A RATIONAL LOOK AT RENEWABLE ENERGY

AND THE IMPLICATIONS OF INTERMITTENT POWER

By Kimball Rasmussen | President and CEO, Deseret Power | November 2010, Edition 1.2

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In December 2009, I had been invited to speak at a conference discussing climate change policy in Las Vegas. It happened to be held at the same time of the National Finals Rodeo. On my way out of town I stopped at a crowded In-N-Out Burger where the majority of the patrons wore cowboy boots and hats, Wrangler jeans and western shirts. One cowboy from Oklahoma noticed the "Electric Power Cooperative" logo on my shirt, and asked if I knew anything about wind energy. He told me, "I own a large ranch in Oklahoma where they have been installing wind mills all over the place. My question is this: with all of those wind mills, why hasn't my power bill come down?"

This seems to be a common misperception, that wind turbines provide an inexhaustible supply of cheap energy—after all, the fuel is free, isn't it? Why don't we simply build more and more renewable energy and achieve low-cost energy independence, while at the same time creating millions of new jobs to fuel a green economic recovery? What's not to like about that? Unfortunately for all of us, the real world poses limits on renewable energy technology, and with those limits come costs—relatively high costs, as will be shown in this paper—that must be paid to integrate even a modest amount of renewable energy into the power supply portfolio.

This paper will explore wind and solar energy in terms of their environmental, operational and economic attributes. We will then place these in context to form a rational look at renewable energy and the implications of intermittent power—the not-so-obvious operational challenges that have to be addressed when large quantities of intermittent energy must be accommodated on the electricity grid.

This analysis is based on the current state of wind and solar technologies. Further research and development efforts of these technologies may produce breakthroughs, which could mitigate some of the impediments to high penetrations of wind and solar power to the electric grid, but as yet these impediments remain significant.

FORWARD

Wind and solar energy—two of the primary sources of renewable energy—are sometimes touted as the answer to the world's energy challenges. Some advocates of these energy sources want us to believe they can mitigate everything from the disastrous 2010 oil leak in the Gulf region to the global concern of climate change. Wind and solar energy are routinely promoted with the promise of green jobs, and that they will lead to a green technology revolution while improving the environment. But how well do wind and solar energy solutions actually perform on these promises? Let's take a rational look.

WIND ENERGY

Wind energy is becoming a significant consideration in the planning and development of the modern electric system. In the past decade, the United States wind energy output grew, as a sector, 10 times faster than the combination of all other forms of electric energy.[1] The growth in wind turbines is remarkable, given that the U.S. wind industry installed more turbines in the years 2008 and 2009, than all previous years combined. We are truly in a wind boom. This is attributable to a number of factors, including the fact that wind farms are much quicker to design, permit and construct than traditional coal- or gas-fired plants, and wind energy tends to be one of the least expensive renewable energy options. As a result, the U.S. now undeniably leads the world in total wind energy, surpassing nations such as Germany and Denmark. How far we go from here depends on some specific attributes of wind and the systems required to deliver it.

FUNDAMENTAL ISSUE: INTERMITTENCY

Despite robust wind development in the U.S., wind faces a nearly insurmountable issue: intermittency. Simply put, the intermittent nature of wind makes it difficult to harness effectively on a power grid that is finely tuned to deliver electricity around the clock. The down side of this intermittency is clearly evident in the actual performance data of wind turbines already installed. Wind performs poorly across all traditional utility metrics for generating resources. For reliability, stability, forecast ability, proximity to load centers, and economics, wind power is a poor choice for large-scale power production.

NAME-PLATE RATING VERSUS ACTUAL ENERGY DELIVERY

For the sake of this discussion it's important to know that all power producing equipment comes with an output rating stating how much power the facility will produce. This is referred to as name-plate capacity and it is expressed in kilowatts (kW) or megawatts (MW).[2] For large utility grade generators the customary expectation is that once installed, they will deliver the name-plate output when supplied with sufficient fuel. Additionally, they will operate, if required, around the clock. In the case of wind energy installations this is simply not the case. The output over time is only a small fraction of name-plate rating because of the intermittency of the fuel resource. The ratio of actual output divided by maximum potential output is defined as capacity factor. The entire sector of U.S. wind energy is currently operating at a capacity factor of only 25 percent.[3]

It is troubling that we see some astonishingly simplistic reports in the media which assert the number of homes that a given "wind farm" will allegedly supply. When reliability, expressed as capacity factor, is taken into account, the serviceability of wind is much lower than advertised. A misleading claim by a developer may contribute to the sentiment that renewable energy can easily replace fossil fuels—it cannot.

WIND IS WEAK AT PEAK

The intermittent and unpredictable nature of wind is further compounded by the fact that the wind tends to be weak during electrical peak load conditions. Wind blows most consistently and creates the best generation opportunities during off-peak hours, cooler days and evening hours; directly opposite

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[1] U.S. Energy Information Administration, Net Generation by Energy Source, (2010), http://www.eia.doe.gov/electricity/epm/table1_1.html. Wind data shown on Table 1.1.A. Net Generation by Other Renewables: Total (All Sectors), 1996 through July 2010. Based on a comparison of 2009 versus 1999, wind energy output expanded by 78 percent, natural gas electric generation grew 65 percent, nuclear grew 10 percent, coal declined 6 percent and hydroelectric declined 15 percent. The entire electric mix from all sources grew a total of 7 percent.

[2] One megawatt is equal to one thousand kilowatts.

[3] The same reference as in the preceding note.[1]

the electric customer usage profile. This is a natural consequence of the climate forces that determine wind: daily and seasonal temperature differentials. On the hottest days of the summer the wind tends to be low or non-existent when air conditioning demands are at their peak. Then when it gets windy, the temperatures will naturally moderate and air conditioning loads drop off just in time for the wind energy to pick up. Therefore, during the summer months, wind generation is low during high demand times, and can be shown to reach maximum generation when power demands are down. The same phenomena can be demonstrated to occur during winter peak conditions. The very coldest days are also the days when the wind is not blowing. For this reason, utility-scale balancing regions simply do not plan for significant contribution of wind at peak demand periods. This can be amply demonstrated in real-world, large scale examples from Texas, California, the Pacific Northwest region, and the entire western United States.

TEXAS

Texas is home to the largest collection of wind generation facilities in the nation. More than one out of every four wind turbines in America is found in Texas. The Electric Reliability Council of Texas (ERCOT) only plans for 8.7 percent of wind name-plate rating as the "dependable contribution to peak requirements," in accordance with ERCOT's stakeholder-adopted methodology.[4] This means that more than 91 percent of Texas wind turbines are expected to be off-line when it matters most—at peak load periods.

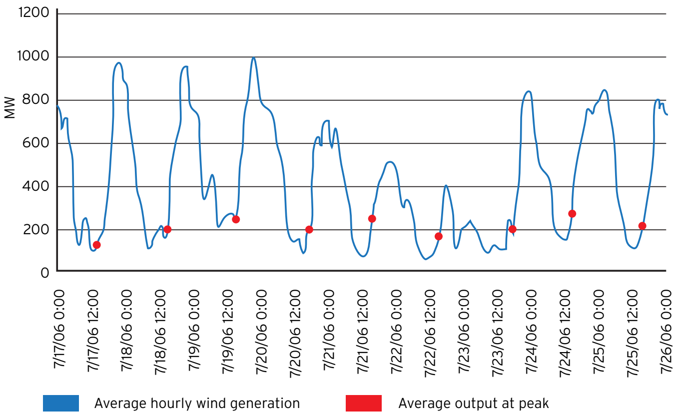
CALIFORNIA

The State of California ranks third in the U.S. for total installed wind energy (behind Texas and Iowa). California is also the third largest state geographically (behind Alaska and Texas). According to the California Independent System Operator (CAISO),

> *"California is a national leader in the development of renewable resources. Because California has large quantities of renewable resources already on-line, a significant amount of historical data is available to accurately model and forecast future performance of the various types of renewable resources."*

> *"Wind generation presents . . . significant operational challenges. Wind generation energy production is extremely variable, and in California, it often produces its highest energy output when the demand for power is at a low point."*

CAISO's graph demonstrates its summer wind generation and average variation by hour:


WIND GENERATION & OUTPUT AT PEAK
ACTUALS - WEEK JULY 17, 2006

The wind capacity available at California peak demand times is about 200 MW. The name-plate capacity of California-based wind generators is about 2,600 MW. Hence, the wind power available at peak is less than 10 percent, which is very similar to the Texas experience. In other words, about 90 percent of California wind turbines are idle at peak load conditions.

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[4] Kent Saathoff, *ERCOT Expects Adequate Power Supplies for Summer,* ERCOT, May 12, 2010, www.ercot.com/news/press_releases/2010/nr-05-12-10.

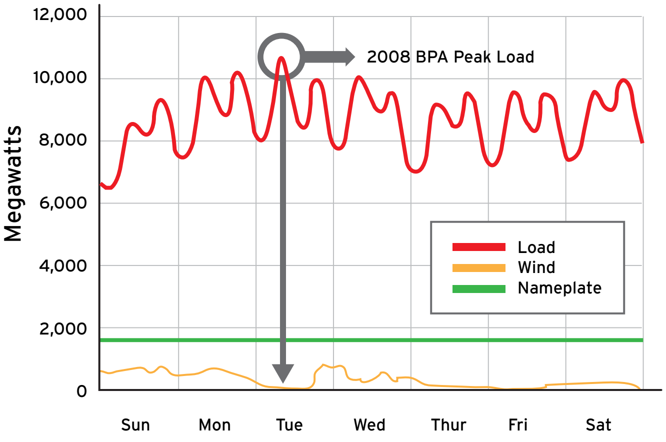
Note that Texas and California are both summer-peaking systems. Let us consider a vast winter-peaking region—the Pacific Northwest—to see how wind energy performs in that situation.

THE PACIFIC NORTHWEST

Oregon and Washington rank fourth and fifth in the U.S. for total installed wind energy. The prominent Federal Power provider in the region—the Bonneville Power Administration (BPA)—is a winter-peaking system with about 10,000 MW of load.

BONNEVILLE POWER ADMINISTRATION

ACTUALS - WEEK DECEMBER 14, 2008



Data: Bonneville Power Administration

On Tuesday December 16, 2008, the BPA system reached its peak for the entire year, with a demand of 10,762 MW. At the time of peak demand, the output of the entire fleet of wind resources, with a name-plate value of 1,599 MW, was only 116 MW, or about seven percent of the name-plate potential. This is very similar to the Texas and California wind experience, only in this case about 93 percent are not producing at the winter peak.

THE WESTERN UNITED STATES

Now let us consider an even broader region—all eleven western states, from Montana to New Mexico, from Washington to California, and everything in between. This vast area is served as a single "reliability" region known as The Western Electricity Coordinating Council (WECC). During the heat wave of July 2006, the WECC system reached its peak on Monday, July 24, 2006. The hottest day was actually July 23, 2006, but this was a Sunday so total loads did not peak until Monday. On the hottest day, the capacity factors for wind resources through most of WECC were well under five percent, and on the peak day, which was a slightly cooler day, the wind capacity factors were less than ten percent.[5] Again, this is very similar to Texas, California and the Pacific Northwest.

These real-world lessons illustrate the grave shortcomings of wind. Approximately 90 percent of wind turbines can be expected to NOT PRODUCE power at peak load periods, even when distributed over broad geographic areas.

Incidentally, I recently had a conversation with a trustee of a large mid-western utility that is home to 450 MW of wind generation. He asked me to guess how much of the 450 MW of wind was actually producing during their system peak. I responded, "Probably between 30 and 40 MW." He gasped, "How did you know? That is exactly what we are seeing!" Yes, wind is weak at peak.

ENTER THE "TWILIGHT ZONE"—A CONTROL AREA[6] NIGHTMARE

The demonstrated low performance of wind energy during peak load conditions is only one side of the coin. The other side occurs during off-peak periods when unscheduled, unanticipated wind energy

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[5] WECC, *Wind Capacity Issues Working Draft*, March 17, 2010.

[6] Control Area - A power generation regulation region that maintains and balances its power load and power interchanges with other control areas. See also, Control Area Concepts and Obligations, North American Electric Reliability Council, 1992.

comes booming onto the system ready to serve loads that are nowhere to be found.

This can easily happen because of the physics of wind energy: the power output of a wind turbine accelerates at a much faster rate than the simple change in wind speed. For instance, if the wind speed changes from 10 to 20 mph (a doubling of the wind speed) the associated power output will change by a factor of eight.[7]

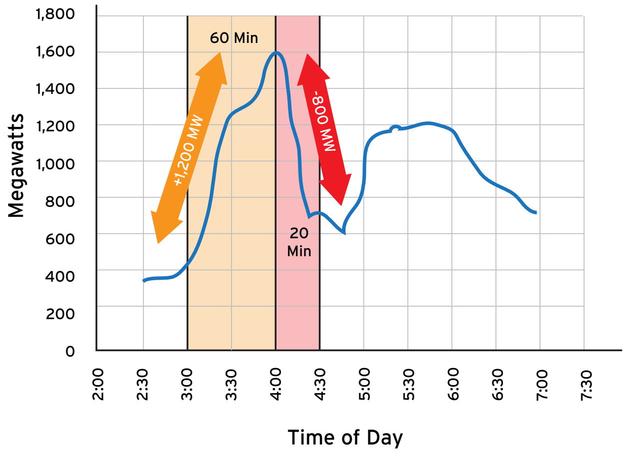
An actual case with the BPA brings the control area problem into perspective. On April 27, 2010 about 3:00 a.m., wind generation on the BPA system ramped up by 1,200 MW in only one hour, and then down 800 MW in only 20 minutes. Such rapid changes cause extreme stress to a control area and in many cases result in market price distortions and environmental degradation.

Such erratic changes in generation run directly counter to the needs of utility operators who select from a pool of different traditional generators to provide the right amount of power at the instant it's required. In a normal day they blend the outputs of traditional power plants that include coal, nuclear, natural gas, and in some regions hydroelectric to work in concert to minimize operating costs while maintaining reliability.

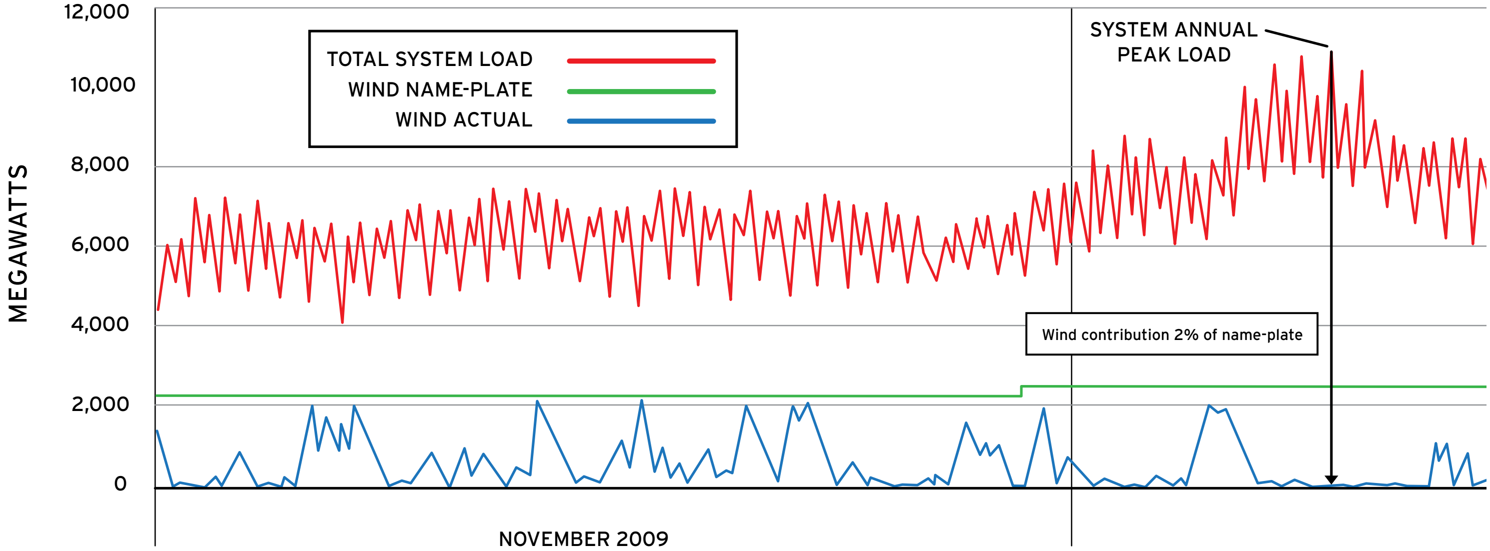
CONTROL AREA/TWILIGHT ZONE IN ACTION:

BONNEVILLE POWER ADMINISTRATION

ACTUAL – APRIL 27, 2010



BONNEVILLE POWER ADMINISTRATION 2009/10 TOTAL SYSTEM LOAD AND WIND CONTRIBUTION



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[7] Note that the physics of wind energy is such that the change in power of a wind turbine is proportional to the cube of the change in wind speed. This means that if the wind speed cuts in half, the power output will cut to one-eighth. See also, Wind Systems Power Calculation, http://windpower.generatorguide.net/wind-speed-power-.html.

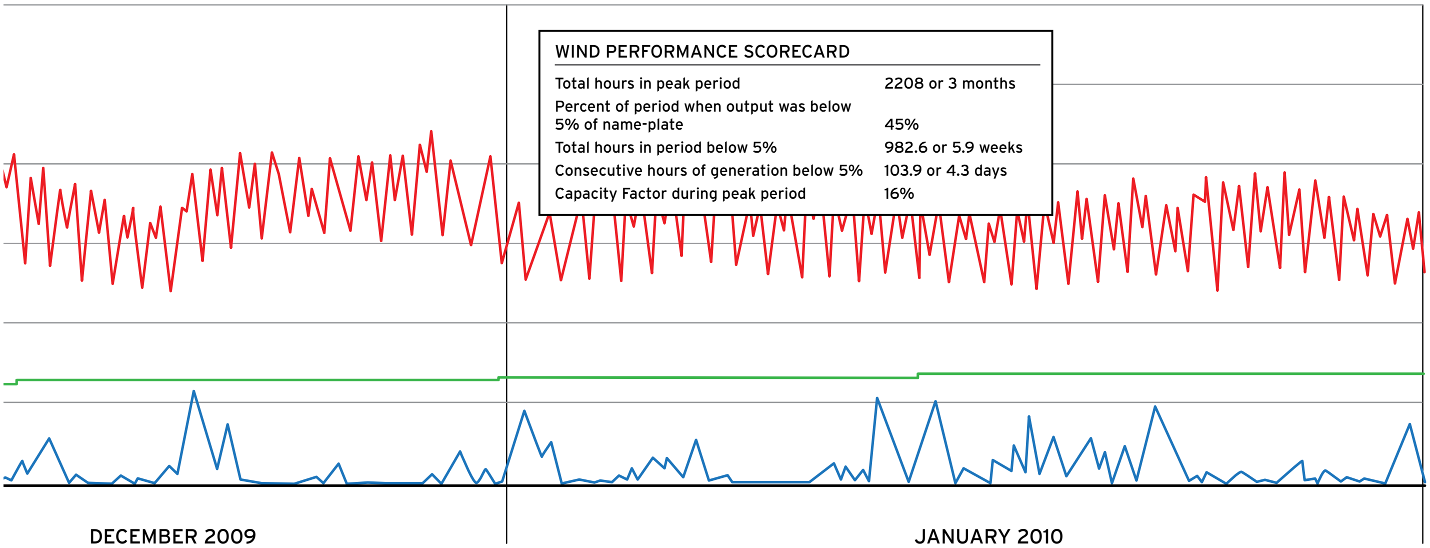
Now we have the advent of wind. The use of wind energy creates an unprecedented challenge, which can easily launch utility power systems into an off-peak condition, something that can be described as the "twilight zone."

Consider an event that occurs during off-peak or twilight hours. The various utilities are operating with all of the peaking plants off line and many of the intermediate resources off line. Still running are base-load, coal-fired generators but they have been reduced to minimum-load status. The nuclear plants are running because they remain in "must-run" condition for safety and economic reasons. The wind turbines are cruising along at a modest output.

Now assume that a sudden, unanticipated, change in the weather brings with it a rapid ramping of wind energy output. This can result in a large block of several thousand MW of unplanned energy that when combined with the operating status just described, that can easily swamp out the total load requirements of the utility—meaning there's literally no place for the energy to go.

Now the utility is forced to make quick and drastic decisions to balance loads and resources. I call this the twilight zone—a control area no-man's land. One option might be to enact the costly decision to shut down a base-load resource, such as a nuclear or coal unit, and then subsequently face a high cost "re-start" with its attendant unusual wear and tear on the affected units. In the case of a coal-fired unit, emissions will increase as the unit and its pollution control equipment ramp up during the few hours after startup.

Another twilight zone choice is to try to sell the "hot potato" energy to a neighboring utility, or to another control area authority. What if the neighbor already is operating at optimum balance?



WIND PERFORMANCE SCORECARD

Total hours in peak period	2208 or 3 months
Percent of period when output was below 5% of name-plate	45%
Total hours in period below 5%	982.6 or 5.9 weeks
Consecutive hours of generation below 5%	103.9 or 4.3 days
Capacity Factor during peak period	16%

Choices are limited, and the market price for electricity can plunge so low that the price actually goes negative.

The host utility might actually have to pay a neighboring utility to accept the surplus schedule and allow delivery onto its system. This absurd result is a reality in a system that has a high percentage of wind generation installed, and can be very costly to the host utility.

Do you think the twilight zone problem is insignificant? Is this just a remote hypothetical? Think again. Many utilities have found themselves in precisely this situation. For this reason some system operators are now requiring wind turbines to be equipped with a "cut out" switch that disconnects the wind farm from the grid by remote control. This becomes an obvious waste of energy.

THE SHADOW GRID—THE FOSSIL FUEL STAND-IN FOR NO SHOW WIND

Wind's unpredictable nature tends to provide energy that does not match consumer demand. As noted in the examples of ERCOT, California and the Pacific Northwest, wind volatility makes it unsuitable for electricity planners to rely on wind energy to meet peak demand needs. In order to mitigate these negative effects, the grid operators and planners must construct a shadow grid, typically consisting of fossil-fueled power plants (particularly gas-peaking units). This shadow grid stands as reserve generation for those times when wind resources are not delivering their potential capacity. At those times, homes still need heat and light, commercial and industrial sites still have to run electric equipment, when the wind may not be producing up to its potential.

Effectively, we end up building new fossil-fueled peaking power plants (usually natural gas) to back up the wind resources that were intended to eliminate fossil-fueled resources in the first place.

This duplication of costs is forced onto consumers, who must pay for both the wind turbine and the back-up generator.

THE LOS ANGELES DEPARTMENT OF WATER AND POWER (LADWP) recognizes the need to back up wind with gas in order to maintain capacity and reliability. Consider the following statement from the LADWP's executive summary of its 2010 Draft Integrated Resource Plan:

> *"There is ongoing debate regarding the level of on-peak reliability of renewable resources. However, the renewable resources were added mainly to satisfy Renewable Portfolio Standard (RPS) target requirements, while natural gas resources were incorporated to ensure system reliability."*

In other words, the LADWP overtly recognizes that the wind projects on the system are only meeting the legislatively mandated RPS as they provide intermittent energy. But to actually operate a reliable system, with capacity and energy, LADWP must install natural gas generation resources. In spite of the obvious environmental objective of wind energy, the shadow grid of gas generation will result in air emissions, including carbon dioxide. Many such generators are "simple cycle" peaking units, which tend to be less efficient and have the highest emissions among gas-fired generators.

The need to develop a shadow grid has also resulted in the actual filing of new tariffs to charge for the cost of such a grid. Puget Sound Electric has recently filed a tariff with a proposed charge of $2.70 per kilowatt-month to offset the carrying cost of a shadow grid of gas turbines that are required to stabilize the volatility of wind.[8] This can result in an energy charge of one- to two-cents per kWh—or an additional 10 to 20 percent (or more) tacked onto the already high cost of a wind turbine in order to integrate it operationally into the grid.

INCREASE IN CARBON DIOXIDE FROM WIND POWER—IT IS POSSIBLE

In addition to the obvious investment and operating cost of the shadow grid, there is another unintended consequence of this fossil-fueled backstop system: carbon emissions. As discussed above, a significant penetration of wind turbines into an electric grid can cause base and intermediate resources to be fired up and energized onto the grid or dispatched at levels where design efficiencies are very poor. This results in unintended carbon emissions.

Think of it like this: Suppose that you were to go on a road trip where you are required to maintain an average speed of 60 mph. In the base case you do this by setting the car on cruise control. Now imagine an outside influence that requires you to suddenly stop, and then rapidly accelerate to 120 mph, and to do so at unpredictable intervals, all the while you are required to average 60 mph. Can you imagine the fuel economy differences between these two cases? This is more or less what happens to an electric system that attempts to accommodate a high percentage of wind resource into the grid.

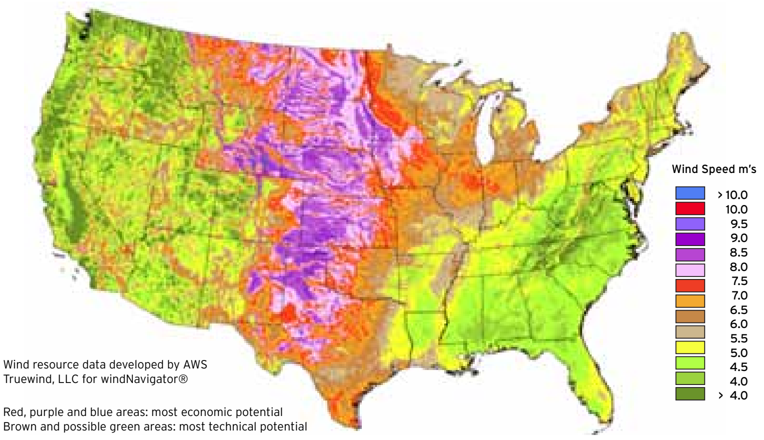
The concept and conclusion is as valid as it is alarming:

Wind power does not produce all of the claimed benefits of reductions in fossil fuel consumption and CO_2 emissions when the fuel consumption and related emissions of the shadow grid of gas-fired resources are taken into account.

The actual benefits are much less. When real-world efficiency losses and additional emissions from the gas turbines are taken into account, the perceived environmental savings of wind energy are greatly diminished.

GOT TRANSMISSION? THE MISSING COST ELEMENT.

No matter where you live, or how windy you think it is, some regions of the country see relatively little sustained wind at all. Below is a basic map of the United States' wind energy potential.



Wind resource data developed by AWS Truewind, LLC for windNavigator®

Red, purple and blue areas: most economic potential
Brown and possible green areas: most technical potential

Note that the regions of maximum wind potential (the areas of red, purple and blue) do not coincide with the areas of dense population. The wind speed and duration are generally the greatest in the least populous areas far away from the big cities on

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[8] Energy News Data - California Energy Markets, July 16, 2010, No. 1087, 11-12.

either coast. This mismatch between resource and population is one of the reasons that developers of wind energy are challenged to find and exploit locations close to existing high-voltage transmission lines that can carry electricity from wind turbines to big city distribution lines. As more of these locations become occupied, adding more wind generators can only happen in locations where new additional transmission corridors are cleared and constructed, to carry out the delivery process from high wind zones to urban centers. Obviously the lack of new transmission adds a significant hurdle when considering wind development. Too often this component of cost gets overlooked in discussing the relative costs and benefits of wind energy. This tends to duplicate the investment cost of the wind, and will also require less efficient gas resources to supplement the wind energy so that the composite product is usable to the system.

The western continental United States is home to eight of the largest states, in terms of land area (with Alaska and Texas completing the top ten). Of these eight states, only California ranks in the top ten in terms of population. The relatively sparse population in the vast, open areas call for lengthy, and therefore costly, transmission lines.

TECHNICAL POTENTIAL VERSUS ECONOMIC POTENTIAL

After studying the U.S. map (shown on the previous page), you can easily determine where the best wind energy potential lies. The sites of economic potential will produce wind energy at the least cost; the sites with technical potential will produce wind energy but will experience relatively poor economics. Hence if a study touts significant technical potential to develop wind energy in a given region this does not in any way suggest that doing so will be an economically viable option.

The very best "economic potential" wind sites can produce capacity factors in the range of 30 to 40 percent, while the poorer "technical potential" sites can be much worse at 20 percent or less.

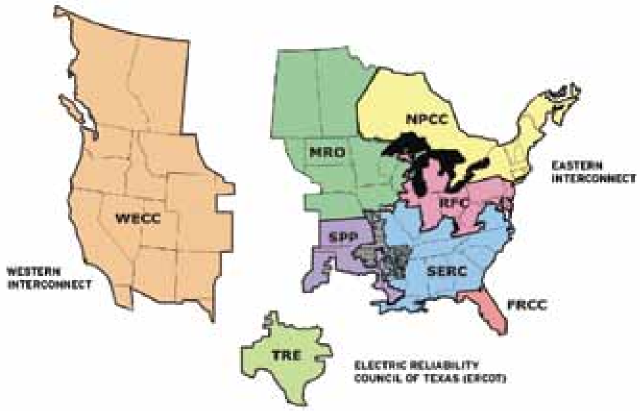
The national average performance through 2008, for all wind turbines in America, was a capacity factor of about 25 percent.[9]

This means that, in terms of their operating characteristics, and even for the best wind resources, the grid must be designed and operate as if 60 to 75 percent of the time a typical wind turbine produces very little or nothing at all. Wind is as fickle as weather, and electrical wind generation is as fickle as weather to the third power,[10] literally.

THE ELECTRIC CONTINENTAL DIVIDE

The United States electric delivery system does not operate as a single grid, but rather as three separate grids as shown on the map below:

NORTH AMERICAN ELECTRIC RELIABILTY CORPORATION (NERC) REGIONS



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[9] U.S. Energy Information Administration, *Summary Statistics for the United States,* (2010), www.eia.doe.gov/cneaf/electricity/epa/epates.html. Calculated using total wind energy as compared to name-plate capacity multiplied by 8,760 hours per year.

[10] Note that the physics of wind energy is such that the change in power of a wind turbine is proportional to the cube of the change in wind speed. This means that if the wind speed cuts in half, the power output will cut to one-eighth.

Because electric energy is instantaneously generated and consumed, the operation of these grids requires a coordinated balancing of generation and consumption of power within each grid. Control Area Operators (CAOs) perform this function, as well as other important tasks, that allow the interconnected electric power systems and their components to operate together both reliably and efficiently. There are approximately 150 Control Areas in the nation. Most are run by the dominant large investor-owned utility in a geographic area defined by an interconnected transmission grid and power plant system. The CAOs dispatch generators from a central control center with computerized systems in such a way as to balance supply and demand and maintain the transmission system safely and reliably.

The Western Interconnect boundary (WECC) consists of 30 such "control areas" that include most of Montana, Colorado, New Mexico, and all states to the west. The Eastern Interconnect includes everything east of this border, with about 120 individual control areas. And Texas? I guess you don't mess with Texas! They do their own thing down there.

These three grids operate independently from one another. Since the three large grids are not in synchronous operation with one another, they cannot be interconnected with one another through traditional "alternating current" (AC) transmission lines. The only possible means of interconnection is through "direct current" (DC) and this is very costly. Consequently there are only six DC ties connecting the Western Interconnect and the Eastern Interconnect in the United States and one additional DC tie in Canada. The capacity of these ties is quite limited (due to cost). Six or seven interties of several hundred MW will simply not get the job done. Besides, the current interties, being already in service, have little excess capacity to move new renewable power.

In addition to the obvious transmission challenges of renewable energy, there is a virtual wall between east and west. Unfortunately, the greatest "economic potential" of wind energy is electrically trapped in the Midwest. It is virtually impossible, or at least very cost prohibitive, to consider transmitting this resource to the west. It is also impractical and cost prohibitive to transmit this energy to the east coast population centers that are, in some cases, more than a thousand difficult miles away.

Just as precipitation will naturally drain within a continental divide, in similar manner the nation's energy resources are virtually constrained to remain within the three "electric continental divides" of the West, the East and Texas. What happens in the west stays in the west. What happens in the east stays in the east. What happens in Texas stays in Texas.

WIND ENERGY STORAGE—NOT READY FOR PRIMETIME

What if we could just store the wind energy when it is produced (and not needed) and then call on it in times of need? Consider this statement from the North American Electric Reliability Corporation (NERC):[11]

> *"Unlike water or gas, electricity cannot be stored. It must be generated as it is needed, and supply must be kept in balance with demand. Furthermore, electricity follows the "path of least resistance," so it generally cannot be routed in a specific direction. This means generation and transmission operations in North America must be monitored and controlled in real time,*

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[11] North American Electric Reliability Corporation, *About NERC: Understanding the Grid,* http://www.nerc.com/page.php?cid=1|15.

> *24 hours a day, to ensure a consistent and ample flow of electricity. This requires the cooperation and coordination of hundreds of electricity industry participants."*

Storage of electricity would, indeed, answer many of the operational concerns raised when it comes to renewable energy. The notion that electricity cannot be stored is not entirely accurate, and in fact, there is much effort underway to develop new storage technologies. An ideal storage mechanism would be able to capture unlimited quantities of electricity, at a near infinite rate of charge and discharge on demand. It would be able to hold a charge for long periods of time and would be free, or at least very inexpensive to install and operate, with little or no losses. Unfortunately, as of today, this dream set of criteria is a fantasy, although there is an obvious need for energy storage technology. An effective wave of new, renewable energy can only function properly in a world that is ripe with near-ideal energy storage opportunities.

It is true that devices have been invented to store bulk electric energy. These are all miniscule in scale, and expensive to acquire and operate.

One particular state-of-the-art storage device consists, essentially, of a high-speed flywheel (30,000 rpm) that is suspended (or levitated) above cleverly designed magnets, resulting in a storage that is almost frictionless. Such a device can begin charging (or discharging) in a fraction of a second—it is clearly able to respond to any sudden changes in wind or solar output. It is recommended by the developer of this technology that about 2.5 MWh of storage capacity (at a cost of $1.4 million) will accommodate a wind system of about one MW name-plate rating. The one MW wind system, according to the JEDI model (discussed later), would come with an installed cost of about $2.3 million. Storage, in this case, therefore adds about 60 percent to the installed cost of wind. Such a storage device is capable of offsetting any unanticipated effects of the wind system for a period of at least 2.5 hours, or longer. This gives the utility system more opportunity to operate with predictability; it also mates capacity with the wind energy. The storage does not, however, mitigate the paltry capacity factor of 25 to 40 percent energy output that is typically associated with wind.

Based on the above estimates, storage would add about 4.7 cents per kilowatt-hour to the cost of wind. It is doubtful that such a system is economically justified, but it is quite interesting nonetheless. Such exotic storage systems are typically reserved for the most rare of applications—remote islands, arctic outposts, etc., or for research and development pilot projects. None of these technologies currently exist with sufficient supply and at a low enough cost to make a meaningful difference to the bulk power system.

Not every region or location is suitable for the most promising storage opportunities. It should also be noted that storage technologies always come at a cost—both a capital cost to develop and acquire the storage mechanism, as well as an operating cost or storage penalty (essentially the execution of thermodynamic laws). There is always some amount of energy loss associated with storage. The flywheel system previously described claims a storage penalty of about five percent, including transformation, while hydroelectric pumped storage requires about 30 percent more energy to fill the storage pond than can be extracted upon retrieval. The energy output of storage is always net negative.

WIND TURBINES CAN CONSUME ELECTRICITY

One of the little known ironies about utility scale wind turbines is that they require an external source of grid-provided electricity in order to run properly. Particularly in cold climates, where much of the best wind resources can be found, these units must be heated to maintain proper viscosity in lubricating fluids and to protect vital components from damage. When it's cold in Wyoming and up into the Dakota badlands where the calm night air drops to below-zero, it will be the fossil-based fuel from gas and coal-fired power plants in the region that are called upon to warm the massive wind turbines towering hundreds of feet above the windswept plains. Wind turbines typically will not operate at all when temperatures drop below minus 25° F. The turbines will also shut down when temperatures rise to more than about 105º F. This further compounds the lack of wind turbine availability at peak load conditions.

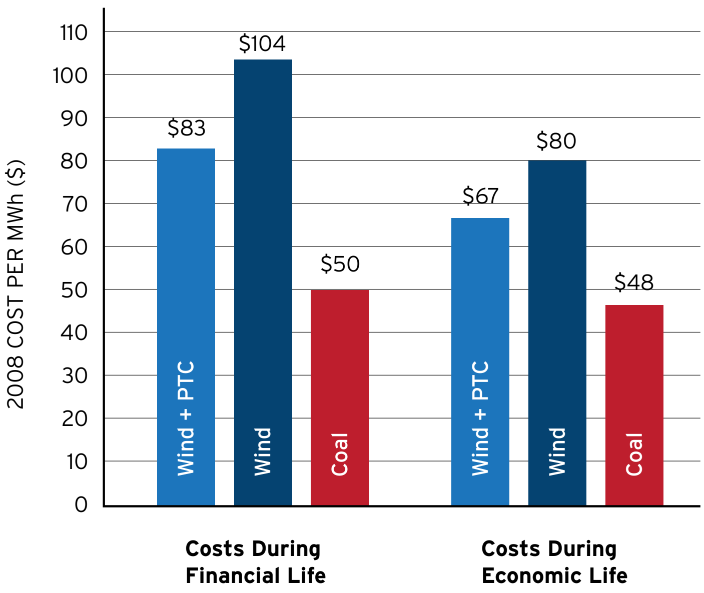
As we gather more and more real-world data in the production of wind energy, it is apparent this resource has a long way to go before becoming a viable contributor to the world's energy needs. While there may be a worthy role for subsidies and taxpayer support of wind, the inescapable fact is that wind is unlikely to ever be more than a supplemental resource, which must be backed up by natural gas plants and/or energy storage technology.

THE HARD REALITIES OF RENEWABLE PRICING

Studies and claims regarding the cost of renewable energy abound—some seemingly very optimistic and others less so. One established baseline value for wind versus coal costs is available from the Jobs and Economic Development Impact (JEDI) model, jointly sponsored by the Department of Energy (DOE) and the National Renewable Energy Laboratory (NREL). The JEDI model was developed over a two-year period and involved a serious collaboration of government and industry professionals to determine the jobs and economic development costs and benefits of power generated by new wind, solar, gas, and coal projects.

Consider the following graph showing JEDI cost comparisons for wind and coal:

DOE / JEDI WIND AND COAL COMPARISON



As is evident, the wind power without the Renewable Energy Production Tax Credit (PTC) is about double the cost of coal. Even with PTC wind is 70 percent more costly. (The PTC is a corporate tax credit incentive provided to industrial and commercial companies building renewable energy plants.)[12]

Besides the obviously lower per-unit cost, power from a new coal-fired facility also has the significant advantage of being available upon demand at or

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[12] Database of State Incentives for Renewable & Efficiency, *Renewable Electricity Production Tax Credit (PTC),* (2010), http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US13F.

near-full capacity to serve load, rather than available only when strong winds are blowing.

The JEDI model is a good indicator of theoretical energy costs. As another benchmark of the cost of wind energy, let us consider data taken from actual projects being developed with real money at risk.

NV Energy, the electric service provider serving Las Vegas and the surrounding area in southern Nevada, has, since 2008, been issuing annual Requests for Proposals (RFPs) for power from renewable energy projects to comply with requirements of the state Renewable Portfolio Standard (RPS).[13] The most recently completed RFP process began in 2009 and resulted in NV Energy's selection of the seven best projects based on its bidding criteria (from among more than 30 responses). Contracts were executed with these project developers in the first half of 2010.[14]

The table in the next column summarizes the prices of the selected projects, all of which include a one percent annual escalation for the term of the contract. It is noteworthy that the solitary wind project comes at a price—nearly 10 cents per KWh—which is significantly greater than the baseline estimated by the JEDI model, even based on JEDI's accelerated repayment of capital over only a 10-year term.

Compare the highlighted column, the first year price of various renewable energy resources, with the costs of a coal-fired plant: $50 per MWh over its financial life, and $48 per MWh over its economic life. The renewable energy plants come at a cost of 60 to 180 percent of the JEDI per-unit cost of a coal-fired plant.

NV ENERGY SELECTED PROJECTS

Project Developer:	Type/ Fuel Source:	MW	1st Yr Price ($/MWh):
Ormat	Geothermal	25	86
Ormat	Geothermal	40	88
Ram Power	Geothermal	53.5	98
Solar Reserve	Solar w/ storage	100	135
Next Light Renewable	Solar PV	50	132
Pattern Energy	Wind	150	98
Waste Management	Landfill Gas	3.2	81

Source: Letter from Shawn Elicegui, Associate General Counsel, NV Energy to NPSC in Docket 10-02009, July 9, 2010.

VALUE OF POWER— DEMAND VERSUS ENERGY

Commercial and industrial electric power is typically priced and valued based on two components: demand and energy. Demand, or capacity, is the ability to supply electricity at the very instant it is needed. Energy refers to the amount of electricity that is actually delivered and used over the course of time (such as a monthly billing period). Depending on the utility rate structure, the demand charge component can be as large or larger than the energy charge component. This reflects the fact that the utility must purchase, construct, and have available all of the generating and transmission resources necessary to meet peak demand needs, as well as the cumulative energy needs measured over a period of a month or a year.

Demand is closely associated with the notion of dependability or reliability.

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[13] The impacts of the Renewable Portfolio Standard (RPS) are significant and far-reaching. RPS will be covered in-depth on page 19.

[14] Over the protests of the project developers, the Las Vegas *Review-Journal* filed a public records request regarding disclosure of terms of these contracts, including pricing. The Nevada Public Service Commission ruled July 2, 2010 in favor of the public records request and required NV Energy to make the pricing information public.

Consumers want the power to be there the very instant that it is demanded.

Having electricity intermittently available, at unpredictable times and quantities, is not acceptable in today's electric system.

A practical example will help illustrate this point. When it comes to our automobiles, we have a tendency to demand cars be reliable and to meet our wants and needs at our beck and call. Consider a choice between two automobiles: one gets 50 miles per gallon, but only runs intermittently about 25 percent of the time; the other car gets about 20 miles per gallon, but it runs all of the time. How would you value each of these cars? If the first car had low fuel cost, but no reliability, how much would you pay for such a car, and are you prepared to call a taxi when your car stalls half way down the road? If the value of a car is based, shall we say, half on fuel economy and half on reliability, then the market value of the intermittent car will be intrinsically lower because it fails to meet the primary purpose of reliable transportation. Who wants a car that rarely runs?

This concept is very relevant to a discussion about renewable energy. A claim might be made, for instance, that a certain wind turbine can produce power at a cost of 8 cents per kilowatt hour (kWh). But cost is only half the story. The actual value of such power is properly assessed by considering both the demand and energy provided by any given resource.

SOLAR ENERGY

There is significant national and international interest in the development of new solar energy. While this is obviously an energy source that has more applicability to regions with high levels of sunshine, it is a promising technology for many reasons. The single greatest challenge to solar power is the immutable fact that the sun is only available, at best, half of the time, no matter how ideal other conditions may be.

A well-designed and situated solar project will typically provide available energy at about 20 percent. At this low availability, solar energy can never be more than a supplement to a larger portfolio of power generating resources.

And like wind, solar energy begs for supplemental storage in order to provide a degree of reliability to the grid.

NOT ALL SUNSHINE IS EQUAL

Photovoltaic cells, or PV solar, are by far the most common application for electric generation from solar energy. Although there are other forms of solar renewable projects, given the availability and popularity of PV, we will focus on it first.

PV panels are made from materials such as crystalline silicon and cadmium telluride, which convert photons from the sun's rays into electric energy. To make use of the energy produced by these cells, an inverter is attached to a PV array to create alternating electric current. Some PV panels are small, roof top applications, and a few are larger, utility scale facilities. PV solar panels have no moving parts. Hence the operations and maintenance consists largely of a careful cleaning from time to time with glass cleaner. But even a very large PV solar project will have a fairly modest output.

The entire United States' output of PV solar for the year 2009, was 807,988 MWh, about one-tenth of one percent of the U.S. nuclear output.

HOW EXPENSIVE IS PV SOLAR?

Apart from the day/night cycle of solar power, which can't be avoided, another disadvantage of PV solar is its high cost. California provides robust rebates and incentives under its California Solar Initiative and has produced some valuable benchmarks for the cost of solar power. According to a study produced for the California Public Utilities Commission in 2009, the price of installed PV under the California program averaged $7,090 per kW for large industrial customer installations, and $8,490 per kW for residential installations.[15] Assuming a 20 percent capacity factor, a cost of capital of six percent and a life of 25 years, the cost per kWh of these installations would run from 32 to 38 cents per kWh.

This example helps to explain why solar energy is only a miniscule resource in the United States. Still, solar is a growth industry and significant improvements in both design and cost are forthcoming. Indeed there are anecdotal evidences of less costly solar installations—as little as $4,000 per kW—but even at that installed cost, the bottom line energy cost to the consumer would be in the range of 15 to 20 cents per kWh. To be competitive, solar would need to cut even further, probably another 50 to 70 percent below even these levels.

LARGE PV SOLAR

Three years ago the much-publicized PV solar facility at Nellis Air Force Base was the largest such facility in North America, and the third largest in the world. It sits on 140-acres and produces about 30,000,000 kWh per year. Yet this amount of production is only equivalent to one day's output of a 1,200 MW coal-fired plant. If we were to attempt to replace the entire fleet of coal-fired electrical generation in the United States with large PV solar projects, we would have to install a Nellis-sized facility each month for each of the next 5,000 years.[16] Indeed we are a long way from accomplishing much with PV solar energy. With growth in the solar industry, there are now three other PV solar facilities in the United States that are larger than the Nellis facility, and 40 larger PV facilities in the world.

Given the inefficiencies of scale associated with PV solar, it is not realistic to envision the entire electric system consisting solely of such distributed units. Homes cannot run entirely from PV solar panels without some form of backup or battery storage. Even large arrays on commercial buildings are almost always tied into the electric grid because of the various shortcomings in PV systems, and largescale utility systems require enormous tracts of land while providing only modest energy output.

CONCENTRATED SOLAR

PV technology directly converts solar energy into electrical energy through panels. Concentrated solar, on the other hand, uses parabolic mirrors, or similar technology, to focus solar energy into heating a fluid that then goes through a heat transfer process that is not unlike a traditional gas- or coal-fired steam electric turbine. In fact, many concentrated solar facilities will have natural gas-based generation as a back up or supplement. Concentrated solar installations tend to cost around two-thirds, or less, compared to the cost of a PV installation. This is a significant step in the right direction, but still very expensive power compared to traditional base load resources.

Nevada Solar One boasts one of the newest and largest concentrated solar facilities in the United States. This project delivers 64 MW of capacity

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[15] California Energy Markets, July 2, 2010.

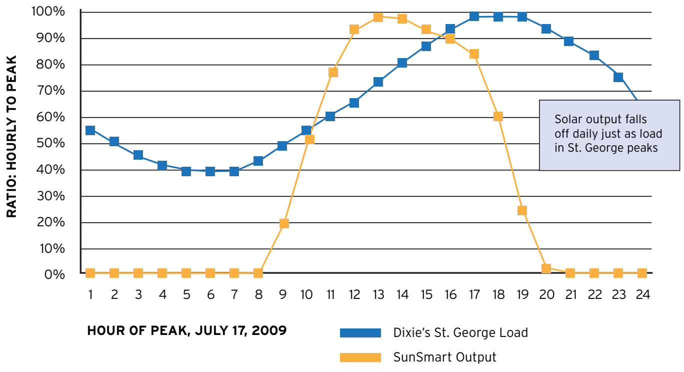
[16] Based on the United States' coal-fired electrical generation of 2 billion MWh per year compared to Nellis' advertised annual output of 30,000 MWh. (2 billion / 30,000) / 12 months = 5,555 years.)

and approximately 134,000 MWh of energy. Gilbert Cohen, vice president of Engineering and Operations for Solargenix, said the project installation costs are somewhere in the range of $220 to 250 million. At that price, the power is more expensive than most wind power projects, but less expensive than typical PV projects. Energy from Nevada Solar One currently cost about 13 cents per kWh.[17] The developers of Nevada Solar One believe that a target of seven cents per kWh will be achievable in the future. At that price, concentrated solar would be fairly competitive as a viable, utility grade source of power.

SOLAR DEMAND VERSUS SYSTEM PEAK

A desirable attribute of solar energy is that it is produced during hours that roughly coincide with utility system peak loads. The coincidence is not perfect, but much better than wind. Following is an actual output profile of the 100 kW SunSmart project in St. George Utah.

ST. GEORGE CITY PEAK LOAD VS. SUNSMART'S OUTPUT:



The solar output shown in yellow tends to ramp up around 10 a.m. and then ramps down in the afternoon. The shape of the output curve is very predictable, barring the unpredictable effects of intermittent cloud cover. If solar panels are spread over a wide enough area, some of the cloud cover effect can be mitigated through diversity. However, the peak solar output tends to occur prior to the time of peak load for the utility shown in blue.

Based on the graphic, about 30 to 60 percent of the solar peak was useful during the peak hour. The fit between solar-produced energy and the demand curve for electricity usage is not as close as one might expect, and certainly not as good as one would hope. This can be significantly mitigated and improved if the solar project is combined with an energy storage facility, which would obviously add to the cost.

A similar result can be demonstrated across a much larger system. Last year, CAISO reported peak demand of 45,994 MW, which occurred at 3:00 p.m. on September 3, 2009. In that hour, even though California had installed PV capacity of nearly 250 MW, that was operational and online on the state's electric grid, only about 144 MW of solar energy was being generated to help serve the peak demand, or around 58 percent of the amount that the installed solar units were capable of producing.

By contrast, as of noon that same day, the PV solar units reached their maximum capacity factor at about 72 percent, which is the typical peak performance for the California PV system. What happened to all the rest of the capacity that should have been available? The report submitted to the California Utility Commission indicates that dust and dirt affect the performance of PV panels in the afternoon, and panels do not perform at top efficiency above temperatures of 68°F, which is commonly exceeded on summer afternoons in California.[18] And frankly, the sun is on its way down in the afternoon at the same time electric loads are picking up.

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[17] Jesse Broehl, Renewable Energy World.Com, *A New Chapter Begins for Concentrated Solar Power,* (2006), www.renewableenergyworld.com/rea/news/article/2006/02/a-new-chapter-begins-for-concentrated-solar-power-43336.

[18] California Energy Markets, July 2, 2010.

It is also ironic that summer PV solar output is not markedly better than spring or fall. While summer days are longer, they are also hotter and unfortunately solar panels lose efficiency in the heat.

THE VALUE OF SOLAR POWER—DEMAND VERSUS ENERGY

Solar power can be used to offset the fuel costs of traditional power plants, but it is expensive. For traditional production, energy-only costs tend to be in the range of 1.5 to 4 cents per kWh, hence, most utilities would view the 13.5 cent cost of solar energy as quite expensive—coming with a premium of 200 to 800 percent in terms of raw energy value.

Solar is generally the most expensive form of renewable energy.

THE SOLAR SYNOPSIS

Solar energy, while costly, is grid friendly. Indeed the general rate of change of the solar output curve is as calm as a morning sunrise or as smooth as an evening sunset. The peak solar output precedes a typical system demand peak, with only about 60 percent of the solar maximum still available at the time of actual utility demand peak. Compared to wind, the solar output shows a significant advantage as a fairly reliable peak-period supplier, especially when combined with a reasonable investment in complementary storage and/or backup resources.

The major hurdle with solar is cost. It is generally the most expensive form of renewable energy. However, significant strides are being made to bring down the cost and increase the reliability. Solar is not "in the money" yet, but with continued support from taxpayer subsidies and incentives, solar is likely to be a capable and significant resource of the future, at least in some regions of the country.

GREEN JOBS—WILL THEY MATERIALIZE AS PROMISED?

A claim of "five million new green jobs" has become something of a national mantra.[19] This promise of millions of green jobs is not supported by extensive studies performed by the DOE or NREL, at least in terms of the electric energy sector. In its highly developed JEDI model, the DOE calculates only 121,417 gross number of direct jobs, or 2.4 percent of the five million jobs promised. What a disappointment!

Additionally, this level of direct job creation—121,417 jobs—will not be achieved until 2030. JEDI also does not account for net job losses in the coal, oil, and gas sectors of the economy for each new job gained in the renewable sector. When wind jobs are compared head-to-head with coal-fired electric alternatives, the gross job gains in wind are more than offset by net job losses in coal.

Every new wind-related job comes at the cost of 1.5 to 2.7 coal-related jobs.[20]

The JEDI model also fails to account for the dampening effect on the economy of significantly higher power costs associated with wind power, as well as carbon tax programs. Yet it is quite clear that the country depends on low-cost, abundant energy to power its economy.

With all factors considered, a green mandate in the electric sector will not meet the goal of five million new jobs and, in fact, will likely result in net job losses.

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[19] Barack Obama and Joe Biden, "New Energy for America," (August 3, 2008), www.barackobama.com/pdf/factsheet_energy_ speech_080308.pdf.

[20] From testimony given by Kimball Rasmussen to the U.S. House and Senate Western Caucus on Energy Issues, July 30, 2009, based on the "Jobs and Economic Development Impacts Model" developed by the U.S. Department of Energy, in a side-by-side comparison of wind and coal, and published by Rasmussen in *A Rational Look at Green Jobs and the Implications for the U.S. Power Sector*, (September 2009).

THE RENEWABLE PORTFOLIO STANDARD (RPS) OR HOW 20 PERCENT CAN EASILY BECOME 100 PERCENT OF A UTILITY'S PLANT INVESTMENT

There is significant political pressure for states and/or the Federal Government to adopt a Renewable Portfolio Standard (RPS) which mandates utilities to acquire a portion of their energy requirements—typically 20 percent—from renewable sources such as wind, solar, biomass, and geothermal energy. Note that the so-called RPS, or RES (Renewable Energy Standard) as it is sometimes called, is generally spun as a "standard." In reality it is not just a standard, but a legally enforceable "mandate." RPS mandates are proposed across the board, even when some utilities have relatively little access to renewable energy, or only very expensive alternative generation sources available. The RPS mandate too often trumps market-based choices.

While a 20 percent RPS may sound modest, the resulting effect on the rate base can be much larger than one might think. There are two underlying facts that support the materiality of this concern. First, renewable resources have an intermittent output that renders low capacity factors—typically in the range of 20 percent to 40 percent of full name-plate rating for wind, and 15 percent to 25 percent for solar. Coal, gas, and nuclear power, on the other hand, will typically achieve capacity factors of 70 percent to 95 percent. Renewable energy projects tend to produce about one-half to one-third the energy of comparable name-plate quantities of coal, gas and nuclear power. So a 20 percent "energy" RPS really looks more like a 50 percent RPS in terms of the actual installed name-plate quantity that is required to meet the energy mandate.

The second area of pricing concern has to do with the installed cost of new, renewable resources versus the depreciated book value of existing resources. The installed cost of new wind generation, according to the DOE JEDI default values discussed earlier, is about $2,300 per kW. The installed cost of solar capacity is in the range of $5,000 to $8,000 per kW. Compare this to a "Production Plant" depreciated book value of about $700 per kW for a typical utility.[21] The new renewable "capacity" comes at an installed cost that is triple, quadruple, or even more than the existing "Production Plant" rate base of a utility.

Now combine these two effects: the 20 percent RPS which acts like 50 percent in terms of installed name-plate capacity, and the "new versus used" differential of installed cost of $2,300 versus $700. These two effects, when combined, can easily more than double the dollars of rate base for installed generation of a utility. This will necessarily result in significant rate increases—much more than suggested at face value by a 20 percent RPS.

It is worth noting that this evaluation does not include the substantial expense and challenges of building additional transmission that almost inevitably would have to be built to interconnect the new RPS portfolio. Nor does it include the "shadow grid" of gas resources that would be required to "firm" the supply of our new book of intermittent resources. It also does not include any planning or operating reserve margins that would be imposed on the utility. And finally, it does not include any margin for underperformance of the RPS portfolio. If the utility, in good faith, acquires a block of wind and solar resources, but for unforeseeable reasons these resources underperform, what sort of liability or penalties would the utility face for its failure to meet the RPS mandate? All of these questions need to be addressed.

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[21] The "Total Production Plant Investment, $/kW" reported in the G&T Trend 2009 by the National Rural Utilities Cooperative Finance Corporation is $697 per kW, averaged across all Generation & Transmission Cooperatives in the United States. This represents a sample of 51,885 MW of generation. Many of the units in the sample are jointly owned with investor-owned utilities.

Proponents of the RPS standard will invariably appeal to the jobs creation aspect of such a program. But as previously discussed, the jobs impact will be net negative—we can expect to lose 1.5 to 2.7 traditional jobs for every new "green" job created. In addition the local and general economy will feel the negative impacts in response to the price increases that will result from the RPS implementation.

An RPS of 20 percent may sound harmless or benign, but just the opposite will likely occur. A Renewable Portfolio Standard of 20 percent can easily compel a utility to more than double its rate-base investment in generating plant with only modest increases in capacity and energy production.

Inevitably, rates will increase for the end consumer. Yet, we continue to march forward with empty promises of economic expansion, job growth and a new era of green prosperity while concurrently ignoring the realities of higher energy costs forced upon consumers due to renewable energy mandates, and net job losses. This does not make sense.

Furthermore, not all RPS mandates are equal. As if 20 percent were not enough, some states have legislated even more aggressive targets. Colorado has ushered in legislation requiring utilities to generate 30 percent of their electricity from renewable energy sources by 2020.[22] This requirement is the second-highest renewable energy standard in the nation and is surpassed only by California, which has laid out a goal to reach 33 percent renewable energy by 2020.[23] At a time when California is experiencing a serious corporate exodus in large part because of higher energy costs and other government mandates. It is likely that enormous deficits and higher and higher tax burdens will dampen the state's economy for the foreseeable future. For Colorado to adopt a similar scenario at this time seems like a recipe for economic disaster.

SUMMARY

Wind energy has a highly intermittent output that significantly mismatches peak demand and delivers energy largely when it is less needed during offpeak periods. Wind cannot satisfy the peak demand requirements of a utility unless it is backed up with fossil fuel plants and/or energy storage projects. This results in duplication of resources and additional costs, with little, if any, carbon mitigation. Further, wind's occasional steep increases and declines in power delivery, unless skillfully managed, put the reliability of the grid in question. The tactic of switching off excess wind supply only diminishes the already weak pattern of intermittency and adds to the per kWh cost of wind. Typically, wind resources are located far away from where the power is needed and require significant additional costs of building new transmission. Intermittency, duplication, and grid operations all significantly increase the already high cost of wind energy.

While solar power is much more grid friendly than wind, it is generally the most expensive form of renewable energy. Solar energy quasi-matches system peak load periods, but the peak solar output significantly misses actual electric system load peaks. In addition, solar facilities still produce only about 18 to 25 percent of the time. Without electricity storage, solar energy will not be able to do more than serve as a supplement to other forms of energy. It is not currently a full-scale alternative to baseload energy.

A Renewable Portfolio Standard, or mandate of 20 percent, can result in a utility-scale duplication of net investment in generating plant of 100 percent

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[22] Lynn Bartels, *Ritter Signs Bill Requiring Greater Use of Renewable Energy by 2020*, Denver Post, (March 23, 2010), www.denverpost.com/search/ci_14735606.

[23] Executive Order S-14-08, http://gov.ca.gov/executive-order/11072/.

or more. The mandate can also cause the wide variation of rate impacts, depending on availability of renewable energy projects and other utility-specific parameters.

As with other claims for renewable energy, the claim of five million new jobs is grossly overstated. The DOE methodology used in the green jobs estimate reveals only 121,417 direct jobs will result from an aggressive build out of 20 percent renewables by the year 2030. When considering all-in net effects, each new green job in the electric sector will come at the cost of 1.5 to 2.7 traditional jobs.

EYES WIDE OPEN

As our nation embarks on the path of a green policy, we should recognize the U.S. electric sector, built over the last 100 years, has been successfully engineered for reliable low-cost energy. It has served us exceedingly well and has made a major contribution to our standard of living in virtually all areas of modern life.

As we consider how best to transition to a greener energy economy, we must move forward cautiously and recognize that such a transition will take years, if not decades. After all, how can we expect to reinvent in a few years what took a hundred years to build in the first place?

Renewable energy can be helpful to meet improved environmental targets, but we the people must recognize that the environmental benefits will come at a high price: an increase in electric rates, an increase in capital requirements, a challenge to grid reliability and net job losses. Only with our eyes wide open can we strike an informed balance and adopt a thoughtful energy policy without hype and pretense.