Wind Energy Does Little to Reduce CO2 Emissions by Willem Post; 4 September 2011

Here is an important article regarding wind energy doing little to reduce CO_2 emissions. The article summarizes two studies using measured, real-time grid operations data; the first one is of the Colorado and Texas grids and the second one is of the Irish grid, all with significant wind energy penetration. The studies show adding wind energy to these grids does little to reduce CO_2 emissions.

For some years wind turbines were presented to the public as renewable energy producers that would reduce the CO_2 emissions from fossil plants, because less fossil fuels would be burnt, which would make the US less dependent on energy imports from unstable regions, even though about 1% of US electric energy is from oil, even less from imported oil.

Wind turbine vendors, project developers, financiers managing tax shelters, trade organizations, etc., popularized wind energy as saving the planet from global warming with PR campaigns that claimed there would be significant CO_2 reductions/kWh, that capital costs/MW would decrease, and that wind energy costs/kWh would be at grid parity in the near future.

Apparently many people, including many legislators and the US president, believed it all, because a fear-driven, ill-advised, heavily-subsidized, multibillion dollar build-out of wind turbine facilities occurred.

End December 2010 installed US wind turbine capacity: 41,400 MW. The top 5 states: Texas 10,085 MW; Iowa 3,675 MW; California 3,177 MW; Minnesota 2,192 MW; Washington 2,104 MW.

End December 2010 estimated direct capital cost: about $70 billion for erecting the wind turbines, plus the direct capital cost of grid modifications, plus the cost of accommodating wind energy to the grid, plus the cost to the government of capital grants and various subsidies, including the taxes not collected due to various write-offs from taxable incomes (tax sheltering), plus the cost of above-market feed in tariffs and/or production tax credits.

The net result of the wind turbine buildout during the past 10 years is a 2010 wind energy production of 94,650 GWh, or about 2.3% of total US production, and higher electric rates for consumers and CO_2 reductions.
http://en.wikipedia.org/wiki/Wind_power_in_the_United_States

It may take another 10 years to install the next 40,000 MW of wind turbines and have 4.6% wind energy. However, there may not be sufficient capital due to the likely shrinking of future subsidies, because the US economic, fiscal and monetary conditions will be dismal for years to come.

The worst of it is that these funds were diverted from increased energy efficiency measures that would have significantly reduced CO_2 emissions without the various controversies associated with wind turbine facilities. Energy efficiency provides the quickest and biggest "bang for the buck", AND it is invisible, AND it does not destroy the environment, such as pristine ridge lines in New England, AND it would more effectively reduce CO_2, AND it would do it without public resistance and controversy.

Skepticism About CO2 Reductions: After skepticism was expressed by power systems engineers in the US, Canada, the UK, Denmark, the Netherlands, Australia, etc., about claims regarding CO_2 reductions/kWh due to wind energy for at least the past 10 years, several studies were performed which have accurately quantified the CO_2 reductions/kWh based on measured operations data of the grids of Colorado, Texas and Ireland, all with significant wind energy penetration.

ERCOT of Texas, Public Service of Colorado, and EirGrid of Ireland are three grid operators that publish 1/4-hour or 1-hour operations data of relevant parameters that can be used to analyze the effects of wind energy on the operations of the other plants (coal, nuclear, hydro, gas) on their grids.

For many years, numerous studies, mostly performed by proponents of wind energy, such as the one below, used simulations, modeling, statistical methods and assumptions regarding grid operations, dispatch of generators, wind energy variation, wind energy forecasting, etc., instead of using measured, real-time, 1/4-hour operations data sets.

Denny & O'Malley "Wind generation, power system operation, and emissions reduction" Feb. 2006
http://ee.ucd.ie/erc/member/2005transdenny.pdf

These studies reached incorrect conclusions, because of the assumptions made and methodologies used. They should have been based on measured real-time, 1/4-hour operations data sets, but they were unavailable at that time. It is unfortunate those studies were used to justify worldwide investments in wind turbines totaling several hundred billion dollars during the past 15 years.

There may be a deliberate withholding of 1/4-hour data sets by utilities and wind turbine owners to make it difficult for energy system analysts to accurately determine the wind energy impacts on the grid, CO_2 emissions/kWh and fuel consumption/kWh. That sort of fine-grained data is essential to perform accurate analyses of wind energy impacts.

For example: Public Service of Colorado records 1/4-hour wind energy production but refuses to release the data; it is citing "trade secrets". These wind turbine facilities were built with significant public subsidies; should not the public know whether or not its money is invested in the most effective manner to reduce CO_2? The $500 million Solyndra fiasco comes to mind.

Balancing Wind Energy: Wind energy balancing plants, usually consisting of quick-ramping gas turbines or hydro plants, are required to ramp down when wind energy surges and ramp up when wind energy ebbs at least 100 to 200 times per day to ensure a near-perfect balance of supply and demand is maintained on the grid. The balance needs to be maintained to minimize excessive frequency and voltage deviations from target values to avoid brownouts, blackouts and overloads.

The balancing plants are required to operate at a percent of rated output to be able to ramp up and down. Such operation is very inefficient for gas turbines and ramping up and down at a percent of rated output is even less efficient. This results in significantly increased Btus/kWh and increased CO_2 and NO_x emissions/kWh and SO_x emissions/kWh by coal plants.

When coal plants are used as wind energy balancing plants, as is the case with Colorado and Texas, the rapid up and down ramping at part-load causes their combustion systems (designed for optimum, steady operation near rated output) to become unstable, and because the up and down ramping causes the chemical composition and quantity of the flue gas to vary, the scrubber-based air pollution control systems (designed for optimum, steady operation near rated output) also become unstable as the required stoichiometric chemical ratios cannot be maintained in a timely manner.
http://theenergycollective.com/willem-post/57905/wind-power-and-co2-emissions

Gas turbine Heat Rates: The gas turbines of the balancing facility, most efficient near rated output, would have to operate at reduced outputs to be able to immediately vary their outputs to accommodate all variations of wind energy, including unpredictable, sudden, large variations of wind energy. Gas turbine heat rates, Btu/kWh, and CO_2 emissions, lb of CO_2/kWh, increase because of increased operation below rated output. Gas turbines are rarely operated below 40% of rated output, because of much degraded heat rates.

For example: at 80, 50 and 20 percent of rated output, the heat rates are equal to the rated heat rate divided by 0.95, 0.85 and 0.55, respectively, or a heat rate degradation of $(1/0.95 - 1) \times 100 = 5.3\%$, 17.6%, and 81.8% respectively. This is for steady operation at a percentage of rated output. If the balancing facility is operating at a percentage of rated output AND irregularly and rapidly ramping up and down, the heat rate degradation increases further.

For example: If a gas turbine rapidly cycles from 60% down to 40% and back up to 60%, 5 minutes down at 15 MW/min, 5 minutes up at 15 MW/min, its roundtrip fuel consumption and CO_2 emissions are about 20% greater than if it had operated at 100% for the same 10 minutes. The average output was 50% which would have a steady heat rate degradation of about 17.6%, plus a rapid-ramping degradation of, say 2 - 3%, for a total of about 19.6 - 20.6 percent.

Existing gas turbines are designed to perform a few cycles per day. Cycling at least a hundred times per day to balance wind energy will significantly increase wear and tear, i.e., increase (owning + O&M) costs. Who should pay these additional costs? Rate payers or wind turbine owners?

http://www.ge-mcs.com/download/bently-nevada-software/1q05_performancemonitoring.pdf
http://www.etsap.org/E-techDS/PDF/E02-gas_fired_power-GS-AD-gct.pdf

For example: a car driven on a level road at a steady speed of 40 mph has a mileage of, say 26 mpg. The same car driven on a level road at irregular and rapidly changing speeds that average 40 mph has a mileage of, say 22 mpg. The mileage degradation due to the speed changes would be $(26-22)/26 \times 100\% = 15\%$. A car's best mileage usually is at 55 mph, at a steady speed, on a smooth and level road; it is the oft-quoted EPA highway mileage.

STUDY OF COLORADO AND TEXAS WIND ENERGY

The Bentek study of the Colorado and Texas grids, based on measured hourly (in case of Colorado) and 1/4-hourly (in case of Texas) power plant operations data of fuel consumption and CO_2, NO_x and SO_x emissions, proved that wind energy on the grid needs to be:

- balanced with energy from other plants, preferably quick-ramping CCGTs and OCGTs, to ensure grid stability and,
- that this balancing produces more CO_2/kWh, more NO_x/kWh, and more SO_x/kWh (from coal plants on the grid), and uses more fuel/kWh with wind energy on the grid than without.

Colorado

Public Service of Colorado, PSCO, owns insufficient gas-fired CCGT capacity for balancing wind energy on its grid. As a result PSCO is attempting to use its own coal plants for balancing for which they were not designed and for which they are highly unsuitable. The results have been significantly increased pollution and CO_2, NOx and SOx emissions/kWh.

The heat rate of a coal plant operated near rated output it is about 10,500 Btu/kWh for power delivered to the grid. It is lowest near rated output and highest at very low outputs. If a plant is rapidly ramped up and down in part-load-ramping mode, its heat rate rises. See Pages 26, 28, 35, 41 of the Bentek study.

On Page 28, the top graph covering all PSCO coal plants shows small heat rate changes with wind power outputs during 2006. The bottom graph shows greater heat rate changes with wind power outputs during 2008, because during the 2006-2008 period 775 MW of wind facilities was added. For the individual PSCO plants doing most of the balancing, the heat rate changes are much higher.

On Page 26, during a coal plant ramp down of 30% from a steady operating state to comply with the state must-take mandate, the heat rate rose at much as 38%.

On Page 35, during coal and gas plant ramp downs, the Area Control Error, ACE, shows significant instability when wind power output increased from 200 to 800 MW in 3.5 hours and decreased from 800 MW to 200 MW during the next 1.5 hours. The design ramp rates, MW per minute, of some plants were exceeded.

On Page 41, during coal plant balancing across the PSCO system due to a wind event, emissions, reported to the EPA for every hour, showed increased emissions of 70,141 pounds of SOx (23% of total PSCO coal emissions); 72,658 pounds of NOx (27%) and 1,297 tons of CO_2 (2%) than if the wind event had been absent.

Those increases of CO, CO_2, NOx, SOx and particulate per kWh are due to instabilities of the combustion process during balancing; the combustion process can ramp up and down, but slowly. As the varying concentration of the constituents in the flue gases enter the air quality control system, it cannot vary its chemical stoichiometric ratios quickly enough to remove the SOx below EPA-required values. These instabilities persist well beyond each significant wind event.

PSCO refuses to release 1/4-hourly wind energy data of privately-owned wind turbine facilities, because it is a "proprietary trade secret". Such information is critical for any accurate analysis and comparison of alternatives to reduce such CO_2 emissions.

PSCO deliberately withholding such information is inexcusable and harms progress regarding global warming. Any renewables subsidized with public funds should be subject to full disclosure to make sure public funds are not misused for projects with poor economics and poor CO_2 reduction.

Texas

The Texas grid in mostly independent from the rest of the US grids; the grid is operated by ERCOT. The grid has the following capacity mix: Gas 44,368 MW (58%), Coal 17,530 MW (23%), Wind 9,410 MW (12% - end 2009), Nuclear 5,091 MW (7%). Generation in 2009 was about 300 TWh. By fuel type: Coal 111.4 TWh, Gas CCGT 98.9 TWh, Gas OCGT 29.4 TWh, Nuclear 41.3 TWh, Wind 18.7 TWh. Summer peak of 63,400 MW is high due to air conditioning demand.

Wind provides 5 to 8 percent of the average energy generation, depending on the season. Its night contribution rises from 6% (summer) to 10% (spring). Texas capacity CF = 18.7 TWh/yr/{(9,410 + 7,118)/2) MW x 8,760 hr/yr)} = 0.258. Texas has excellent winds and should have a statewide CF of 0.30 or greater. Explanations for the low CF likely are:

- grid operator ERCOT requires significant curtailment of wind energy to stabilize the grid.
- wind turbine vendors, project developers and financiers of wind power facilities, eager to cash in on subsidies before deadlines, installed some wind turbine facilities before adequate transmission capacity was installed to transmit their wind output to urban areas.

Much of the gas-fired capacity consists of CCGTs that are owned by independent power producers, IPPs, which sell their power to utilities under power purchase agreements, PPAs. That capacity is not utility-owned and therefore not available for balancing to accommodate the output of more than 10,000 MW of wind power facilities. Instead, utilities are attempting to use coal plants for balancing for which they were not designed. The results have been significantly increased use fuel consumption, pollution and CO_2 emissions.

Unlike PSCO, ERCOT requires reporting of fuel consumption by fuel type and power generation by technology type every 15 minutes. The 2007, 2008, 2009 data shows rising amplitude and frequency of balancing operations as wind energy penetration increased. In 2009, the same coal plants were cycled up to 300 MW/cycle about 1,307 times (up from 779 in 2007) and more than 1,000 MW/cycle about 284 times (up from 63 in 2007). The only change? Increased wind energy penetration.

On Page 69: The ERCOT balancing of plants to accommodate wind energy produced results similar to the PSCO system; increased balancing resulted in significantly more SOx and NOx emissions than if wind energy had been absent. Any CO_2 emission reductions were minimal at best, due to the significantly degraded heat rates of the balancing plants. See websites.

http://docs.wind-watch.org/BENTEK-How-Less-Became-More.pdf
http://theenergycollective.com/willem-post/57905/wind-power-and-co2-emissions

STUDY OF IRISH WIND ENERGY

Ireland's Energy Generation: Ireland's total electricity production was about 26,000 GWh in 2010. Gas-fired OCGTs and CCGTs provided about 65.5%, coal 13.2%, peat 8.2%, wind 9.8%, hydro 2.5% of which 1.7%, or 442 GWh, was impounded/run-of-river hydro. Ireland imports 100% of its coal, about 90% of its gas and produces 100% of its peat.

Wind Energy: In Ireland, good wind energy months are April, May, June, November and February. On the west coast of Ireland, wind energy is greatest during summer daytimes, because of increased wind speeds as the lands warms up. The greater wind energy is cocurrent with greater daytime demands which is fortuitous. However, much of the energy needs to be transmitted to the east coast (line and transformer losses), as few people live on the west coast.

Coal/Peat: The below website shows coal/peat plants are base-loaded, i.e., not used for balancing wind energy, i.e., their CO_2 emission intensities are essentially constant.
http://ee.ucd.ie/erc/member/2005transdenny.pdf

Hydro: Ireland has many small hydro plants and a few larger plants, such as the Ardnacrusha power plant, built 1929, capacity 85 MW, output 332 GWh/yr, Cathaleens Falls 45 MW, Poulaphuca 30 MW and Inniscarra 19 MW. The below website shows hydro plant outputs follow daily demand, i.e., not used for balancing wind energy.

http://www.dconnolly.net/files/Modeling%20the%20Irish%20Energy-System%20-%20Data%20Required%20for%20the%20EnergyPLAN%20Tool.pdf

The almost 40-year old, 292 MW Turlough Hill pumped-storage facility pumps to add to its upper reservoir during low nighttime demand and produces energy during peak daytime demand. Its net effect is to "flatten" the daily demand profile. It is not used for balancing wind energy. Currently, it operates at about 50% of capacity, because of ongoing modifications.

Combined-Heat-Power: Ireland has about 195 units totaling about 282 MW of operating combined heat power, CHP, plants of which a few larger units totaling 248 MW is dedicated to industrial processes, such as food, manufacturing and pharmaceutical. The output of these units is independent of the weather.

Electricity generation was 6.3% of Ireland's total energy generation in 2008 (latest data).
Only 11 CHP units (mostly associated with industrial processes) exported 1,013 GWh to the grid in 2008, or 1,013/260 = 3.9% of total production. Eirgrid includes the output and CO_2/kWh of these units in its 1/4-hour data sets.

Heat generation was 4% of Ireland's total heat generation in 2008 (latest data).

The above indicates CHP operations have no material impact on the 1/4-hour CO_2/kWh posted by EirGrid.
http://www.seai.ie/Publications/Statistics_Publications/EPSSU_Publications/CHP%20in%20Ireland%202010%20Report.pdf

OCGTs/CCGTs: A part of the OCGT/CCGT capacity serves base-load, follows daily demand, provides peaking power and performs voltage and frequency regulation. It also performs wind energy balancing, if it has sufficient spare ramping range to ramp down with smaller wind energy surges and ramp up with smaller wind energy ebbs.

Because larger wind energy surges and ebbs are unpredictable, additional OCGT/CCGT capacity needs to be in spinning and part-load-ramping mode for balancing wind energy; the greater the wind energy, the greater the additional balancing capacity.

Because of much degraded heat rates, gas turbines are rarely operated below 40% of their rated output which limits their ramping range from 40 to 100 percent.
http://theenergycollective.com/willem-post/57905/wind-power-and-co2-emissions

Who should pay for the balancing (owning + O&M) costs? Rate payers or wind turbine owners?

The Udo Study: A new report by Dr. Fred Udo, a Dutch engineer, describes his analysis of the CO_2 emissions of the Irish electric grid, managed by EirGrid, which posts on its website 1/4-hour operations data of total electricity demand, wind energy and CO_2 emissions on the Irish grid. Analysis of the data of April 2011 proves wind energy reduces the CO_2 emission intensity, gram/kWh, by just a few percent. April 2011 was selected because the hydro contribution was minimal.

The results of the analysis of the Eirgrid data sets shows the following:

During April 2011, 12% wind energy reduces the grid's CO_2 intensity, gram CO_2/kWh, by 4%.
During April 1st and 2nd, 28% reduces it by 1%.
During April 3rd and 4th, 34% reduces it by 6%.
During April 4th, 5th and 6th, 30% reduces it by 3%.

The above reductions are not anywhere near to what is claimed by the PR of wind energy proponents.

The above variations of the CO_2 percentages are largely due to the heat rates, Btu/kWh, of the combination of CCGTs and OCGTs selected by the grid operator during wind energy balancing. See website.

Increased CO2/kWh With Increased Wind Energy Penetration: The fit lines of the scatter diagrams of CO_2 intensity, gram/kWh, versus wind energy penetration, %, show increasing CO_2/kWh as wind energy penetration increases. Where the fit line intersects the Y-axis is the lowest CO_2/kWh, i.e., no wind energy.

This appears entirely reasonable to power system engineers who know the more their power generators are operated at part load, and the more they are ramped up and down at part load, the less efficient they become and the less efficient the whole grid becomes, i.e. increased owning and O&M costs, increased electric rates.

Greater wind energy penetration produces greater up and down ramping amplitudes of wind energy to be compensated for by balancing plants, and more balancing plant capacity is required to be in part-load-ramping mode, which increases their CO_2 emissions/kWh.

Just as a car, if operated at 20 mph, then accelerated to 50 mph and back down again a few hundred times during a 24-hour trip would use more gas and pollute more, so would the balancing CCGTs and OCGTs. However, gas turbines have even greater degradations of heat rates, Btu/kWh, when operating in part-load-ramping mode than gasoline engines. The extra fuel consumed and CO_2 emitted by the gas turbines are so much that they mostly offset the fuel savings and CO_2 reduction due to wind, according to Udo analysis of the EirGrid data sets posted on its website.

Below is the URL of the Dr. Fred Udo report.

http://www.clepair.net/IerlandUdo.html

Note: Paste this URL in the left field of your browser window to access the site.

How EirGrid Calculates CO2 Emissions: The following is a direct quote from the site of EirGrid:

"EirGrid, with the support of the Sustainable Energy Authority of Ireland, has developed together the following methodology for calculating CO2 Emissions.

The rate of carbon emissions is calculated in real time by using the generators MW output, the individual heat rate curves for each power station and the calorific values for each type of fuel used.

The heat rate curves are used to determine the efficiency at which a generator burns fuel at any given time.

The fuel calorific values are then used to calculate the rate of carbon emissions for the fuel being burned by the generator"

Grid operators know the heat rate curves of the plants on their grids which were obtained by testing. They need to know this for economic dispatch.

Eirgrid takes the percent of rated output each plant is operated at and multiplies it by the heat rate for that output percentage (from the above mentioned heat rate curve) to calculate the fuel consumption/kWh and CO_2 emissions/kWh every 1/4 hour. It posts the grid CO_2 intensity (CO_2 emissions of all plants/total kWh produced by all plants) as gram CO_2/kWh on its website every 1/4 hour.

By plotting the CO_2/kWh data vs wind energy percentages, also posted every 1/4 hour, on scatter diagrams for a period, say 2 days (192 points), as shown in Dr. Udo's article, and fitting lines to the data one can make calculations and draw conclusions.

The key difference with all prior studies is that Dr. Udo's study is not based on modeling, assumptions, forecasts, statistics, etc., but on measured data.

What EirGrid does not take into account in the above calculation method is the heat rate degradation due to ramping down the fossil-fired plants with wind energy surges and ramping up with wind energy ebbs; i.e., the grid CO_2 intensity posted on the EirGrid website is understated, i.e., the above small reductions of CO_2/kWh will likely disappear, or become increases.

This is devastating news for wind energy proponents who have been claiming more and more wind reduces CO_2/kWh more and more, exactly opposite of the results of Dr. Fred Udo's analysis of the EirGrid real time, 1/4-hour operations data.

Wind proponents made their claims without any substantiation based on 1/4-hour operations data. They could not have, because such data has been available only during the past 3 to 4 years.

The above results have very significant policy implications regarding the continued promotion of wind energy through various subsidizing schemes.

The above is only part of the story. The other part is capital costs.

Exporting Wind Energy to the UK: Assume the future installation of 1,333 onshore wind turbines, each 3 MW, 466.5 ft tall with 373 ft rotors, for a total of 4,000 MW mostly in western Ireland which has greater wind speeds. Capital cost about $8 billion, plus capital costs for transmission systems.

At low wind speeds (less than 7.5 mph) and at very high wind speeds there is no wind energy (occurs about 10 -15 percent of the time).
At high wind speeds the connected wind turbines may have an output up to about 80% of wind turbine rated capacity (occurs about 2 to 3 percent of the time); it can be kept below 80% by automatic curtailment, i.e., feathering the rotor blades which is much resisted by wind turbine owners because it reduces their incomes.

The design capacity of the HVDC lines would need to be about 4,000 MW x 0.8 = 3,200 MW. This would require at least (4) 200 ft wide corridors each with 800 MW HVDC lines on thousands of 80 to 135 ft tall steel structures from Ireland's western areas to the Irish Sea, plus HVDC cables under the Irish Sea, plus HVDC lines on steel structures to UK population centers. The balancing function would be performed by the UK generating plants for a fee/MWh.

The exported wind energy would be 4,000 MW x 8,760 hr/yr x capacity factor 0.30 = 10,512,000 MWh/yr. The energy transmission of a conventional HVDC line is at an average of about 60% of its capacity. Thus the owning and O&M costs for dedicated wind energy transmission is about 2 times greater/MWh than for conventional transmission.

Exporting Only Excess Wind Energy to the UK: If Ireland were to export only its excess wind energy to the UK via HVDC lines, Ireland would be selling nighttime excess wind energy to the UK when grid prices are minimal and the UK would require a fee/MWh for the balancing operations. The transmission lines would have a very low utilization factor, i.e., high (owning + O&M) costs/MWh. A profitable transaction? See example.

Example: Denmark has been "selling", i.e., more or less giving away, its excess wind energy to Norway and Sweden for balancing by their hydro plants for a fee/MWh for about 20 years. Denmark has found it to be an unprofitable transaction, if the (owning + O&M) costs, balancing fees and line losses are accounted for. One reason the Danish household electric rates are the highest in Europe. France has the lowest.

Storing Excess Wind Energy: Instead of exporting excess wind energy to the UK, Ireland can use the Turlough Hill, 292 MW, pumped storage hydro plant to store excess wind energy by pumping water from the lower reservoir into the upper reservoir.

The pump capacity is 272.8 MW, pump efficiency 79.9%, turbine capacity 292 MW, head 285.75 m, volume of water in upper reservoir 2.3 million m3, hydro turbine efficiency 79.9%, energy storage capacity 1,431 MWh.

For example: If 1,000 MWh of excess wind energy is generated by various wind turbine facilities and collected and transmitted to the pumps, about 900 MWh arrives at the pumps (after wind turbine-to-pump line and transformer losses), about 720 MWh arrives in the upper reservoir (after pumping losses), about 576 MWh leaves the hydro plant (after hydro turbine losses, ignoring evaporation losses, a factor in Spain), about 518 MWh arrives at the consumers (after line and transformer losses); an example of "detouring" excess wind energy to pumped storage.

Wind energy storage is not very efficient and probably not cost effective, because the pumped storage hydro plants are expensive to build, and because of various losses, as shown above.

http://www.dconnolly.net/files/Modeling%20the%20Irish%20Energy-System%20-%20Data%20Required%20for%20the%20EnergyPLAN%20Tool.pdf

CAPITAL COSTS OF WIND ENERGY

The total capital cost of the wind turbine facilities (average onshore about $2,000/kW, average offshore about $4,200/kW), PLUS the capital cost of the new quick-ramping balancing plants required at higher wind energy penetrations (many grids, such as Colorado and Texas, do not have enough of such capacity), PLUS the capital cost of extensive grid modifications, including new HVDC lines on 80 to 135 foot-tall steel structures to transmit the wind energy from windy areas to population centers is about 2 to 3 times greater than the total capital cost of a capacity of 60% efficient CCGTs (about $1,250/kW) that would produce, in base-loaded mode, near rated output, the same quantity of energy, use about the same quantity of fuel/kWh and emit about the same quantity of CO2/kWh than the above (wind energy + balancing energy) combination, but do it at a much lower cost/kWh (see next paragraph), AND at minimal transmission system changes (the new CCGT plants would be located at or near the same sites as existing coal plants), AND at minimal impacts on quality of life (noise and infrasound, visuals, social controversy, psychological), property values and the environment.
http://theenergycollective.com/willem-post/47519/base-power-alternatives-replace-base-loaded-coal-plants

Capital costs of RECENT wind turbine facilities are about $1,800 to 2,000/kW in the Great Plains and about $2,500 to 2,700/kW on 2,000 ft high ridge lines in New England.
http://theenergycollective.com/willem-post/61774/wind-energy-expensive

Example: Green Mountain Power is building the 63 MW Kingdom Community Wind facility (21 Vestas @ 3 MW each, 466.5 ft tall, 373 ft diameter rotors) on the Lowell Mountain ridge line in Vermont at an estimated cost of about $2,500/kW. GMP estimates the levelized wind energy cost at 9.2 cent/kWh with subsidies equivalent to about 50% of the capital cost, about 15 cent/kWh without subsidies. New England grid average for utilities is about 5.5 cent/kWh.
http://theenergycollective.com/willem-post/61309/lowell-mountain-wind-turbine-facility-vermont

Vermonters will have higher electric rates and lower living standards with wind energy than without; closing the Vermont Yankee nuclear plant will further increase electric rates, lower living standards and eliminate jobs.

Wind Energy Transmission Cost: Owners of wind turbines do not want to pay for HVDC transmission facilities to transmit their wind energy from windy areas to population centers. They say the US grid needs to be upgraded anyway, why have us pay? Or, they say the US has to move to smart grids and supply and demand management anyway, why have us pay? Or, they say the US has to move to renewable energy which implies reorganizing the US electric grids, why have us pay?

They also do not want to pay for:

- wind energy accommodation fees to compensate for the costs of increased wear and tear of existing generators due to the 24/7/365 up/down ramping
- any new quick-ramping CCGTs and OCGTs required for balancing wind energy
- increased grid management efforts
- weather forecasting system (owning + O&M) costs.

T. Boone Pickens: The main reason he got out of wind energy is because ERCOT, the Texas grid operator, told him to pay part of the cost of the HVDC lines to get his wind energy from his 4,000 MW of wind turbines from the Panhandle in the west of Texas to the population centers in the east of Texas, about 800 miles.

At low windspeeds (less than 7.5 mph) and very high wind speeds wind energy is absent (occurs about 10 -15 percent of the time).
At high wind speeds the connected wind turbines may have an output of 80% of wind turbine rated capacity (occurs about 2 to 3 percent of the time); it can be kept below 80% by automatic curtailment, i.e., feathering the rotor blades.

If the maximum output of the Pickens turbines is assumed at 3,200 MW and if 4 corridors are used, each 200 ft wide, each at 800 MW capacity, over 3,200 miles of corridors would require about 15,000 steel structures, each 80 to 135 ft tall, to carry the HVDC lines. The utilization would be at about 30% of capacity. No wonder Pickens got out of wind energy.

The wind energy transmitted would be 4,000 MW x 8,760 hr/yr x capacity factor 0.30 = 10,512,000 MWh/yr. The energy transmission of a conventional HVDC line is at an average of about 60% of its capacity. Thus the (owning + O&M) costs for dedicated wind energy transmission is about 2 times greater/MWh than for conventional transmission. This ratio can be reduced by overbuilding wind turbine capacity by about 20 to 30 percent and using wind energy curtailment to prevent transmission system overload. The economics of overbuilding wind turbines is feasible only in very high capacity factor areas, 0.40 and greater, not too far removed from population centers.
http://nwenergy.adhostclient.com/wp-content/uploads/OlsenWind-Trans.pdf

NREL Remedy for a Lack of Wind Energy: This above lack of wind energy 10 to 15 percent of the time means wind turbines do not replace any conventional generating units. All the units that would be needed WITHOUT wind turbines, would also be needed WITH wind turbines. Some of the conventional units would have less production with wind energy on the grid, but without wind energy, the production of all the conventional units would be needed to supply the daily demand.

However, there are some (mostly wind turbine vendors, project developers and financiers managing tax shelters, trade organizations, NRELs, etc.) who say with smart grids, supply/demand management, building wind turbines everywhere there is wind, and connecting all of them with a national HVDC overlay grid (similar to the US Interstate Highway System overlaying state and local roads) there will be little or no need for wind energy balancing because the system will be self-balancing, i.e., smart, and that there will always be wind energy no matter what the weather conditions in any geographical area. Several National Renewable Energy Laboratories have made studies of this scheme, such as EWITS.

The estimated capital cost of this scheme would be about $413 billion for wind turbines (400,000 MW/3 MW each) x (0.5 x $4,200,000/MW offshore + 0.5 x $2,000,000/MW onshore) + $83 billion for a 20% overbuild of wind turbines to better utilize the HVDC overlay grid + $200 billion for cross-country HVDC transmission systems + $250 billion for 200,000 MW of new OCGTs and CCGTs for balancing = $946 billion.

The scheme would provide 400,000 MW x 8,760 hr/yr x net national capacity factor 0.25 (after losses) = 876 TWh/yr, or about 876/4,000 x 100% = 21.9% of the current US annual consumption, less of the projected consumption.

At current wind turbine construction rates of 6,000 MW/yr, it would take (400,000 - 41,400)/6,000 = 59.7 years to implement. The environmental (visual and noise) impacts of wind turbines and transmission systems would be at least 10 times greater than at present.
http://theenergycollective.com/willem-post/61774/wind-energy-expensive

Energy Cost Projections: The US Energy Information Administration projects levelized production costs (national averages, excluding subsidies) of NEW plants coming on line in 2016 as follows (2009$) :

Offshore wind $0.243/kWh, PV solar $0.211/kWh (higher in marginal solar areas, such as New England), Onshore wind $0.096/kWh (higher in marginal wind areas with greater capital and O&M costs, such as on ridge lines in New England), Conventional coal (base-loaded) $0.095/kWh, Advanced CCGT (base-loaded) $0.0631/kWh.
http://www.energytransition.msu.edu/documents/ipu_eia_electricity_generation_estimates_2011.pdf

IS WIND ENERGY GOOD ENERGY POLICY?

Within federal, state and local governments tens of thousands of people are busying themselves promoting renewables by with holding meetings and public hearings, preparing studies, writing reports, energy plans, laws, rules and regulations, monitoring projects for compliance, etc.

Outside of government wind turbine vendors (Siemens, GE, Vestas, Iberdrola, etc,), project developers/owners, financiers managing tax shelters, trade organizations, etc., are busying themselves popularizing wind energy as saving the planet from global warming with PR campaigns that claim there would be significant reductions of fossil fuel consumption and CO2 reductions/kWh, that capital costs/MW would decrease, and that wind energy costs/kWh would be at grid parity in the near future. These claims have largely not been realized.

Global Warming is a Given: A just-released report from EIA shows the actual world energy consumption data and projected consumption data for the 1990 to 2035 period. The report shows world energy consumption is estimated to increase from 505 quads in 2008 to 770 quads in 2035, a 52% increase. The biggest part of the increase is by (non-OECD nations + Asia).
http://www.eia.gov/forecasts/ieo/world.cfm

See spreadsheet associated with figure 12
World energy consumption by fuel (quadrillion Btu)

Liquids: From 173.2 in 2010 to 225.1 in 2035; 30% more
Natural gas: 116.7 to 174.7; 50% more
Coal: 149.4 to 209.1; 49% more
Nuclear: 27.6 to 51.2; 86% more
Renewables: 55.2 to 109.5; 98% more

Renewables fraction of total consumption: From 10.6% in 2010 to 15.2% in 2035
Fossil fraction of total consumption: 84.1% to 79.1%

The significant increase in projected fossil fuel consumption during the next 24 years means global warming will continue unabated, because (non-OECD + ASIA) will have energy consumption growth far outpacing the energy consumption growth of the rest of the world; i.e., global warming is a given.

The above indicates the enormous investments required to achieve the 2035 projected renewables energy production would have practically no benefit regarding global warming.

This means policy makers should shift renewables subsidies to energy efficiency which will not only reduce CO2 without controversies, but will actually do some good for household and business energy bills and thereby raise their living standards and profits.

That would be the rational thing to do. However, using Greenspan's words, the people, including legislators and bureaucrats, have become "irrationally exuberant" regarding renewables reducing global warming. The above shows, it is an expensive and futile tilting at wind mills a la Don Quixote.

A Wiser Energy Policy: In the US and elsewhere, it would be much wiser and more economical to shift subsidies away from expensive renewables that produce just a little of variable, intermittent energy and instead use those funds for increased energy efficiency, because it provides the quickest and biggest "bang for the buck", AND it is invisible, AND it makes no noise, AND it is benign to the environment, i.e., does not destroy pristine ridge lines/upset mountain water runoffs, AND it reduces the most CO2 emissions per invested dollar, AND it creates more jobs per invested dollar, AND does all this without divisive controversies.

Competitiveness: The above begs the question: If wind energy reduces CO2 by so very little/kWh, or not at all, or increases it, AND requires so much capital/MW to implement, AND produces energy at such a high cost/kWh, AND has such huge adverse impacts on quality of life (noise and infrasound, visuals, social unrest, psychological), property values and the environment, why are we, as a nation, making ourselves even less efficient relative to our competitors by this slavish, lemming-like pursuit of expensive wind energy?

Who Benefits: Could it be that the Wall Street elites see the 30% federal cash grants, accelerated write-offs, generous feed-in tariffs and renewable energy credits as major tax shelters and long-term income streams (preferably tax-free) for themselves and their high-income clients, all at the expense of the Main Street economy which is already economically depressed?

If the amounts of the grants and taxes-not-collected due to these deductions from taxable incomes are totaled, it would be evident wind energy is very expensively subsidized indeed; not helpful for reducing budget deficits.

Roll more and more such expensive wind energy into rate schedules and the US will become even less competitive than at present: not helpful for reducing trade deficits.

Wind energy proponents often use Denmark as the model to emulate. However, Denmark is in the unique position of having a large capacity of hydro plants of Norway and Sweden available for balancing wind energy; i.e., other grids with little or no hydro plants cannot use Denmark as a model. This unique position has been unfortunate for Danish households, because their electric rates are the highest in Europe; France, 80% nuclear, has the lowest.

Quality of Life: Wind energy reduces the quality of life, health and psychological well-being of people who live near wind turbines. During the past 5 years, Denmark has stopped adding to its ONSHORE wind turbines for exactly these reasons. See "Wind Energy and Low Frequency Noise" in this article.
http://theenergycollective.com/willem-post/61309/lowell-mountain-wind-turbine-facility-vermont

Due to demonstrations by the Danes during at least the past 5 years, the government finally decided in August 2010 that any future wind turbines will be OFFSHORE and beyond the horizon. That is a huge admission on part of the Danish government. i.e., wind turbines near people have become an anathema in Denmark.

A similar development is shaping up in The Netherlands and Germany. As both have finally realized and admitted their winds are marginal for onshore wind energy; Germany's wind CF is 0.167, Denmark's is 0.242 and The Netherland's is 0.186.

Their future wind energy development will likely be offshore as well. However, offshore wind energy has a capital cost of about $4,200/kW (more than two times onshore) and O&M costs of about three times onshore, compared with wind turbines in the Great Plains.

AN ALTERNATIVE TO WIND ENERGY

The below article describes an economically and environmentally more attractive alternative to wind energy that is based on 60% efficient CCGTs.

The new "GE FlexEfficiency 50" plant has a capacity of 510 MW and a 61% efficiency at rated output. Its design is based on a unit that has performed utility-scale power generation for decades. The plant fits on about a 10-acre site; i.e., minimal visual impact.

It is quick-starting: from a cold start, it reaches its rated output in about one hour. Its average efficiency is about 60% from rated output to 87% of rated output (444 MW) and about 58% to 40% of rated output (204 MW). It can be ramped at 50 MW/minute. CCGTs are usually not operated at less than 40% of rated output because of very high heat rates, Btu/kWh.

The GE unit is designed to efficiently produce electric energy in base-loaded mode and in daily-demand-following mode which implies 365 cycles per year.

Its high ramp rate enables it to also function as a balancing plant to accommodate the variable energy from wind turbine and solar facilities. However, such use would significantly increase wear and tear and shorten the useful service life of the units, because they would have to ramp up and down hundreds of times per day to follow the wind surges and ebbs.

The above shows its efficient ramp range is from 510 MW to about 204 MW; below 204 MW significant degradation of heat rates occurs. See websites.

http://www.ge-energy.com/content/multimedia/_files/downloads/FlexEfficiency%2050%20Plant%
20eBrochure.pdf
http://theenergycollective.com/willem-post/59747/ge-flexefficiency-50-ccgt-facilities-and-wind-turbine-facilities