Wind and Solar Production and the Sustainable Development Code

Erica Heller

The Rocky Mountain Land Use Institute

Sustainable Community Development Code
Research Monologue Series:
Energy

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About the Research Monologue Series
The Sustainable Community Development Code, an initiative of the Rocky Mountain Land Use Institute, represents the next generation of local government development codes. Environmental, social, and economic sustainability are the central guiding principles of the code. Supporting research for the code is represented by a series of research monologues commissioned, presented and discussed at a symposium held at the University of Denver in September of 2007. RMLUI and the University of Denver's Sturm College of Law extend its gratitude to the authors of the papers who have provided their talents and work pro bono in the service of the mission of RMLUI and the stewardship of the creation.

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About the Author

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Introduction


Solar and wind energy production as residential accessory uses.
Source: IEEE Spectrum online

Alternative energy production through the harnessing of renewable natural resources is an important component of environmental and economic sustainability.[1] In many places in the U.S., the cost of wind power development is now comparable to more traditional energy development, such as coal-fired plants. Wind resources in the U.S. could provide as much as 20 percent of our total electrical power demand. Currently, solar power is cost-effective on the utility scale only in the desert southwest, but small-scale solar has proven cost-effective over time for tens of thousands of small-scale users. According to the U.S. Department of Energy, 48 states and a U.S. territory have some type of solar or renewable energy incentive—including investment credits, rebates, sales tax, or property tax waivers.[2] Benefits of renewable energy include reduced carbon emissions, diversified energy production, avoided of utility expansion costs, improved air quality, reduced reliance on foreign oil, and others.

Wind power development is expanding in the U.S., and technologies are being developed and improved, increasing the ability to harness wind in a variety of rural and urban settings. Improved solar energy collection panels and materials, such as roof tiles and flexible textiles that can expand solar collection applications, are also being developed. Many communities are entirely unprepared to review wind turbine permits and lack standards that can ensure safe installation in compatible locations, resulting in lengthy, costly public review processes that yield mixed results. In the case of solar energy production, many communities adopt design standards and/or allow restrictive covenants that inadvertently restrict the ability of property owners to install solar panels. Wind and solar are two kinds of alternative energy production that should be addressed in a sustainable local land use development code.

A sustainable land use development code should allow and encourage alternative energy production in locally appropriate areas. It should provide reasonable compatibility standards to protect against intrusive impacts of alternative energy production – such as glare, noise, or bird kill – without unduly restricting the potential of alternative energy production for sustainability. This report addresses the technology,

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[1] Many fine thinkers have explored the definition of "sustainability" at length. For the purposes of this paper, the 1987 Brundtland Commission definition of sustainability is succinct and adequate: "Meeting the needs of the present generation without compromising the ability of future generations to meet their needs."

[2] Department of Energy. *Learning About PV: Quick Facts.* http://www1.eere.energy.gov/solar/pv_quick_facts.html

energy generation potential, and land use impacts of wind and solar power generation, as well as the potential for carbon emission reductions. It then suggests a variety of land use code changes to remove barriers, allow, and encourage wind and solar energy production.

Wind Power

Windmills are one of the oldest non-consumptive means of harnessing energy for human endeavors. While the original windmills simply used the power of wind through direct mechanical transfer, such as for milling grain or pumping water, today's efficient wind turbines convert wind into charged ions, providing electricity for any imaginable use. Wind energy development is expanding in the rural U.S. with more large-scale wind "farms" (utility power plants consisting of many large-scale turbines) in areas with rich wind resources. Small-scale wind power is also on the increase, with a variety of private companies developing turbines that increase the ability to harness wind in settings that range from rural to urban. Consequently, many local governments increasingly should be prepared to review and permit wind turbines for a variety of applications in the near future.

Source: AeroVironment Press Release

State of wind power technology

Wind power technology has diversified in the last decade, with turbines of more sizes and configurations, of quieter and more efficient design. These include (See photos, below and throughout document.):[3]

- Large utility turbines for wind farm settings that are typically 250-300 feet tall with rotor diameters of 60-100 feet (19-30 m) or more;
- Mid-sized turbines for estate or agricultural uses, generally tower- or pole-mounted up to 125 feet tall with 25-55 foot (6-18 m) rotor diameter; [4]
- Small-scale turbines with 9-15 foot (3-5 m) rotor diameter, on 50-80 foot tall poles, for residential use;
- Roof-top turbines for installation on flat-roofed buildings such as commercial, institutional and industrial with 10-20 foot (3-6 m) rotor diameter;

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[3] Except as otherwise noted, the source of all images in this paper is the National Renewable Energy Laboratory web-based publicly available photographic library.

[4] Height is expressed in feet because local height regulations are typically expressed in feet in the U.S. Because NREL energy potential calculations for small wind (used later in this paper) key off of rotor diameter in meters, rotor diameter is indicated in both feet and meters.

- Turbines with 3-6 foot (1-2 m) rotor diameter that can be mounted on utility or light poles; and
- Micro-turbine panels, with rotors of a foot or less in diameter, are under development to be used in areas with low-to-moderate wind speeds. These micro-turbines would likely supplement, rather than replace, other power sources.

The range of new turbines types enable wind power to be harnessed in a much wider variety of settings than ever before. This may mean that many communities that have never processed an application for a turbine permit may need to review one in coming years.

Micro-wind turbines. Source: Science and Technology Online

The potential of wind power

Wind is an abundant resource in much of the U.S. According to some estimates, the wind resources in North Dakota alone could theoretically power more than 25 percent of U.S. demand. Table 1 shows the theoretical wind energy potential of the top twenty states in the U.S.

Table 1: THE TOP TWENTY STATES
for Wind Energy Potential as measured by annual energy potential in the billions of kWh, factoring in environmental and land use exclusions for wind class of 3 and higher.

	B kWh/Yr		B kWh/Yr
1. North Dakota	1,210	11. Colorado	481
2. Texas	1,190	12. New Mexico	435
3. Kansas	1,070	13. Idaho	73
4. South Dakota	1,030	14. Michigan	65
5. Montana	1,020	15. New York	62
6. Nebraska	868	16. Illinois	61
7. Wyoming	747	17. California	59
8. Oklahoma	725	18. Wisconsin	58
9. Minnesota	657	19. Maine	56
10. Iowa	551	20. Missouri	52

Source: An Assessment of the Available Windy Land Area and Wind Energy Potential in the Contiguous United States, Pacific Northwest Laboratory, August 1991. PNL-7789

Because wind power generation is dependent on an intermittent resource, and power demand is relatively constant day-to-day, theoretical wind energy potential and practical wind power development are not the same. Still, Battelle Pacific Northwest Laboratory, a federal research laboratory, conservatively estimates that wind energy could reliably supply at least 20 percent of the nation's electricity, while wind energy advocates see potential for greater percentages. By the end of 2007, however, wind supplied approximately one percent of all U.S. power generation.[5]

Power and energy basics

Watts (W) are units of power. A kilowatt (kW) is 1000 watts, and megawatt (MW) is 1000 kW. Turbines are generally rated for their maximum power output capacity under normal wind conditions (as defined by the manufacturer). Energy production and use are commonly expressed in kilowatt hours (kWh), meaning a kilowatt of power used continuously for an hour. Over the course of a year, the number of kWh that a turbine will produce depends partly on its rated capacity and partly on the amount of time that wind conditions are within operating parameters (not too weak, too strong, too gusty, etc.).

Wind resource maps

The U.S. Department of Energy (DOE) and National Renewable Energy Laboratory (NREL) have mapped the wind resources in the U.S. (See Figure 1 below.) and provide state-level wind resource maps for nearly every state in the U.S.[6] These maps show the average strength of the wind at 50 meters above the ground, with a ranking between 1 (weakest) and 7 (strongest). These rankings are shown in Figure 1 with weaker ratings in lighter colors and stronger ratings in darker colors. Some state governments, including Iowa, California, and Minnesota, have undertaken more detailed wind resource mapping within their respective states.

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[5] Personal communication, January 2008.

[6] Wind maps are not available for some southeastern states, where wind resources are generally very limited.

Areas with potential for large-scale generation

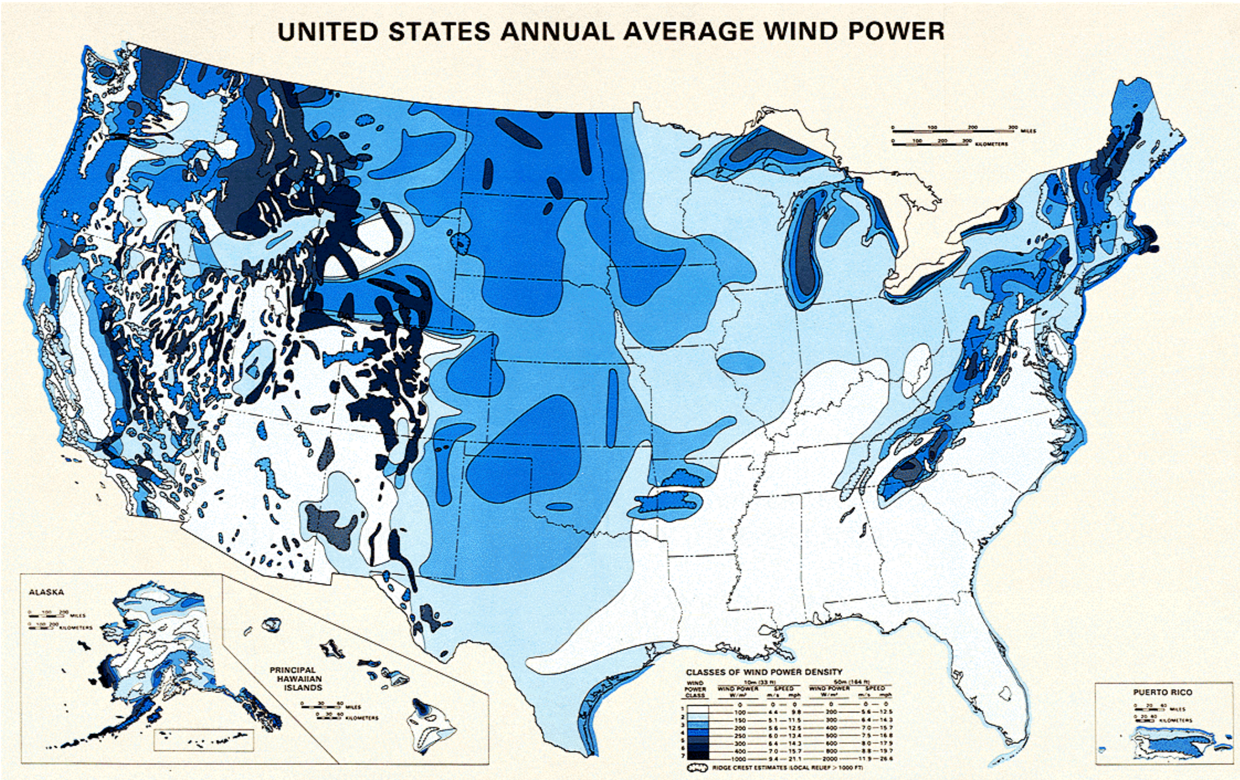

Figure 1: United States Annual Average Wind Power

Large-scale wind maps can help a community determine generally whether the potential for large scale or small-scale wind power generation exists in their area.[7] According to NREL, areas designated class 3 or greater are suitable for large scale wind farms.[8] Most utility wind developers today look for areas with steady class 4 or 5 winds near an existing large-scale utility grid (to keep transmission costs and efficiency in line). Local governments with undeveloped windy areas near population centers should consider land use regulations and permitting processes to enable and address utility-scale wind power generation. (See discussion under land use regulations, below.)

Areas with potential for small-scale generation

"Small wind" refers to wind power generated by turbines rated 100 kW or less, which are generally smaller than 120 feet tall, and can be used to power farms, homes, or

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[7] Note that site-specific wind resource assessment by a qualified professional is essential to determine actual wind power generation potential of a given site. Large-scale wind maps are a free resource that can help a community to understand generally if potential is likely to exist, so that the community can prepare appropriate zoning standards.

[8] National Renewable Energy Laboratory. *Wind Maps.* http://www.nrel.gov/gis/wind.html#high

businesses. Where utility wind farm development is infeasible, communities should be prepared to review and permit small-scale wind turbines. Class 2 wind is generally adequate for mid-scale turbines that can serve rural and agricultural uses such as pumping water or powering off-grid homes, or to generate supplemental power in industrial and commercial urban settings. Class 3 wind can power mid-size and small turbines that may be compatible in a variety of urbanized areas, including residential areas. Even in areas with low annual average wind speeds, seasonal or diurnal winds may be harnessed to supplement other power sources, if installation is not cost-prohibitive.[9] Many urban communities that have never reviewed a turbine permit application actually have substantial potential for small-scale wind power generation using newer technologies, and should be prepared for permit applications.

Net metering and State incentives

Small-scale production is increasingly feasible in areas with state and local government regulations that encourage wind energy development. For example, many state and local governments require utility providers to allow “net-metering” for small-scale producers. In net-metering, kWh sent to the grid by the turbine is credited against the kWh drawn by the turbine owner. Usually, if the turbine owner sends more energy than she uses, the utility must pay the turbine owner for the excess energy produced at wholesale, producer rates. Net-metering typically makes the turbine more cost effective, and thus makes it more likely that an individual property owner will choose to invest in small-scale energy generation. In addition, according to AWEA, nineteen states – including California, Massachusetts, Montana, New Jersey, New York, Ohio, Rhode Island, Wisconsin, and Vermont – offer rebate or buy-down incentives help overcome initial small turbine costs.

The case for local action

In addition to helping reduce CO_2 emissions, local governments should draft reasonable standards for wind turbines to protect local wind resources, maintain local autonomy, and diversify energy sources. Moreover, it benefits communities that control their local power utility.

Wind source protection

Because prime wind resources are tied to particular locations, local government typically has jurisdiction to regulate these key areas. When a local community is aware of local wind energy generation potential, it can decide whether to try to protect the wind resource from incompatible development and to allow wind power generation. Otherwise, the wind resource may be blocked or built over without due consideration.

[9] Cost effectiveness of wind power technology is dependent on site-specific wind potential, the cost and efficiency of the turbine, and a variety of factors that may change based on political and market conditions such as local power cost, permitting costs, and available rebates or incentives. Therefore, determining cost-effectiveness of installing a given wind power technology in a given location beyond the scope of this paper. Useful calculators are available from a variety of organizations on the internet.

Local autonomy

Maintaining local autonomy is another key reason why local governments should act with regard to wind power regulation. In several windy states, such as Nevada and California, state legislatures have preempted local government by writing regulations that restrict the ability of local governments to deny permits for wind turbines that meet state standards. By proactively regulating wind turbines with reasonable, locally appropriate standards, local governments can reduce the likelihood that higher levels of governmental power will override local control.

Diverse energy sources

Adding both large- and small-scale wind power sources helps to diversify energy supply. A more diversified energy supply is better insulated from volatile oil and gas markets that can leave lower-income local residents in some areas unable to pay heating bills. From a security standpoint, a large number of small energy producers are less vulnerable to attack than a single centralized source. Also, if a major weather or terrorism event shuts down primary energy sources or transmission networks, small wind energy would provide some power to at least a limited number of residents and institutions, potentially in a dispersed pattern, creating pinpoints of communication and assistance.

Private investment in energy production

In communities that control the local power utility, large-scale and small-scale wind power generation has several obvious benefits. As noted above, diversifying production is an excellent hedge in oil and gas markets. In the long term, allowing small-scale producers to connect to the grid and net meter is probably one of the least-cost alternatives for small increases in capacity expansion of the energy production and delivery system, since individuals rather than the utility purchase and maintain the infrastructure. Such investments may delay or reduce the need for major capital investments by the utility, particularly where alternative sources can help to meet or reduce peak demand.

Land use impacts and challenges

As indicated, a wide variety of wind turbines are available that are applicable for a range of settings. Like many beneficial land uses, wind turbines can have impacts on surrounding property owners and land uses. Differently sized and designed turbines have different impacts, which may be of greater or lesser concern depending on the setting. For simplicity, this report addresses three applications of wind turbines and their land use implications: utility, rural/agricultural, and urban.

Utility Turbines

This report uses the term “utility turbines” to refer to turbines designed for large-scale wind farms. As a rule, these are larger, taller, and may be louder than turbines that would be used for agricultural and urban applications. They also generate substantially more power. Land use impacts and challenges of utility turbine applications include:

Potential impacts:

- **Visibility/aesthetics:** While opinions differ, some people find wind farms to be unattractive in rural or natural landscapes. Utility turbines are quite tall and are often located on ridge lines to catch optimal winds, making them visible from far away and increasing their overall aesthetic impact. Rather than comparing the visual impact of a wind farm to existing undeveloped conditions of a given parcel of land, it may be more appropriate to compare them to the visual impact of other, more traditional power plants and their emissions. If power generation capacity must be expanded, wind turbines may not be the worst aesthetic choice.

- **Land consumption:** A large wind farm, such as Altamont Ridge in California, may cover several square miles. In this sense, wind power generation is land consumptive. However, the turbine footprints are relatively small, and other uses, such as crop production or rangeland, may be coupled with wind farms. In some places, solar power generation may also be a compatible additional use.
- **Transmission lines:** Like other power plants, wind farms require transmission lines to send the power they generate to users. Wind farms are more cost effective to install when they are closer to the existing power grid and demand centers. Also, the transmission lines can have additional visual and land consumption impacts. Although public utilities have the power to take easements for the public purpose of power transmission, such takings are typically unpopular, making closer locations with shorter transmission corridors more desirable.
- **Noise:** Wind turbine rotors moving at high speed emit noise, typically broadband "whooshing" type noise. Early (1980s) models also emitted tonal sounds; humming or whining noise that could be heard as much as a mile away. Today, however, a modern wind farm registers between 35-45 decibels – about as noisy as a kitchen refrigerator – at just 750 to 1,000 feet away.[10] Another related consideration is the vibro-acoustic effect of the spinning blades, where a rapid thumping sound is heard and felt from a distance, not unlike the way a bass drum may be heard and felt even when the other parts of the music are not audible. Residential neighbors living up to 1700 feet from 2MW utility wind turbines report that the repetitive vibro-acoustic effect is a nuisance, and some report health effects such as difficulty sleeping and irritability.[11] New wind farms should be

[10] American Wind Energy Association. *Noise Factsheet.* EA http://www.awea.org/pubs/factsheets/WE_Noise.pdf

[11] A good compilation of individual reports and researched articles on this topic is available on the Industrial Wind Action Group website: http://www.windaction.org/documents/c43/.

located far enough from residential areas so that sound does not to disturb residents, but close enough to reduce transmission distance and cost. For example, noise and vibro-acoustic impacts generally are not reported at 2000 feet from a 2 MW turbine.

- **Ice throw:** A final concern about turbines in northern climates is that, when they are covered in ice in winter and then begin to spin, they can throw ice off at high velocity that could harm persons or property. It is true that ice can be thrown from utility turbines, and that to date, the only documented injury from ice throw is a wind plant employee. The larger the turbine blades, the faster the top speed of the blade tips. In optimal conditions, 40-foot blades turn up to 150 mph while 80-foot blades turn as fast as 187 mph. Opinions vary about, however, about the realistic distance that a large, heavy chunk of ice might be able to travel based on how much the ice will interfere with aerodynamics of the blades and slow them down. Physics calculations, that do not accounting for any slowing from the ice, yield a figure of 2000 feet as a guaranteed safe distance from a turbine with 80-foot blades.[12] Many industry experts suggest that 1.5 times the turbine height is adequate distance to protect against reasonable risk from harm from ice throw.
- **Flickershadow:** Opposite the sun, the spinning rotor blades of a large wind turbine cast flickering shadows. For a person in the flickershadow area, particularly near sunset or sunrise, the effect can be similar to a strobe light. Some residents living close to wind farms without intervening trees or buildings complain that the effects of flickershadow range from loss of enjoyment of sunsets, to annoyance, to triggering migraine headaches. Modeling and analysis can accurately predict the location of flickershadow so that turbines can be located to prevent impacting existing structures. The separation distances suggested to address vibro-acoustic impacts would also prevent flickershadow problems.
- **Bird deaths:** When spinning rapidly, the large rotor blades of utility turbines can be a hazard for birds that may not see them. This problem has received much attention due to a high number of documented bird kills at Altamont Ridge wind farm in California, which is located in a major raptor migration corridor. Numerous studies in other areas show that bird losses to rotors are relatively rare; even the National Audubon Society has issued statements supporting that well-sited wind turbines are no more harmful to birds than other sources of power. Nevertheless, wind farms should not be located in major bird migration corridors, where many birds pass through, or in critical endangered bird species habitat, where small population losses may be unacceptable. Furthermore, crops planted near turbines should not be those that attract birds (such as grain crops) or rodents (which, in turn, attract birds of prey).
- **Radio signal interference**: Utility scale wind turbines have been observed to interfere with radio signal transmission when placed directly in line between transmitters and receivers. The result is reduced quality of television and other radio signals. Radio signal interference can be prevented by considering a wind

[12] Dr. Terry Matilsky. "PART I – basic kinetics" and "PART II---comments on inclusions of drag coefficients and risk assessment" found at: http://www.physics.rutgers.edu/~matilsky/windmills/throw.html.

farm's location with respect to transmission towers prior to installation. Corrective measures that boost transmission or reception can be installed to overcome some of the interference, but prevention is the better practice. Local government should pay particular attention to protecting transmission towers for essential communications, such as airport or emergency uses.

Other concerns:

- **Flight hazard:** A red herring for wind turbines, especially utility turbines, is the notion that they constitute a flight hazard. Except within close proximity to an airport, the FAA does not consider any structure less than 500 feet in height to be a flight hazard. Spinning utility turbine rotors do not exceed this height limit and therefore turbines may be allowed without FAA review and do not have to be lighted. However, utility turbines should not be located in close proximity to airports or areas where they would interfere with crop dusting aircraft, which fly at very low altitudes.
- **Property value:** Neighbors of wind farms often worry about the impact of a wind farm on property values. Generally, on wind farm properties with detectable nuisance impacts (such as noise, vibro-acoustic, or flicker-shadow) property values decrease. However, evidence does not support a generalization that simply being within sight of a wind farm decreases property value. A much-critiqued 2003 report by the Renewable Energy Policy Project is the only longitudinal study on this issue. It looked at property values in the vicinity of nine different wind farms across the U.S. and found "no evidence that property values decreased as a result of [being within sight of] wind farms." The study concluded that, "for the great majority of [wind farm] projects the property values actually rose more quickly in the view shed than they did in the comparable community. Moreover, values increased faster in the view shed after the projects came online than they did before."[13] It is not clear from the study why this is so. A number of single-case studies have presented counter-evidence that property values fall within view of a new wind farm, however they are less conclusive about whether the impact on property values continues over the long-term. In any case, it is clear that possible nuisance impacts must be addressed to protect property values nearest to a wind farm.

Rural/Agricultural Turbines

This section refers to the use of small or mid-scale turbines on farms or in rural areas (but not utility turbines, even when land around a utility turbine is also used for agriculture, which is addressed above). Most often, these are turbines with 3-10 m (10-33 ft.) rotor diameter, with the hub of the rotor mounted on a pole or

[13] Renewable Energy Policy Project. *The Effect of Wind Development on Local Property Values.* http://www.crest.org/articles/static/1/binaries/wind_online_final.pdf

tower 100-150 feet tall. They are typically located where neighboring residences are too far away to experience noise impacts or thrown ice; they do not require special transmission lines, are not high enough to be a flight hazard, and while opinions differ, many people consider wind turbines in farm settings to be aesthetically compatible or pleasing. Thus, rural/agricultural turbine applications generally have very few negative land use impacts, with the exception of potentially posing a hazard for birds. Note that most studies find that small wind turbines that are not in migratory routes compare favorably to a single domestic cat or sliding glass door in terms of annual bird kill.[14] Still, it may be advisable to consider limiting rural/agricultural turbines in major migration corridors, or in endangered bird species habitat.

Urban Turbines

In using the term “urban turbines”, this report refers to turbines of 1-7 m rotor diameter (3-23 ft.), either rooftop or pole-mounted, when installed in urban settings.[15] When pole-mounted, generally the hub is 50-80 feet high, but may be up to as much as 120 feet. These turbines range from the 100 kW turbine shown at right, at the offices of the International Brotherhood of Electrical Workers Local 103 in Dorchester, Massachusetts, to the rooftop turbines pictured on page 2, to small (less than 2 m diameter) turbines mounted on the light poles of a commercial shopping center parking lot in Lakewood, Colorado, to offset the power used by the lights.

Urban applications of wind turbines, particularly in residential areas, can be very controversial due to both real and perceived impacts. One of the great challenges to permitting turbines in urban areas is inaccurate perception. Many people base their assumptions about turbines on older technologies (noisier, less efficient models), exaggerated data (for example, assuming that all turbines will kill birds at the rate observed in Altamont, where conditions were worst-case), or extremely unlikely events (a small turbine throwing ice a long way at high speed). Therefore, the following list includes not only actual land use impacts, but also concerns that are commonly expressed by neighbors that may or may not be true impacts.

Potential impacts:

- **Aesthetics:** A serious concern for many neighbors is the appearance of wind turbines. Opinions vary widely about whether wind turbines are an eyesore, just as for many other aspects of the urban landscape, such as satellite dishes and

[14] See for example, National Fish and Wildlife Service. “Migratory Bird Mortality Fact Sheet”. http://www.fws.gov/birds/mortality-fact-sheet.pdf

[15] Micro-turbines, due to their small size, are generally expected to have very limited potential for land use impacts and be exempt from local permitting procedures because they are not structures.

modern architecture. Generally, wind turbines are not considered more visually offensive than other, more common power generation and transmission fixtures such as utility poles and transmission towers, which are accepted in most communities and neighborhoods. However, the height of turbines may be greater than those structures, impacting more peoples' view. Compounding the issue, wind turbines cannot be screened from view without reducing their function. The aesthetic impact of wind turbines may be especially unacceptable in areas, such as historic districts, where they clash with an established character. Studies show that the factory-painted light gray color of most turbines is the best for blending into a range of skies, thus requirements to "camouflage" turbines by painting them in tree-colors should generally be avoided.

- **Noise:** Modern, small-scale wind turbines emit very low levels of noise in broadband frequencies and may also emit some tonal noise. Smaller, faster rotating turbines do not create the thumping vibro-acoustical effects of utility-size turbines. For many current small turbine models, the noise level measured 50 feet away from an 80 foot tower is approximately 45 decibels. Noise levels are reduced by a factor of four for each doubling of distance. Thus, off-property noise intrusion of a turbine that is set back 100 feet or more from the property line is typically very limited. When operating in extremely windy conditions, noise levels may be slightly higher, but will also be more comparable to ambient wind-related noise, such as that made by wind in trees. Due to variation in noise performance of different turbine models, local government should adopt a standard for noise at the property line to protect neighbors from noisy models.
- **Attractive nuisance:** Wind turbines mounted on towers sometimes raise the concern that children may try to climb supporting structures and fall, causing injury or death. Many modern small pole-mounted turbines lack climbable features (they are designed to be lowered to the ground for servicing). Local governments should treat climbable wind turbines with regulations equivalent to those that apply to other attractive nuisances (e.g., fencing around swimming pools or cell phone towers), but exempt designs that lack climbing features.
- **Structural or electrical failure:** A concern with wind turbines near property boundaries is that the supporting pole or tower could fall down. There are at least two ways to address this concern. Many communities require that a turbine be set back from property lines a distance equal to the height of the pole plus the rotor radius. However, as the Canadian Wind Energy Association notes, "Trees are much more likely to fall than a properly installed wind turbine, but no setbacks or minimum property sizes are required for trees."[16] Some communities allow an engineer to certify correct installation as an alternative to setbacks. Soil testing in the installation area is generally unnecessary for the stresses that could be created by small turbines and is often cost-prohibitive, and generally should not be required. To address concerns about electrical failure, most communities require that turbines meet national building code and electrical code standards,

[16] Canadian Wind Energy Association, http://www.smallwindenergy.ca/en/FAQ.html#Are%20small%20wind%20turbines%20safe?

and some require that it be certified by a credible small wind power turbine certification program (for example, one recognized by AWEA).

- **Bird deaths:** Bird deaths from small turbines are generally very limited, but it may be advisable to limit urban turbines in major bird migration corridors, and/or in endangered bird species habitat.

Other concerns:

- **Height and wind access:** Generally, turbines on taller poles have access to better, more constant wind. Although greater pole height may increase visual impacts to some degree, urban turbines should generally be mounted at between 50 to 120 feet - the higher the better - in order to perform well. Communities that allow or encourage wind turbines may need to consider protecting the wind resource available to an installed turbine. To function optimally, a turbine should be at least 25-35 feet taller than and 300 feet away from surrounding trees and structures. In single-family residential areas, turbines should be allowed at heights that are at least 25-35 feet higher than maximum residential building heights. This is also true in commercial and industrial areas, where codified building height limits – even if they are higher than what is typically built – can ensure wind access for those considering a substantial investment such as a mid-scale turbine. Even for rooftop turbines, an established maximum building height can guide individual choices about where to mount turbines (e.g., on buildings that are 300 feet or more away from property lines, or are of the maximum allowed height) in order to prevent possible interference from future development.
- **Property value:** Another concern for many neighbors is the impact of wind turbines on surrounding residential property values. This research found no longitudinal or multi-case studies of the effect of a small wind turbine on nearby residential property values. Wind power advocates point to anecdotal evidence of strong market values for neighboring properties where the purchaser hopes to install a similar turbine, or feels that the presence of the turbine indicates community conservation values.[17]
- **Ice throw:** The concern about small turbines in northern climates is that, like utility turbines, they may throw ice off at high velocity that could harm persons or property. However, the smaller blade length and maximum speed of small turbines and the smaller size of the ice chunks that can form on them reduce the potential hazard considerably. An AWEA research report indicates that generally, chunks of ice on the surface of small turbine blades will alter aerodynamics so as to slow or stop the blades from turning until most ice has melted,[18] and most evidence suggests that ice accumulates at the base of small turbines, rather than being thrown. English and German scholars in a 1998 study

[17] American Wind Energy Association. *Advice from an Expert: Residential Wind Turbines and Property Value.* http://www.awea.org/faq/sagrillo/ms_zoining_propertyvalues.html

[18] American Wind Energy Association. *Advice from an Expert: Home Sized-Wind Turbines and Flying Ice.* http://www.awea.org/faq/sagrillo/ms_ice_0306.html

calculated that, at any distance, the risk of personal or property damage from flying ice from a small wind turbine is lower than the risk of being hit by lightning.[19]

- **Radio signal interference**: While some older models were made with metal blades that could theoretically create radio interference, modern small-scale wind turbine blades are made from non-metal materials that are "invisible" to radio frequency transmissions.

Addressing urban impacts, weighing benefits

While turbines certainly can have a variety of potential impacts in urban areas, many of these are easily remedied through reasonable standards. Performance standards such as permissible noise levels, setback requirements, and height limitations and exceptions should be used to ensure that one man's turbine is not another man's migraine. Finally, the aesthetic impact of turbines is a real concern for many residents. The aesthetics of wind turbines should be considered in comparison to other possible power generation facilities and installations, acknowledging that power generation is an essential part of modern society. The potential of small-scale wind turbines to supply clean power to urban environments, reducing fossil fuel use, emissions of carbon and other air pollutants, and utility infrastructure costs, is substantial (as discussed in further detail in the next section). Ultimately, a community may need to decide if the benefits of clean, local power generation are valuable enough to justify the aesthetic impact of turbines, in at least some urbanized locations.

Measuring the potential of local wind power

Alternative energy is an important component of sustainability because of the potential to substantially reduce carbon emissions. Atmospheric carbon levels are linked to climate change. Reducing fossil fuel use appears to be the most likely means of avoiding catastrophic changes in our global climate and weather patterns. Additional benefits may include diversification of energy production, avoidance of utility expansion costs, improved air quality, and others. But, how much power can be generated by wind turbines, and how much carbon would be off-set? It is difficult to give a simple answer that is generally applicable, because the answer depends on the model and design of turbine and on the site-specific strength and constancy of wind, as well as on factors such as air density based on temperature and elevation. However, some generalizations can be made using small wind energy productivity estimates available from NREL.

Power generation of utility-scale wind.

1.5 to 1.8 MW is a typical power rating for large-scale turbines for utility use. AWEA indicates that each 1 MW of wind power capacity can power 240 - 300 homes.[20] Thus,

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[19] Morgan, Colin, Bossanyi, Ervin and Siefert, Henry. *"Assessment of Safety Risks Arising From Wind Turbine Icing".* BOREAS IV 31 March - 2 April 1998, Hetta, Finland. Available at: http://www.renewwisconsin.org

[20] American Wind Energy Association. *Wind Industry Statistics.* http://www.awea.org/faq/wwt_statistics.html

a utility wind farm of 100, 1.8 MW turbines operating at full capacity would power 43,000 to 50,000 homes.

Power generation of small- scale wind.

Table 2, below, from NREL, indicates yearly energy generation potential of small wind turbines by wind power class. The productivity is expressed as kWh per square meter of "swept area," meaning the total area of the spinning rotor blades. NREL offers a range of productivity for each wind class, because of the range of wind conditions within each class and the many other factors that can influence productivity.

Table 2: NREL Yearly Energy Production Estimates for Small Wind Turbines

Wind Power Class	Productivity per m2 of swept area (kWh/year)
1	<350
2	350 - 500
3	500 - 610
4	610 - 690
5	690 - 770
6	770 - 880
7	880 - 1170

According to NREL, the 44 turbines at the Mountaineer Wind Energy Center in West Virginia pictured above produce a maximum of 66 MW of electricity. Each turbine stands 228 feet above Backbone Mountain with rotor blades of 115 feet in diameter.

Using the NREL Small Wind Turbine Productivity Estimates, it is possible to roughly estimate electricity generation potential for various turbine sizes and wind classes. Table 3 (next page) uses the median NREL productivity estimate for each wind class multiplied by swept area of selected rotor diameters to estimate yearly energy produced by a range of small wind turbines. Next, using data from Table 3, it is possible to estimate the number of homes that could be powered by a range of small wind turbine sizes operating in classes 2-7 of wind power. In Table 4 (next page) the median energy output figures in kWh/year are divided by U.S. national average annual home energy usage (10,565 kWh) to estimate the number of average homes powered per year. These estimates are useful for understanding the scale of small wind potential and how it relates to wind class and turbine rotor size. For example, a wind turbine 5 m in diameter (about 16 feet across, or eight-foot blades) can power one home for a year in class 3 winds, while a turbine of twice the diameter can power more than four homes in the same wind.

Table 3: Estimated Median Energy Production (kWh/year) for small wind turbines and wind power classifications						
Rotor diameter	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7
3 m	2,755	3,921	4,592	5,157	5,829	7,206
5 m	7,654	10,892	12,756	14,326	16,191	20,018
7 m	15,001	21,348	25,002	28,079	31,734	39,234
10 m	30,615	43,568	51,025	57,305	64,763	80,070
12 m	44,086	62,737	73,476	82,519	93,258	115,301

Table 4: Median Number of Homes Powered per Year for selected small wind turbine sizes and wind classifications						
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

Carbon emission reductions from wind-generated energy

According to the DOE,[21] on average in the U.S., production of 1 kWh of energy releases 1.55 pounds of CO_2 into the atmosphere (this reflects the current national mix of all types of energy production plants). Energy generated by wind turbines does not release any carbon dioxide.[22] Table 5, indicates how much carbon emissions are reduced when 100% wind-generated energy is used compared to typical energy. Table 5 (next page) presents the reductions per number of homes, assuming average annual home energy use of 10,565 kWh. To make this figure more meaningful for the reader (since most of us cannot easily picture a ton of CO_2 gas), the final column indicates how many typical U.S. passenger cars' emissions would be offset by the 100% wind-powered homes.[23]

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[21] Department of Energy. *Energystar Useful facts and Figures.* http://www.energystar.gov/index.cfm?c=energy_awareness.bus_energy_use

[22] Neither of the estimates for carbon emissions per kWh include emissions during manufacturing/installing of the power plant(s).

[23] Table 5 uses the U.S. Environmental Protection Agency's most recent (2000) estimate that the average passenger car emits 11,450 lbs. of CO_2 per year.

Table 5: Estimated Reductions in Carbon Dioxide Emissions and Cars Offset by Number of Homes Powered by Wind		
Homes	Tons of CO_2	Cars Offset
1	8	1.4
5	41	7
10	82	14
100	819	143
1,000	8,188	1,430
10,000	81,879	14,302
50,000	409,395	71,510

As indicated in the tables, small wind turbines have the potential for power generation in a wide variety of settings and applications, including in moderately windy (Class 2 and 3) areas, which can substantially reduce carbon emissions (as well other air pollutants that contribute to asthma and acid rain). The strong potential of wind power to enhance local sustainability suggests that communities should seriously consider how and where to allow wind turbines locally.

Land Use Code strategies and actions for wind power

Many individuals that install a wind turbine report that the local permitting process is the most challenging and expensive aspect of their project. Often, this is because the community lacks set standards for permitting turbines and the applicant must go through a time-consuming special permit review process requiring extensive public hearings. Sometimes, design standards or other universally applicable regulations inadvertently prohibit the equipment, forcing the applicant to apply for discretionary review.

This section describes a variety of specific strategies for development code revisions that allow and promote wind power. Note that a variety of states and advocacy organizations have developed model ordinances for allowing utility-scale wind power development that may serve as a good starting point. However, as described above, the land use impacts differ somewhat for smaller-scale turbines, and appropriate adjustments should be made.

This section is divided in three parts: actions to remove obstacles to wind power generation and ensure compatibility of small-scale wind turbines; incentives to encourage wind power development, and regulations that require actions to protect the wind resource, or require installation of wind power generation equipment under certain circumstances.

<u>Remove obstacles and ensure compatibility</u>

Many communities' codes include provisions written for other purposes that inadvertently prohibit wind turbines. Some communities may also have provisions for wind turbines that are overly strict, treating wind turbines differently than other, similar structures such as flag poles or cell phone towers. This may also be true of subdivision covenants. Certain key regulations should also be included in the sustainable development code to ensure that wind turbines are compatible with a safe and healthy community. Local governments can take the following steps to remove code-based obstacles and ensure compatible wind turbine development:

Allow Turbines

1. List rooftop and pole-mounted wind turbines as a permitted accessory use in industrial and commercial districts; exempt rooftop turbines from screening requirements for rooftop mechanical equipment.
2. List small-scale wind power generators as a permitted accessory use in single family residential districts, subject to use standards.
3. List small-and mid-scale wind power generators as a permitted accessory use in agricultural and rural residential districts, except in major migratory bird flyways.
4. List utility-scale wind turbines as a permitted use in appropriate rural areas (i.e., at least one-half mile away from urban and suburban density residential development).
5. List wind turbines as an exception to basic height limitations (similar to flag poles).
6. Do not require lighting, fencing, or other "protective" measure that are not necessary or required of similar structures such as cell phone towers.
7. Overrule subdivision covenants that would otherwise prohibit wind turbines.
8. Revise design standards that would not allow rooftop turbines on flat-roofed buildings.

Compatibility Standards

1. Adopt use standards to ensure compatibility of turbines, provide positive examples, and allay fears. These could include:
    a. Adopt a setback requirement for wind turbines of pole height + rotor length.
    b. Adopt a maximum building height in each district that is at least 35 feet lower than the maximum allowed height for wind turbines, to ensure that all turbines can access the wind resource. Small scale turbines can typically be effective at heights of 50-120 feet, as long as they are 25-35 feet higher than surrounding structures.
2. Adopt a performance standard that regulates permitted decibels levels at the property line. Consider a flat standard or a scaled standard compared to ambient noise, such as "not more than 65 decibels or 10 decibels above ambient noise levels, whichever is greater".
3. Include a flexible standard to keep children off turbine support structures, such as "Turbine shall either be supported by a pole that lacks usable hand- or footholds

below sixteen feet in height, or if supported with a pole or tower that could be climbed, shall be fenced with a six-foot security fence around the base."

4. Create a permit process for utility-scale wind generation that considers bird migration routes, compatible concurrent uses, soil stability, etc.
5. Create a permit process for small-scale wind turbines (i.e., rotors les than 20 foot radius and hub height less than 120 feet) that provides for reasonable safety and welfare but does not require excessive, costly studies.

Incentives

Once a community has removed obstacles to wind turbines, the next step toward a sustainable code is to consider incentives that would encourage wind power. Beyond cash incentives, which few communities can afford, some possible incentives include:

1. Give credit for on-site wind power generation in any green-building or other performance-based development review points system.
2. Streamline permitting or reduce permit fees.
3. If the electric utility is locally controlled (and not subject to a state requirement for net-metering), require that the utility net meter and/or provide wholesale payments for net energy produced.
4. Waive or defer tax payments for developments that produce 50% or more of their energy demand through wind turbines.
5. Allow developers the option to purchase and install a wind turbine in lieu of paying development impact fees.
6. Encourage production above the immediate user's needs. Structure incentives programs to encourage individual property owners to select and install equipment that generates the greatest amount of power within the parameters of adopted performance standards, to maximize the societal benefit of each turbine installed without increasing overall impacts.

Regulations

In some cases, it may be appropriate for local government to take action, such as mapping or zoning overlays, to promote wind energy production. Such actions might include:

1. Preserve prime wind farm sites in rural areas that are not currently developed through overlay zones that restrict development not compatible with utility power generation. For example, it may be desirable to restrict residential subdivision development in or near a class 5 wind area near a center of power demand.
2. Map critical bird flyways and habitat, and prohibit turbines in highly sensitive areas.
3. Mandate that new development with energy demands above a threshold amount must install wind turbines to supply 20 percent or more of the estimated power demand.

Wind Power Summary

Wind turbines can capture an abundant renewable energy resource in the U.S. and provide substantial sustainability benefits. Local land use regulations should address wind turbines in order to enable and encourage the safe and compatible inclusion of turbines in locally appropriate settings. Land use planners in areas with abundant wind in non-urban areas should:

(1) Map and protect key wind resource areas that could provide utility-scale wind power (either based on existing development or anticipated future growth);
(2) Use model ordinances as a basis for permitting utility-scale wind; and
(3) Streamline permitting for rural residential and agricultural applications for mid-sized turbines, with modest performance criteria.

In urban and developed areas with class 3 winds or better, small-scale wind can power a significant number of homes and/or offset power demands from commercial and industrial users. Land use planners in urban areas should:

(1) Allow small-scale turbines in most districts as accessory uses by-right and mid-scale turbines in industrial and commercial areas;
(2) Remove unintentional barriers to turbines such as height limitations;
(3) Adopt performance standards as needed – but not more strict than similar uses;
(4) Require reasonable permitting criteria and fees; and
(5) Be familiar with common concerns about turbines in order to calm anxieties.

Solar Power

This section will address solar power generation, both photovoltaic and solar thermal, and the sustainable development code. This report does not address issues of building or site design for passive solar gain.

The state of solar power generation technology

Solar energy technology has vastly improved, both in efficiency and production costs, since the first photovoltaic (PV) panels were engineered for use in space in the 1960s. The two major types of solar energy generation types now in use are PV and solar thermal. This section describes both types of solar energy technology and the applications used or under development.

Photovoltaic solar technology

PV technology uses light energy from the sun. Many of today's rigid PV panels reach an efficiency of 17 percent, meaning they are able to transfer 17% of the light energy of the sun into usable electric current. Demand for solar panels is currently very high and is spurring private companies to build more facilities to produce PV panels. Solar panels are expected to become more available, efficient, and affordable by 2012. According to the not-for-profit organization Regional Renewables:

> Since the late 90's, [PV] prices have been dropping steadily. Average retail cost of a large solar panel in 1990 was around $7.50 per watt. As of 2005 prices are around $4 per watt. In 2004 the worldwide production of solar cells increased by 60%. 2005 is expected to see large growth again, but shortages of refined silicon have been hampering production worldwide since late 2004.[24]

In addition to increasing efficiency in traditional rigid PV panels manufactured using silicone and very high temperatures, NREL and others have developed a "thin film" PV technology that is flexible and is made from less costly materials. These lightweight, flexible PV materials use less energy in production, have lower production costs per foot, and can be used in a wide variety of applications. Thin films are less efficient than today's rigid panels – typically about six percent. Some applications for thin film PV include building applications such as roof panels or shingles.

Left: The house in the foreground has thin film PV panels installed on the roof. Right: Installing thin film roof shingles. (Source: DOE)

Some of the latest PV research is developing concentrated photovoltaic technology, which is expected to achieve efficiencies nearly double that of today's PV technologies within five years. One high performance panel system undergoing testing and development through the NREL High Efficiency Photovoltaic Project is depicted at right.

Small-scale PV systems

While PV is not yet efficient enough for widespread utility application, many individual property owners are motivated

[24] Regional Renewables. http://www.regional-renewables.org/cms/front_content.php?idcatart=50

to invest in PV for a variety of reasons, including environmental values, long-term savings potential, or a remote location without utility energy infrastructure.[25] Some buildings with PV systems are completely “off-grid”, meaning that they do not get any power from a utility provider. These systems are designed to store PV energy that is greater than immediate demand in powerful batteries. Energy in the batteries is later converted back to AC current when demand is greater than production. Conversely, a fully grid-integrated PV system has no batteries, because it transmits excess energy to the grid and pulls energy off the grid as needed. The PV energy is pooled with all other energy on the grid, and net metering determines the ultimate energy bill. Finally, some PV systems are a hybrid battery storage system with grid back-up; excess power is pulled from the grid only when battery capacity is depleted. Grid connected and grid back-up systems greatly improve the ability of an individual user to make PV energy a viable alternative despite inconstant production.

Utility-scale PV

Using current utility accounting practices, PV-generated electricity still costs more than electricity generated by conventional plants in most places in the U.S., according to DOE. However, PV can be a cost-effective way to meet peak demand in some places. For example, Pacific Gas and Electric Company installed a 500-watt PV system in Fresno, California to meet demand on hot summer days, when both air-conditioning and agricultural water-pumping needs are greatest. The PV system was substantially lower in cost compared to adding another conventional plant, making it a good choice for the utility. The solar power plant pictured below was completed in Sicily, Italy in 2006. Its 107, 12-panel modules are rate to 210 KW and employ sun-tracking technology to increase yield. This solar plant produces about 600,000 kWh per year -- equivalent to the annual electricity consumption of approximately 500 households. The largest commercial PV installation in the U.S. as of 2003 was 3.4 MW for Tucson Electric Power in Tucson, Arizona. The largest PV plant in the world, located in Germany, has a 10 MW capacity.

Source: Regional Renewables.org

[25] Depending on size, local solar potential, and available incentives or rebates, small-scale solar systems make take anywhere from 5 to 25 years to pay back installation costs. Even so, demand for small-scale solar is high, and growing.

Solar thermal technology

Solar thermal systems use the heat energy of the sun. The most basic solar thermal systems simply provide heated water, reducing power demand for electric (or gas) water heaters. Although such solar hot water systems do not generate power, they are worthy of brief mention because their land use impacts are very similar to small-scale PV equipment and systems, thus code revisions for both PV and solar thermal systems can be addressed by planners concurrently. Solar hot water systems began as a very basic technology; a metal canister of water on the roof. The canister system fell out of use in the U.S. in the 1920s, but is still used widely in many parts of the developing world. A basic modern system upgrades the original canister idea by combining an efficient panel collector through which water is heated in tubes (cutaway shown above) with an insulated storage tank. The photograph at right shows rows of such rooftop solar hot water heaters on apartment buildings in Yunan, China.

Institutional scale solar thermal hot water

Solar hot water systems have evolved to include highly efficient systems capable of serving the hot water needs of large institutions. Using a parabolic trough reflector system, solar energy can be used to heat oil or other heat-retaining liquids, and then transfer the heat to water through metal coils. The Jefferson County, Colorado, Detention Center has used a parabolic trough solar hot water system (photo, page 23) since 1996. According to NREL press releases and the Department of Energy, the system generates approximately 8000 gallons of hot water each day for cooking, laundry and showers.[26]

Utility-scale parabolic trough solar thermal

On a utility-scale, oil heated with parabolic trough reflectors is used to heat water, converting it to steam. The steam then turns turbines, much like in traditional power plants. In some locations, solar thermal can produce more power than PV. Three parabolic trough solar thermal plants covering nearly 1600 acres were commissioned in the Mojave Desert of California between 1984 and 1991. Two of these are 80 MW plants; individually or together, they are the largest solar power plant(s) on the planet

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[26] Department of Energy. *Solar Water Heating for Commercial Applications.* Undated brochure available at: http://www.nrel.gov/docs/fy01osti/30173.pdf

today. Nevada Solar One, a 400-acre solar plant south of Las Vegas, Nevada, is expected to come online in summer of 2007 with 64 MW.[27]

The 11 MW concentrated solar thermal plant in Seville, Spain.

Source: National Public Radio website

Utility–scale concentrated solar thermal

A newcomer on the utility-scale solar power scene is concentrated solar thermal, which uses parabolic mirrors to focus solar rays into concentrated beams. Multiple beams are focused together, and the resulting heat is used to turn water to steam. As with parabolic trough solar thermal, the steam turns turbines to generate power. The first module of a solar thermal concentration plant came online in May of 2006, in Seville, Spain (see image, right). It has an 11 MW capacity, providing enough electricity to power an estimated 6,000 local houses. Additional modules of the plant are being built, with construction expected through 2013. The ultimate designed power capacity of the plant is 300 MW. The project is heavily subsidized, as an initiative to help meet European Union carbon emissions reductions goals.[28] Similar plants are planned for Algeria and Morocco. Utilities in California, Nevada, and New Mexico are reportedly in negotiations for concentrated solar thermal installations.

The potential of solar energy

According to DOE, the total of all solar energy systems installed in the U.S. since 1988 provide enough electricity to power 250,000 American homes. DOE also states that solar energy could theoretically supply all the electricity consumed in the U.S. if solar panels were installed covering an area of about 110 square miles (this amount of land is equivalent to one-third the land occupied by roadways in the country). However, raw land may not be required, a recent study of San Diego County estimated that if PV panels were installed on all the flat, commercial rooftops in the city, there would be enough PV capacity to supply 100 percent of 2005 peak energy demand in the county and 53 percent of all energy used in the region.[29]

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[27] Robbins, Teddy. “In Nevada, Solar Power on a Massive Scale”. National Public Radio. August 30, 2006.

[28] Socolovsky, Jerome. “Spain Runs Europe's First Commercial Solar Thermal Power Plant” National Public Radio. August 22, 2007.

[29] Anders, Scott and Bialek, Tom. “Technical Potential for Rooftop Photovoltaics in San Diego County.” San Diego State University, 2006. http://www.sandiego.edu/epic/publications/documents/060309_ASESPVPotentialPaperFINAL.pdf

Because PV power generation is only possible on sunny days,[30] a 100 percent solar-powered nation is no more likely than a 100 percent wind-powered nation. Solar energy is best paired with other energy sources that can provide more consistent supply. However, as discussed in the case of the Fresno PV plant, solar energy is well-matched to peak energy demand in many sunny, warm places. The ability of PV to meet peak demand can avoid or delay more costly utility capacity expansions. Probably because it is not yet efficient enough for utility scale production in most locations, estimates of total potential for solar energy as a portion of the U.S. energy supply were not readily available.

Land use impacts and challenges

The land use impacts and challenges associated with solar energy can be divided into three basic categories; aesthetic, safety-related, and land consumption.

Aesthetic impacts

Aesthetics are mostly a concern with small systems that are located where they may impact neighbors. Some people find PV panels and solar hot water systems unattractive and dislike their installation in visible locations such as pitched residential roofs. Elements of many solar panels tend to be somewhat reflective, meaning that they often fall under general prohibitions of reflective materials as may be found in city-wide design regulations or in the covenant controls of some neighborhoods. This may be true even if the regulation was not intended to prohibit photovoltaic equipment.

Safety impacts

An obvious safety concern about solar thermal systems relates to the concentrated heat. Some parts of the systems reach high enough temperatures to produce burns if touched. Systems on the ground (as at the Jefferson County Detention Center, pictured right), may need to be fenced to control access and reduce tampering. An additional safety concern with panels for both PV and solar thermal systems is related to their reflective nature and potential to create glare. In airport approach and departure areas, glare is a hazard if it interferes with a pilot's vision. Highly reflective solar installations may not be appropriate in the immediate vicinity of airports.

Land consumption

Utility- and institutional-scale solar applications can be somewhat land consumptive. However, raw land is not always needed. Utility solar may be compatible in some wind farms, to enhance power generation and take advantage of installed transmission

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[30] While sunny skies are required, note that cold does not inhibit PV function. In fact, cold, sunny days may have less moisture in the air, and can be optimal conditions for non-thermal PV technologies.

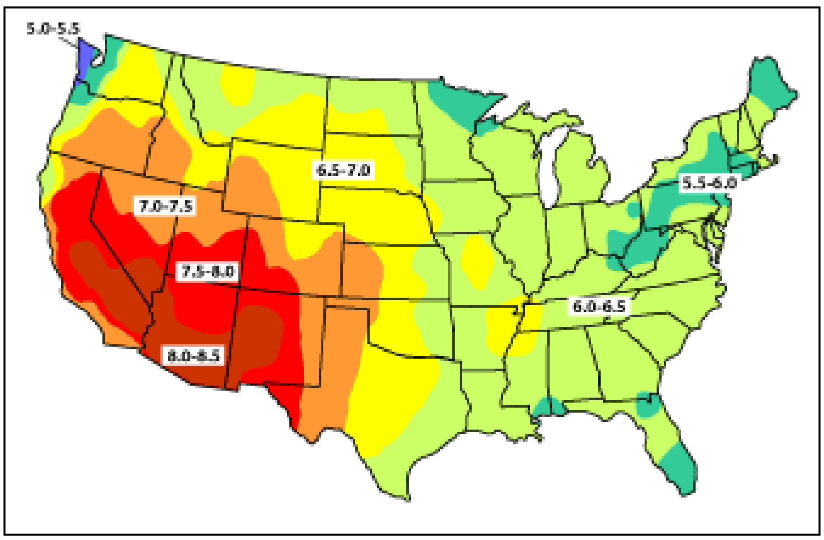
facilities. In the case of small-scale PV, a great deal of PV (and solar hot water) potential can be harnessed by panels installed on commercial and institutional rooftops. Rooftops can be ideal to protect against vandalism and avoid unwanted shading effects, and because it is in addition to a primary land use. In many cases, rooftop placement reduces the aesthetic impact of panels.

Measuring local solar energy potential

Figure 2, produced by the Department of Energy, shows how much solar radiation falls on a square meter of horizontal surface in the month of June. As indicated, the amount varies across the U.S. from 5.0 - 8.5 kWh/m^2. In any given location, solar radiation also varies throughout the year.

The map indicates that the potential for solar energy is best in the western U.S., and particularly in the southwest. Under the market conditions in the U.S. today, only areas indicated in deep red on the map are likely to be cost-effective for utility-scale solar power generation. In other areas of the country, most solar will be either small-scale solar hot water or PV, installed by individual property owners rather than utilities. Numerous case studies show that even in the relatively low solar yield areas such as the northeast, PV panels installed on a residential rooftop can often net enough energy to be cost-effective for the owner within ten years.

Figure 2: Average solar radiation on a horizontal surface in the month of June, in kWh/m^2



Local solar energy production potential

The potential for solar energy production is highly dependent on localized conditions, such as cloud cover and altitude, which affect the amount of solar radiation that reaches the earth's surface (as indicated on the map, above). In addition, the efficiency of a particular solar energy generation system at converting the radiated energy of the sun into electricity and the angle at which panels are placed also greatly effect local solar energy production potential. Tools are readily available online from NREL to estimate the energy production and cost-effectiveness of installing a PV system, based on location and system output capacity rating.[31] Such calculators could help local planners understand what capacity system is likely to be needed locally to be cost effective (or to offset local average home power usage) and plan for development regulations scaled to address typical PV system size.

DOE indicates that a typical 1 kW system of rigid PV panels is between 80-360 square feet,[32] and provides the following estimates that, compared to fossil fuel-generated electricity, each one kilowatt solar system annually offsets up to:

- 2,300 kilograms (about 2.5 tons) of CO_2
- 16 kilograms (35.2 lbs.) of nitrogen oxides
- 9 kilograms (19.8 lbs.) of sulfur oxides

DOE solar energy information indicates that most residential users could achieve “net zero” energy use through installation of between 80-1000 square feet of rigid PV panels. This is a very wide range, corresponding to widely ranging productivity potential and household energy demand. If, as for wind power, we use average figures of residential energy demand, we can estimate the annual carbon emissions reduced by converting a typical U.S. home from conventional energy to 100 percent solar-power. Because solar energy generation produces zero carbon emissions, the emission reductions shown in Table 5 above (page 14) apply.

Small-scale PV has even more potential for benefits when used on commercial buildings. PV installation costs on commercial buildings are often lower per panel than on residential buildings for several reasons: PV is easier to install on flat (rather than pitched) rooftops, commercial rooftops are generally larger and can accommodate more total panels, and commercial electrical systems are often located on the roof, making for easier connection. Also, cost-effectiveness increases in commercial installations because commercial energy rates are usually higher than residential rates, and higher still during peak demand, increasing the potential savings of substituting PV power for some of a building’s overall energy needs. PV energy production is often well matched with peak demand, at time when businesses need power. As discussed above, when PV is used to supplement power during peak demand, it may allow utilities to delay other, more costly expansions.

The case for local action

There are three primary reasons why local governments should take action now to allow and encourage the use of solar energy technology. First, local land use regulations should be in sync with state and regional incentives and rebate programs that

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[31] National Renewable Energy Laboratory. *PWATTS Calculator.* http://rredc.nrel.gov/solar/calculators/PVWATTS/

[32] Department of Energy. *So you want to put PV on your roof*. http://www1.eere.energy.gov/solar/want_pv.html

encourage installation of solar energy generation equipment. In cases where local regulations and fees are currently an obstacle to solar energy, they should be revised. Second, demand for PV systems is high and expected to increase in the next five years as efficiency and cost per kW improve compared to traditional fossil-fuel derived energy. Supply of panels and thin films ready-made for building applications is also expected to increase. Local governments should be prepared to respond to increasing interest on the part of citizens seeking to install solar. Finally, local governments that control an energy utility should consider alternatives for meeting peak demand through solar because it is less expensive than other ways to expand utility capacity, and in order to diversify the energy supply (such benefits are discussed in greater detail in the wind power sections above).

Land Use Code strategies and actions for solar power

This section describes a variety of specific strategies for development code revisions that allow and promote solar power equipment. Many of the strategies are similar to those for wind power generation and are noted more briefly than above.

This section is divided in three parts: actions to remove obstacles to solar power generation and ensure compatibility of small-scale solar; incentives to encourage solar power development, and regulations that require actions that support or develop solar power.

Removing obstacles and ensure compatibility

1. Allow solar hot water heaters and PV panels as a by-right accessory use in all districts.
2. List solar hot water heaters and panels as exceptions to rooftop screening requirements or design standards that prohibit restrict reflective materials.
3. Overrule restrictive subdivision covenants. [33]

Incentives

1. Give credit for on-site solar power generation in any green-building or other performance-based development review points system.
2. Streamline permitting or reduce permit fees.
3. If the electric utility is locally controlled (and not subject to a state requirement for net-metering), require that the utility net meter.
4. Waive or defer tax payments for high energy demand developments (typically, commercial and industrial) that substantially reduce their utility energy demand through solar technology.
5. Allow commercial users to purchase and install solar energy technology in lieu of utility development impact fees.

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[33] Arizona, California, Colorado, Florida, Hawaii, Indiana, Iowa, Massachusetts, Nevada, Utah, and Wisconsin have all enacted state legislation that overrules subdivision covenants that would prohibit solar power systems. In these states, further local government action may not be needed.

Regulations

1. Require all new buildings to incorporate a design that creates a good platform for, and easy installation of, solar power equipment (such as flat roofs where feasible or an unbroken plane of south-facing surface, and pre-installed conduit).
2. Require installation of solar energy systems on commercial buildings that have high demand during peak demand times (possibly in lieu of a portion of development impact fees).
3. Require solar hot water heating systems on new development with high demand for hot water (such as multi-family residential projects, institutional uses, and industrial users).

Solar Power Summary

Under current market conditions with existing technology, solar power generation has somewhat less potential than wind for supplying a large percentage of the U.S. energy demand. Solar energy development at the utility-scale is currently feasible only in the desert regions of southern California, southern Nevada, and New Mexico. In these areas, land use planners should be prepared to permit such plants with appropriate protective standards.

In much of the intermountain west and southwest, institutional, commercial, and residential scale PV and thermal solar applications can effectively reduce utility costs for their owners and can help to supply energy to meet peak demand. Throughout the U.S., enthusiasm for small-scale solar power generation remains high among many individuals, even in locations where installation costs can take a relatively long time to recoup (up to eight or ten years). Given the generally positive perception of solar; the tangible sustainability benefits in reduced carbon emissions and improved air quality; and relatively low impacts of small-scale solar energy production, even in areas with lower solar potential, land use planners should consider how to allow and encourage small-scale solar energy production. Land use planning efforts in these areas should focus on revising land use codes to remove any obstacles to installing small-scale solar (PV and thermal) equipment, and on code provisions that encourage non-utility solar power generation on rooftops and buildings.

Overall Summary

Wind and solar energy production can contribute to important sustainability goals. Reduced carbon emissions, diversification of energy production, avoidance of utility expansion costs, improved air quality, and reduced reliance on foreign oil are among the potential benefits of increasing the national production capacity of energy from these renewable resources. An examination of wind and solar power generation indicates that small-scale production offers substantial untapped potential. Both wind- and solar power generating land uses have impacts that must be addressed to ensure their compatibility with surrounding uses. Land use planners, local decision-makers, and citizens should compare the impacts of alternative energy with the impacts of traditional energy generation and transmission facilities when making decisions about standards, regulations, and incentives for wind and solar power installations. Given the many benefits of alternative energy, local land use planners seeking to create a sustainable development code should ensure that land use regulations allow, encourage, and possibly even require some development of small-scale wind and solar power generators in both rural and urban settings.