in specific unique areas. The aesthetic impact of wind turbines may be unacceptable in historic and character districts or in special view corridors.

PROPERTY VALUE IMPACTS

One concern that resonates with local officials is the potential impact of wind turbines on surrounding residential property values. Although there have been no statistical studies of the impact of small WECs on property values, most available evidence suggests that adjacent property values and sale prices do not decrease. In fact, values may *increase* because the WEC signals a positive community attitude toward renewable energy and because adjacent owners recognize the potential benefits of a turbine on their own property. The likely effect from small systems can also be inferred from studies of large WECs. The only longitudinal study of property values near windfarms shows that on average, after an initial dip during the farm's construction, the value of properties within sight of a windfarm actually increased faster than similar properties.

On properties where windfarms had detectable nuisance impacts (such as noise), value does decrease. It is important that local standards protect against any nuisance impacts of small WECs, but communities should not assume that aesthetic impacts alone lower adjacent property values.

> A community has to decide if the aesthetic impact of a WEC is serious enough to enforce height standards that would compromise a system's functionality.

SUMMARY

While turbines can have a variety of potential impacts in urban areas, most are easily remedied through reasonable standards. Local standards should strive to protect neighbors from nuisance or safety impacts without restricting property owners who wish to install WECs. Performance standards such as permissible noise levels, setback requirements, height limitations, and exceptions can ensure that one man's turbine is not another man's migraine.

Local standards and requirements should consider the impacts of permit costs or regulations that substantially reduce the ability of WECs to effectively serve their purpose. The aesthetic impact of turbines is a real concern for many residents, but aesthetics alone do not appear to have a measurable effect on neighboring property values. The impacts of WECs should be compared to similar structures that are allowed to create visual impacts in our urban settings, particularly those associated with power generation and transmission. Ultimately, each community will need to decide if the benefits of clean, local power generation are valuable enough to justify the visual impact of turbines in some zoning districts.

Cover photo: Small wind turbines like this AIR 403 from Southwest Windpower can be used to recharge recreational vehicle batteries or reduce residential energy. Courtesy of DOE/NREL—Southwest Windpower

VOL. 25, NO. 7
Zoning Practice is a monthly publication of the American Planning Association. Subscriptions are available for $75 (U.S.) and $100 (foreign). W. Paul Farmer, FAICP, Executive Director; William R. Klein, AICP, Director of Research.

Zoning Practice (ISSN 1548–0135) is produced at APA. Jim Schwab, AICP, and David Morley, Editors; Julie Von Bergen, Assistant Editor; Lisa Barton, Design and Production.

Printed on recycled paper, including 50-70% recycled fiber and 10% postconsumer waste.

IS YOUR COMMUNITY READY FOR SMALL WIND?

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AMERICAN PLANNING ASSOCIATION

122 S. Michigan Ave.
Suite 1600
Chicago, Il 60603

1776 Massachusetts Ave., N.W.
Washington D.C. 20036

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058201 Z4I-D
Roland Bartl, AICP
Town of Acton
472 Main St
Acton MA 01720-3952