April 7, 2003

The True Cost of Electricity from Wind Power and Windmill "Availability" Factors

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Question:

Do you have a simple one-page analysis of the current cost of wind power, before and after tax subsidies, and the availability factors of most windmills?

Response:

The short answer is "No." In fact, it will take:

- Several pages to identify and describe the many elements of the full, true cost of electricity from wind (the relative importance of the elements varies widely.), and
- Another 2 pages to explain why "availability" factors are meaningless when talking about windmills, and why "capacity" factors are more important but still limited in value.

However, the questions are good ones because:

- The information on the cost of electricity from wind power that is distributed by all of the following groups is grossly incomplete and misleading:
    - US Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy.
    - DOE's National Renewable Energy Laboratory (NREL).
    - The wind industry and its Washington-based trade association and lobbyists.
- Information distributed by the same organizations about wind turbine "availability" is meaningless.

To help answer your question, this paper will identify the many elements of the full, true cost of electricity from wind energy, including the elements of true cost that the above organizations like to ignore. It will also explain why the "availability" of wind turbines is meaningless.

While this paper does NOT provide the specific answer you are looking for, it may prove helpful to many people around the US (as well as Europe, Australia and New Zealand) who are trying to learn the truth about the cost of electricity from wind energy.

A. TRUE COST OF ELECTRICITY FROM WIND

Note that this paper focuses on the *true cost* of producing and delivering electricity from wind and *not on the price* paid when a utility buys electricity from a "wind farm." This latter number will often have no relationship to the true cost because of the extensive subsidies available to "wind farm" developers and owners. In fact, in the early years of a "wind farm's" operation the value of tax breaks and subsidies generally will *exceed* substantially the income that a "wind farm" owner will receive from the sale of electricity!

In summary, good cost numbers for electricity from wind are not now available because:

- Like all generating units, the true costs vary depending on equipment, site, ownership, etc.

- Only the "wind farm" owners have numbers approaching accounting quality on costs and even those numbers will often be based on assumptions (e.g., O&M costs over the life of a facility; cost per kWh). In any case, owners probably will consider this data confidential.
- Some parts of the full, true costs of producing and transmitting electricity from wind turbines (e.g., backup generation, extra costs imposed on transmission and grid management) vary widely depending on the control area involved, the unit or units providing backup generation, the output and variability of output from the generator, load on the grid, etc. etc.
- Some tax breaks and subsidies are somewhat fixed but others vary, for example, with actual production of electricity – which, when estimating future kWh costs, are based on assumptions and guesses (e.g., the useful life of a facility).
- In fact, except for money already expended and future costs that are locked in (e.g., in contracts), most estimates depend on assumptions, particularly the cost per kWh numbers.
- Thus far, the US DOE, the National Renewable Energy Laboratory (NREL), the wind industry and other wind advocates have shown little interest in providing citizens, consumers and taxpayers with complete, objective information on true costs – possibly because such information would call into question many of their promotional activities.

Many of the elements of cost identified in the pages that follow have "counterparts" in the case of generating units powered by energy sources other than wind (e.g., interconnection costs). However, it is also the case that many of the cost elements differ (e.g., transmission costs). Of all the points about wind energy discussed below, those that deserve particular attention include:

- The fact that very high profits due to generous tax breaks and subsidies for "wind farms" – not claimed environmental benefits -- are probably *the* principal motivation for investments now being made in "wind farms." Often, "green washing" will be part of the motivation.
- The high capital costs of "wind farms."
- The high transmission costs, particularly when wind farms are remote from where electricity is needed and because electricity from wind uses transmission capacity inefficiently.
- Due to the intermittence, variability, and unpredictability of electricity from wind, it has less real value in an electric system than electricity from "dispatchable" sources.
- The small amount of electricity produced by wind turbines, particularly due to their inherently low capacity factors. If all the thousands of windmills in the US as of the end of 2002[1] operated with a 25% capacity factor, they would produce less electricity (10,260,150,000 kilowatt-hours – kWh) than two 750-megawatt (MW) gas-fired combined cycle generating plants operating in base load with an 80% capacity factor (10,512,000,000).[2] The windmills are scattered over thousands acres in 27 states (90% in CA, TX, IA, MN, WA and OR), while the gas-fired plants would take up only a few acres. Also, they are available when needed (i.e., dispatchable), not just when the wind blows.
- The fact that the useful life of today's wind turbines and their lifetime O&M, repair and replacement costs are unknown.

EIA data on costs of windmills. While the data do not answer your question, you may want to note that the US Energy Information Administration (EIA) – which does seek to provide objective information – does make some estimates of costs associated with electricity from wind for use in preparing its Annual Energy Outlook. EIA estimates include (a) total overnight capital cost including contingency for wind -- $1,003 per kW, (b) variable O&M -- $0, (c) fixed O&M of $26.10 per kW -- all in 2001$.[3]

EIA also makes estimates of interconnection costs which are not peculiar to wind but which vary by region from $175 to $457 per kW (in 2001$). Finally, EIA provides estimates for adding transmission capacity to serve "wind farms, which include data for situations requiring transmission in the 0-5 mile range ($8.74 to $15.23 per kW, depending on region), 5-10 mile range ($26.23 to $45.70 per kW), 10-20 mile range ($52.47 to $91.40 per kW) all in 2001$.[4]

EIA indicates that its staff consults with wind experts when developing its estimates and assumptions. While such EIA estimates are essential when making forecasts about future energy markets, the data are not the type and quality required to assess costs and benefits associated with specific wind energy projects.

The next 9 pages identify and describe elements of the full, true costs of producing and transmitting electricity from wind turbines. As indicated earlier, data on the full, true costs are not now available.

1. Capital costs, which are generally specific to equipment, site and owner.

- **a.** Turbines, blades, etc. (including everything mounted at the top of towers). There are a wide variety of turbines available and at least 10 turbine manufacturers, most foreign (e.g., Vestas, NEG Micron, Mitsubishi). GE manufactures some in the US and some in Europe. Vestas often talks of building a plant in Portland, OR. The price undoubtedly varies with demand at the time, quantity, currency exchange rates, and more.
- **b.** Towers. Again, there are a variety of styles and heights. Some are made in the US; others are imported.
- **c.** Base. Lots of concrete – but amount undoubtedly depends on soil conditions, terrain, tower height, turbine size, wind conditions, transportation to site, etc.
- **d.** Access roads and clearing of land. Again, these costs are affected by terrain and other local conditions.
- **e.** Computer equipment, cabling, controls, etc. all vary somewhat from one project to another.
- **f.** Interconnection costs (substations, etc.) – to permit delivering electricity from a "wind farm" to transmission lines that can deliver electricity to places where it is needed.
- **g.** Transmission lines to move the electricity from a "wind farm" to the nearest transmission lines that can move the electricity to places where it is needed. As illustrated by the EIA data cited above, these costs vary widely by region and specific project, particularly due to distance, terrain and availability of rights of way. Also, as noted below, in paragraph 5.b., electricity produced by wind turbines use transmission capacity inefficiently. Since acceptable sites for "wind farms" are often distant from where the electricity is needed, both transmission costs and line losses tend to be high.

h. Cost of development (which can be capitalized if the project becomes operational but must be written off immediately if the project isn't built). This includes the cost of gaining land use and zoning approval from local and/or state authorities that regulate such projects. Costs vary widely and often include significant fees for lawyers, public affairs/lobbyists, and engineers involved in the effort to gain approval. In addition, developers are generally liable for damage to existing infrastructure (e.g., roads) caused by "wind farm" construction. Some states (e.g., New York, Illinois) are now offering up-front grants that may defray some or all of these costs but, as discussed later, the money used to provide these subsidies is often collected from electric customers via charges added to monthly electric bills (so-called "public benefit charges") so they are still a part of the full, true costs of electricity from wind.

i. Cost of financing: These cost depend on such factors the owner's credit rating, the proposed debt-equity ratio, the market for the electricity that would be produced, and whether a contract is in place for its sale.

j. Payments in lieu of taxes: Sharp reductions or exemptions from local government property taxes – which are provided in several states – creates a situation where "wind farm" owners can appear magnanimous by making "voluntary" payments to counties, towns and schools to help cover costs. Such payments tend to be much less than the taxes that have been forgiven.[5]

k. Land. If owned and capitalized. (Or, if leased, lease rates and terms – see below.)

l. Decommissioning cost (if capitalized). (FYI, I generally urge that landowners insist that decommissioning costs be covered by cash bonds held by independent third parties because many wind farm "owners" turn out to be LLCs with few assets. Because tax breaks for wind are heavily front-loaded (depreciation – 5-6 years; production tax credit – 10 years), there are huge incentives for sales of facilities after tax breaks are used, or for abandonment if costs of maintenance, repair and/or replacement rise substantially. There is little protection for landowners from surety bonds that depend on premium payments or cash bonds held by an LLC-owner – in case of insolvency or abandonment.)

2. **O&M, repair and replacement.** There are many variables here, too, and some big unknowns.

a. Actual operating experience is probably around 5 years for the smaller (660 kW – 750 kW) turbines, 2 or 3 years for the 1.5 MW, and a few months for the really big ones like GE's new 3.6 MW turbine. Anyone claiming to have solid numbers may not be telling the truth. (Also, some manufacturers have had costly problems – e.g., with gearboxes – on big, relatively new machines.)

b. Useful life of the turbines (see a., above).

c. Land rent can be expensed. Most land seems to be rented with prices seeming to vary from around $1,500 per MW of capacity to alleged offers as high as $15,000 per MW. Some are fixed payments and some vary with amount of electricity produced.

d. Insurance.

e. Property, sales, use and other taxes: Due to a variety of tax breaks (discussed below, with examples), the tax burden on "wind farms" is very low.

f. Monitoring and Response Costs. Cost of monitoring and response, if any. This might include monitoring and responding to noise complaints, and/or icing and other dangerous conditions. Some municipalities may require establishment and maintenance of a "Complaint Hotline" and/or periodic reporting to ensure compliance with terms of the conditional use permit.

g. Decommissioning (see paragraph 1.l., above).

3. **Income taxes.** Again, due to very generous federal and state corporate income tax breaks (discussed below), the income tax burden, if any, on the "wind farm" owner may be very low.

4. **Cost per kWh.** DOE, National Renewable Energy Lab (NREL) and the wind industry often cite cost per kWh numbers but seldom, if ever, provide the assumptions underlying their estimates. Actual cost per kWh will vary widely depending on all the items identified above, but two variables have an especially large impact on actual average cost per kWh of electricity from wind:

a. **Capacity factors.**[6] Actual costs per kWh depend on the number of kWh of electricity actually produced. For example, wind speed is one critical factor in determining the amount of electricity produced and wind speed varies widely with stronger wind tending to occur at night and in colder months. Wind speed measurements taken during winter months are atypical. Wind characteristics also vary by height of the measurement and are affected by terrain.

Actual capacity factors and actual kWh production tend to be less than claimed by "wind farm" developers. Also, published estimates of "wind resources" and "wind classes" in various areas may be based on limited empirical data.

b. **Useful life of turbines.** Estimates of cost per kWh also depend heavily on assumptions about the useful life of turbines (which is a big unknown because of limited experience with machines now being used). Obviously, the numbers will be a lot different if one assumes 20-year life or 30 year life (i.e., take total estimated costs and divide by kWh produced over 20 years vs. over 30 years).

Published estimates of lower per kWh costs of electricity from wind are often based on vague assumptions (e.g., wind conditions, site availability, bigger machines, higher efficiency, "economies of scale") or guesses that may or may not prove to be correct.

5. **Extra costs of electricity from wind because of the intermittence, variability, unpredictability and uncontrollability of electricity output from wind turbines.** As indicated, these costs vary widely depending on the control area involved, the location of the "wind farm," unit or units providing backup generation, the output and variability of output from the "wind farm," the share of capacity on line coming from wind turbines, the location and amount of load on the grid at the time, the capacity of the transmission lines, etc.

The problem stems from the fact that wind turbines produce electricity only when the wind is blowing with the right speed ranges. For example, the forty-four 1.5 MW turbines employed at FPL Energy's Mountaineer Energy Center (Backbone Mountain, WV), according to the turbine manufacturer (NEG Micon), begin producing electricity when the wind reaches about 3 meters per second (or 8.9 miles per hour, achieve rated capacity at about 15 m/s (or 33.6 mph) and cut out at 25 m/s (or 55.9 mph).

a. **Cost of backup generation**. Since the grid or control area must be kept in balance at all times (supply and demand, frequency, voltage), some generating unit(s) must be immediately available at all times to provide backup service (or balance) for the electricity (if any) coming from the wind turbines. This means that the unit(s) providing the backup service may be operating in an automatic generation control mode, running at less than peak capacity, and/or running in spinning reserve mode.

   Depending on wind conditions, the amount of backup capacity may have to equal the peak capacity of a "wind farm." That is, if wind conditions exceed the cutout speeds, the entire output of the "wind farm" could be lost.

   All the potential modes result in costs – and those costs are properly allocated to the cost of the electricity from wind turbines.

   Some limited empirical work has been done to define these costs but it is quite limited – in terms of the period of time covered and the location(s) studied.[7] There is no universally applicable, empirically based cost estimate available.

   These "costs" may, at some point, be established in wholesale ancillary service markets. PJM, for example, apparently has created or is experimenting with such a market for spinning reserve capacity.

   Almost certainly, a control area that has significant hydro capacity in reasonably close proximity to a "wind farm" would have relatively low backup generation costs because of the excellent load-following characteristics of hydro generation. That is, assuming that variation in the flow of water through the hydro plants can be accommodated within constraints on the hydropower facility (e.g., levels of water in the reservoir and in the river downstream of the plant). However, actual backup power costs are likely to be higher when generation is powered by other energy sources.

b. **Transmission costs.** As indicated earlier, electricity from wind turbines generally makes inefficient use of the transmission capacity that serves the turbines. Enough capacity must always be available to handle the peak output of a "wind farm." However, that peak output is unlikely to occur more than about 30% of the time. The capacity may not be used at all by the electricity from wind turbines for 50 to 70% of the time. Also, as noted above, tend to be high because acceptable sites for "wind farms" are often distant from load centers – which mean both higher capital costs due to longer lines and greater line losses of electricity.

   In some cases, heavy concentration of wind turbines has made it necessary to add transmission capacity to serve the output from "wind farms" (e.g., Texas, Minnesota, Nordel Grid in Europe).

c. **Extra grid management burden.** The presence of variable output from "wind farms" quite likely imposes some extra costs for the management and control of the grid or control area. These costs may be minor if the electrical output from the "wind farms" is small and/or it can be handled with automatic generation control.

d. **Arbitrary assignment of costs.** The owners or managers of some control areas have adopted somewhat arbitrary cost factors to compensate for the above-described costs (e.g., Bonneville Power). Several studies are underway to get a better fix on the true costs but they are complicated by the wide variability in true costs.

e. **Penalties in competitive markets.** Some grid owners or managers have applied penalties to electric generator owners or operators who deliver more or less electricity to a transmission system than was bid into the system. Often these penalties are designed to (a) encourage generating companies to help keep the grid in balance by delivering amounts of electricity promised, when promised, (b) pay for costs imposed when electricity delivered differs from contracted amounts, and (c) discourage "gaming." The wind industry has complained that such penalties are inappropriate for wind because of its inherent intermittence, variability and unpredictability. Bonneville – under pressure from the industry and DOE wind advocates -- recently reduced its imbalance penalty.

f. **Who bears the real costs.** In some cases, all or a part of the costs of a., b. and/or c., above have been imposed on a "wind farm" owner. In other cases, it appears that the purchaser of the output from a "wind farm" pays a specified amount for each kWh of electricity and absorbs the extra costs.

   Unless the costs are clearly assigned to and paid by the "wind farm" owner, it is quite likely that they are rolled through and spread over all of an electric suppliers customers – probably without the knowledge of those customers.

g. **Shifting of costs from "wind farm" owners to electric customers by regulation.** FERC apparently has approved an approach developed in California – and favored by the wind industry -- which limits penalties associated with the impact of electric from "wind farms" on transmission. Also, the Minnesota PUC recently approved a $148 million expansion of Xcel's transmission capacity in Southwestern Minnesota that Xcel claimed was necessary to serve planned new "wind farms." Those costs apparently will be included in rate base and spread over all Xcel's Minnesota customers – rather than being allocated to the owners of the planned "wind farms" that will make the expenditures necessary.

   Also, the American Wind Industry Association (AWEA), the industry's Washington-based lobbyists, have a major effort underway to shift the costs of transmission of electricity from wind turbines away from "wind farm" owners.[8]

6. **Tax breaks and subsidies for "wind farm" owners.** Some of the above elements of the full, true costs of electricity from wind are dwarfed by the value of tax breaks and subsidies available to "wind farm" owners:

   a. **Tax breaks.** Of course, tax breaks for "wind farm" owners don't show up directly in electric bills but, nevertheless, are part of the full, true cost of electricity from "wind farms." These tax breaks shift costs from the "wind farm" owners to remaining taxpayers. Important tax breaks include:

      1) **The Federal Production Tax Credit** (currently $0.018 per kWh but the rate is adjusted for inflation) which is available for the first 10 years of operation of the wind facility.

2) **Five-year double declining balance accelerated depreciation (5-yr., 200% DB)**[9] – a generous form of MACRS (Modified Accelerated Cost Recovery System) now available in federal tax law is available to "wind farm" owners. This benefit permits a wind farm owner to recover the full amount of his capital investment in 5 to 6 years through depreciation deductions from income. (This compares with 20-year, 150% DB accelerated depreciation for most other generating units. Simple cycle gas turbines qualify for 15-year, 150% DB.)

The depreciation deductions by tax year for commercial wind energy facilities are:

	1st Year	2nd Year	3rd Year	4th Year	5th Year	6th Year
Under "Normal" 5-yr. 200% DB:	20%	32%	19.2%	11.52%	11.52%	5.76%
Under "Bonus: 5-yr. 200% DB" established by the Job Creation and Worker Assistance Act of 2002 which applies to qualifying assets purchased after September 10, 2001 and before September 11, 2004, provided those assets are placed in service by January 1, 2005.	44%	22.4%	13.44%	8.064%	8.064%	4.032%

Accelerated depreciation produces huge tax avoidance benefits in the first few years of project ownership. The value of this accelerated depreciation is higher under the "bonus" arrangements described above. However, those are scheduled to end by January 1, 2005, so the value of accelerated depreciation will be illustrated here using the "Normal" deduction schedule described above – which is still exceedingly generous to "wind farm" owners.

To illustrate the value, assume that a 100 MW (100,000 kW) "wind farm" has a capital cost of $1 million per MW (i.e., total capital cost of $100,000,000 million) and comes on line after the "Bonus" provisions have expired, let's say after January 1, 2005. Regardless of when it comes on line after that (i.e., anytime from January 2, 2005 to December 31, 2005, the owner can take a $20,000,000 depreciation deduction from income for the 2005 tax year.[10] With a 35% marginal tax rate, the "wind farm" owner could reduce his federal income tax liability by $7,000,000 BEFORE taking advantage of the federal Production Tax Credit.

If the wind farm began operation on July 1, 2005, and produced at an annual average 30% capacity factor for the rest of the year, it would produce 132,480,000 kWh (100,000 kW x 4416 hours x .30 capacity factor). Therefore, the value of the depreciation deduction in 2005 in reduced federal tax liability would be equal to $0.0528 per kWh ($7,000,000 divided by 132,480,000 kWh).

When the $0.018 per kWh production tax credit is added, the value of the two federal tax benefits in 2003 would add up to $0.0708 per kWh.

In the second year 2006), the owner would be able to take a $32,000,000 deduction from income. With a 35% marginal tax rate, the "wind farm" owner could reduce his federal income tax liability by $11,200,000 BEFORE taking advantage of the federal Production Tax Credit. If the "wind farm" averaged a 30% capacity factor for all of 2006, it would produce 262,800,000 kWh. The value of the reduction would equal $0.0426 per kWh in 2006, not counting the $0.018 per kWh PTC.

When the $0.018 per kWh production tax credit is added, the value of the two federal tax benefits in 2003 would add up to $0.0606 per kWh.

3) **Reduction in state corporate income tax due to federal accelerated depreciation.** In most states, accelerated depreciation available to wind energy facilities can also be used to reduce state corporate income tax liability. For example, in a state that fully conforms its corporate income tax to the federal system and has a 10% corporate tax rate, the "wind farm" owner could reduce its state income tax liability by $2,000,000 in 2005, or the equivalent of an *additional* $0.015 per kWh for a "wind farm" that began operation on July 1, 2005, with a 30% capacity factor. In 2006, the "wind farm" owner could reduce tax liability by $3,200,000 or the equivalent of and additional $0.012 per kWh.

4) **Reduction in state and local property, sales and other taxes.** Several states have also reduced or eliminated other taxes and, therefore, shifted more costs from "wind farm" owners to remaining taxpayers. Here are a few examples:

- Iowa exempts materials used in constructing wind farms from sales and use taxes and has sharply reduced property taxes (eliminating them totally in the first year, then raising them in 5% increments until reaching 30% of normal property taxes.
- West Virginia has reduced both Business & Occupation Taxes and Property taxes for "wind farms" by about 90%.
- Wisconsin, Minnesota and Kansas exempt wind facilities (i.e., the value added, not the land) from property taxes.
- North Dakota exempts large wind project equipment from sales tax and provides a 70% reduction in property taxes.

b. **Subsidies for the wind industry.** There are many subsidies available to the wind industry in addition to the tax breaks identified above. For example:

1) **Federal subsidies**, all of which shift costs from the wind industry to taxpayers, include:

- Some $38 million per year for US Department of Energy "wind energy R&D"
- Promotional "studies," "analyses," "reports," web sites, and conferences paid for with tax dollars flowing through DOE's Office of Energy Efficiency and Renewable Energy, and carried out by DOE employees and employees of DOE National Labs and other contractors, grantees and subcontractors.
- Renewable Energy Production Incentive (REPI) which provides direct per kWh payments to organizations that do not pay income taxes (e.g. rural electric coops, municipal utilities) – at the same per kWh rate as the Production Tax Credit.

2) **State subsidies**. Some of these may be paid from general tax revenues but many are paid from so-called "public benefit charges" added to electric customers' monthly bills – which charges raise well over $1 billion per year. Examples of such subsidies include but are not limited to:

- **New York and Illinois** - Grants to "wind farm" developers (In NY, $22 million have been announced).
- **California** – Payments to customers who agree to buy electricity produced from "renewable" energy sources (this program may be suspended at present).
- **Minnesota –** State production tax credits.
- **New Mexico –** Use of industrial development bonds.

3) **Renewable portfolio standards – an insidious subsidy.** Renewable portfolio standards (RPS) adopted by several states are another form of subsidy for "wind farm" owners. Such standards are a particularly insidious subsidy since they force higher costs on millions of electric customers without their knowledge. The standards force suppliers of electricity to purchase electricity from "wind farms" or other "renewable" energy facilities, generally without regard to its higher cost. In some cases, a few electric customers who agree voluntarily to pay a premium price – through so-called "green" energy programs -- for electricity produced from "renewable" sources pay part of the extra cost. However, the remaining cost of the electricity, as well as the cost of administering the voluntary programs is passed on to electric customers in their monthly electric bills.

4) **"Green" energy programs.** Many electric utilities have established programs that permit customers to volunteer to pay premium prices for electricity generated from "renewable" energy sources (with varying definitions of "renewable). Some utilities adopt these programs voluntarily and others are mandated by state statutes or regulations. Typically, only a very small percentage of customers volunteer to pay premium prices – in fact so small that the premium revenue is unlikely to cover the extra cost of buying or producing the "green" electricity and the cost of administering the program. When this occurs, the portion of costs not recovered from volunteers is likely to be spread over all electric customers.

B. AVAILABILITY, CAPACITY FACTORS AND "HOMES SERVED"

Wind energy advocates often mislead the public, media and government officials with claims about "availability" and "homes served."

1. **Availability factors** are meaningful for generating units that are "dispatchable" (i.e., can be called upon to produce electricity whenever needed) but are *meaningless* for "intermittent" generating sources such as windmills which can produce electricity only when the wind is blowing within certain speed ranges.

   In fact, electricity from wind turbines is of less value than electricity from "dispatchable" generating units because it is available only when the wind is blowing within certain speed ranges. In electric industry terms, it has very little, if any, "capacity" value. It provides "capacity" value only if the wind happens to be blowing when electric demand is at high levels (at or near peak). Winds are not uniform throughout a day or year. Instead, winds tend to be strongest at night and in cold months while many electric systems in the US experience highest demands during summer afternoons.

The wind industry often talks about "availability factors" which the industry seems to define as time when the wind generation equipment *could be* generating if wind was available within the right speed ranges. *Such use of "availability" is totally misleading and deceptive*.

2. **Capacity factors.** Capacity factors for wind turbines and "wind farms" are somewhat more meaningful since they are a measure of kilowatt-hours (kWh) actually produced by the wind turbines. Capacity factors are determined by dividing kWh produced by the rated ("nameplate") capacity of the turbine(s) times the hours in the period for which the factor is calculated – usually a year or a month.

   Capacity factors are not totally meaningful because, as indicated above, the kWh may be generated at a time when the electricity isn't really needed – and when electricity is available at less cost from other generating sources.

   Capacity factors vary WIDELY for many reasons, including wind "class" or wind speed (which varies by location, turbine height, terrain, windmill spacing, obstructions, etc.), vintage of the turbines, condition of the turbine and blades and the specific turbine technologies, time of day and year. For example:

   - Smaller old turbines in California built in response to the unwise tax credits of the 1980s, it they are running at all, probably have capacity factors in the 5% to 20% range.
   - A turbine in Traverse City, Michigan, has achieved a 15.1% capacity factor during a 5+-year period for which data are available (through the fall of 2002) while one in Mackinaw, MI has achieved an 18% capacity factor.
   - Some of the "wind farms" in Wisconsin have had capacity factors in the low and mid 20 percentages.
   - Data on electricity output from "wind farms" reported to EIA (on EIA Form 906) include factors ranging from about 10% to 36%.
   - The Northwest Power Planning Council uses 33-34% capacity factors when estimating the output of wind farms in Washington and Oregon.
   - FPL Energy used an implicit capacity factor of 38.15% when "bidding" into California Energy Commission's "Production Incentive" auctions #2 and #3.
   - Some in the wind industry claim that newer turbines (generally on taller towers) will achieve capacity factors in the 40s.

   In summary, many factors must be taken into account when picking a capacity factor. Also, landowners that are considering renting their land under agreements where payments depend on actual electricity production need to recognize that "wind farm" developers have an incentive to overestimate potential capacity factors – if they are not contractually bound by those numbers.

3. **"Homes served."** Once of the highly deceptive measures of "wind farm" output widely used by DOE, NREL, the wind industry and other wind energy advocates is "homes served." That measure is somewhat meaningful when referring to a "dispatchable" generating unit. It is *meaningless* when referring to electricity from "wind turbines" which produce electricity only intermittently. In fact, NO homes are served by electricity from wind because electric customers – at least in those served by electric distribution systems – in the US and most developed nations are unwilling to "live with" electricity service that is available only when the wind is blowing in the right speed range.

Endnotes:

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[1] The American Wind Energy Association (AWEA) reports that capacity at the end of 2002 totaled 4685 megawatts.
[2] Such gas-fired units are being built in various areas around the US. The calculations of potential windmill output are 4,685 MW x 8760 hours x .25. The assumed capacity factor may be too high because many of the windmills are old ones built in response to tax credits of the 1980s. The calculation for the gas-fired combined cycle plants are 1,500 x 8760 x .80. Other interesting comparisons are that all the wind turbines would produce less electricity than either the Surry or North Anna nuclear plants in Virginia produced in 2001 (12,662,376,000 kWh and 13,096,754,000 kWh, respectively) or the Mt. Storm coal-fired generating plant in West Virginia in 2000 (11,595,299,000 kWh)

[3] EIA, Assumptions to the Annual Energy Outlook 2003, Table 40, page 73. EIA estimates of the cost of generation units and cost of transmission apparently are assumptions based on staff discussions with DOE, National Lab and wind industry experts. Presumably most are nationwide averages that don't reveal likely variability among specific projects.
[4] EIA, NEMS Renewable fuels Module Documentation Report – Wind, pp. 39-40.
[5] Schleede, Glenn R., Energy Market & Policy Analysis, Inc. "Wind Energy Economics in West Virginia," pp.8-9.
[6] Capacity factors are determined by dividing kWh produced by the rated ("nameplate") capacity of the turbine(s) times the hours in the period for which the factor is calculated – usually a year or a month.
[7] Among recent reports dealing with the problems and extra costs of integrating electricity from wind turbines with bulk power systems are the following:

a. "Assessing the impact of wind generation on System Operations at Xcel Energy – North and Bonneville Power Administration," a study for the Utility Wind Interest Group (UWIG) by Electrotek. http://www.uwig.org/opimpactspaper.pdf
b. Eric Hirst, "Integrating Wind Energy with the Bonneville Power System – Preliminary Study," September 2002: http://www.ehirst.com/PDF/BPAWindIntegration.pdf
c. Eric Hirst, "Integration of Wind Farms with Bulk Power Operations and Markets, September 2001: http://www.ehirst.com/PDF/BPAWindIntegration.pdf
d. "Non-Dispatchable Production in the Nordel Network," by Nordel's Grid Group, May 2000. (Nordel is the network that serves Denmark, Sweden, Norway and Finland. This report (which I can provide) describes the problems caused by Denmark's extensive production of electricity from wind and by combined heat and power units. It's not typical of anything found in the US but illustrates the problems and the costs of extensive dependence on wind for electricity).

[8] The effort is described in a 20-page "White Paper" that can be found on AWEA's web site. http://www.awea.org/policy/documents/Transmissionwhitepaper12-2002.pdf
[9] DB = Declining balance.
[10] The depreciation deduction in the first year (20%) is less than the second year (32%) because the IRS prescribes the "half-year convention" which permits deducting one half-years depreciation in the first tax year, regardless of when the facility actually begins operation during that year. See IRS Publication 946.