A Different Model for Transporting Renewable Energy to Market

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Introduction

The use of wind as a significant player in the goal to achieve, by 2020, 20% of US electricity production from renewable sources is inhibited by several problems. Among them are the location of the best wind potential and the huge expense of getting to that potential. In this paper, we examine the problem and propose a means to overcome it.

Wind Potential Is Not Matched to the Grid

Figure 1 shows the location of the best wind resources of the 50 states of the United States. The cost of the proposed lines will be discussed. It is sufficient to note at this stage that the cost is in the tens or hundreds of billions of dollars. Note also that there are areas with enormous wind energy potential that do not even have lines proposed.

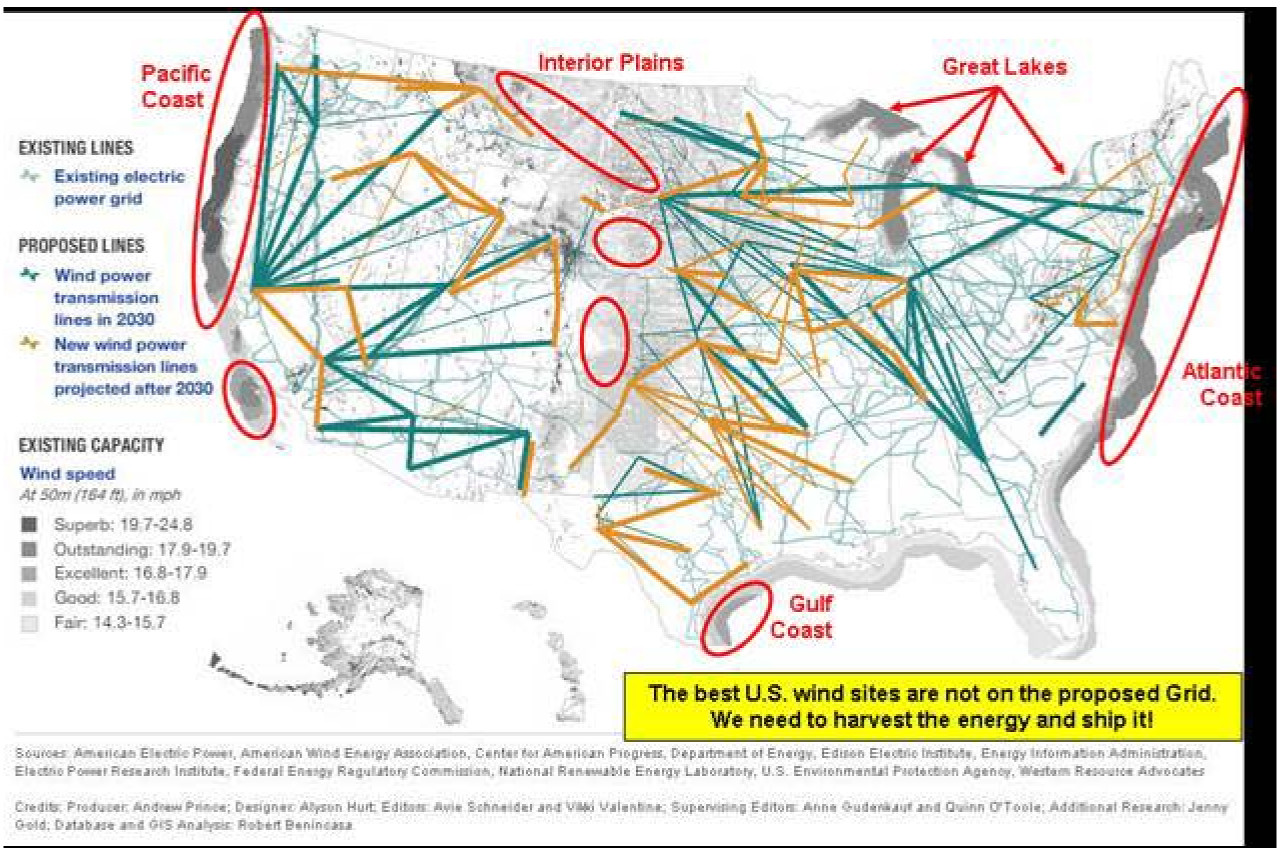

Figure 1. Wind capacity for U.S. land and water, compared to existing electric grid and proposed transmission lines through 2030 and beyond [1].

This potential is shown in Table 1 which shows, in order of potential, the twenty states with the greatest wind energy potential and the offshore wind energy potential. The top six states alone could produce 6,388 billion kWh per year; the top twenty could produce 10,470 billion kWh per year. The off-shore potential is even greater with a capacity of somewhere between 10,970 billion kWh to 17,570 billion kWh.

To put this in context, the estimated US energy consumption for 2008 is 3,873 billion kWh.

Table 1. Annual potential for state wind capacity [2]

Est. Capacity Rank	State	Est. Cap. (billion kWh)	Current Production Rank
1	North Dakota	1,210	13
2	Texas	1,190	1
3	Kansas	1,070	9
4	South Dakota	1,030	20
5	Montana	1,020	19
6	Nebraska	868	22
7	Wyoming	747	12
8	Oklahoma	725	11
9	Minnesota	657	4
10	Iowa	551	2
20 Highest Potential States		10,470	
Not included in report	U.S. Off-Shore*	5,500 - 7,100	
Potential Land & Off-Shore		10,970-17,570	
Est. US Consumption 2008		3,873	

* based on a 70-90% capacity factor

The Importance of the Quality of Wind

The quality of the wind site is critical to the cost of producing electricity. Figure 2, from the US Department of Energy, illustrates this fact. Where the wind blows either more slowly or less often the capacity factor is low. Where the capacity factor is low the cost is high. For example, with a 20% capacity factor the trend line shows that the cost of wind power is almost $60 per megawatt hour produced. But a capacity factor of about 42% or higher would cut the cost by half or more. Thus those areas of the country where more lines are planned are very good, but those areas where no lines are planned are much better!

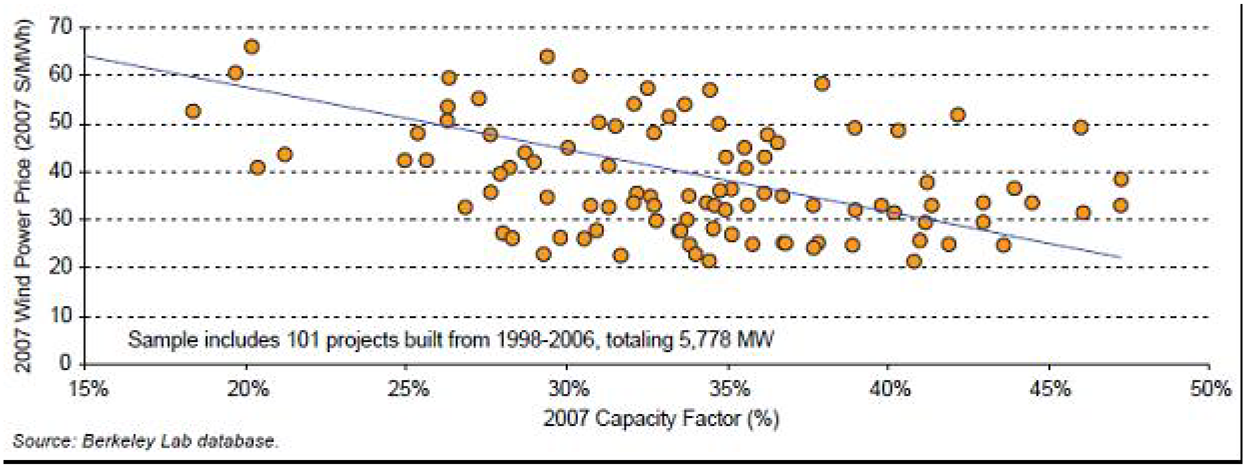

Figure 2. Wind power price as a function of capacity factory ("Annual Report on US Wind Power Installation, Cost, and Performance Trends: 2007," US DOE, May 2008).

The Cost of Adding Power Lines

Recently, Dick Williams of Shell Energy stated, "**There are a lot of good wind resources left in the US. The problem is they are 100 to 150 miles from existing transmission lines**." The May 2008 report also identifies that "**lack of transmission availability remains a primary barrier to wind development**. New transmission facilities are particularly important for wind power because wind projects are constrained to areas with adequate wind speeds, which are often located at a distance from load centers. In addition, there is a mismatch between the short lead time needed to develop a wind project and the lengthier time often needed to develop new transmission lines."

Furthermore, power transmission lines are expensive. The cost of putting them in depends on the terrain, how much power load they would carry, and a variety of environmental and legal factors. The range of costs is illustrated somewhat by recent experiences in Wisconsin. There, one power line installation in Dane county cost over $4 million per mile. Another line was able to take advantage of already existing rights of way and hold the cost to about $1.5 million.

Table 2. Expensive Transmission Lines

Name	**Location**	**Total Cost**	**Cost/Mile**
Femrite-Sprecher	Dane County, Wisconsin	$16,061,617	$4,015,404
Arrowhead-Weston*	Wisconsin	$320,987,041	$1,459,032

*Built Along Rights of Way

Those cost figures for power lines, large as they are, actually understate the cost. Table 3 shows industry estimates for the time required at various steps in the process of building a wind farm and connecting it to the Grid. The time to market is eight to ten years with the usual transmission line installation. However, the Zinc-Air transport to market can reduce this to a three to four year time frame. This would improve time to market by somewhere between 50% and 70%!

Table 3. Industry Estimates for Installing a New Wind Farm and Transmission Lines

Transmission Line Citing and Approval	Transmission Line & Wind Farm Install	Time to Market with Transmission Lines	Cite and Build Wind Farm without Transmission Lines	**Improved Time to Market with Zinc-Air**
5-6 years	3-4 years	8-10 years	3-4 years	**50-70% faster**

As a consequence of the lack of lines and the cost of lines, wind production has tended to be in locations that are inferior. Table 4 shows that the top producing states include very high potential Texas, moderately high potential Iowa and Minnesota, and relatively low potential California. Most of the high potential states are not producing; and for that matter, California is using on-land sites and little of the high potential off-shore.

Table 4. Top Wind Power Producing States (source: American Wind Energy Assoc.)

Current Production Rank	State	Estimated Capacity (billion kWh)	Capacity Rank
1	Texas	1,190	2
2	Iowa	551	10
3	California	59	17
4	Minnesota	657	9

The Solution

Our solution is to use zinc energy storage to

1. capture the power at the windmill,
2. transport it by electric powered vehicles (trucks/rail on land, ships on the oceans) ,
3. discharge the power at an optimum point along the currently existing grid. (possibly at points currently under-utilized).

The discharge point might very well be a currently underutilized point on the grid. This would save billions of dollars worth of new grid lines, save years of idle time for wind farms, and improve the green characteristics of wind. Off-shore this would make it much easier to locate out to sea and thus protect seaside views.

The concept is illustrated in Figure 3

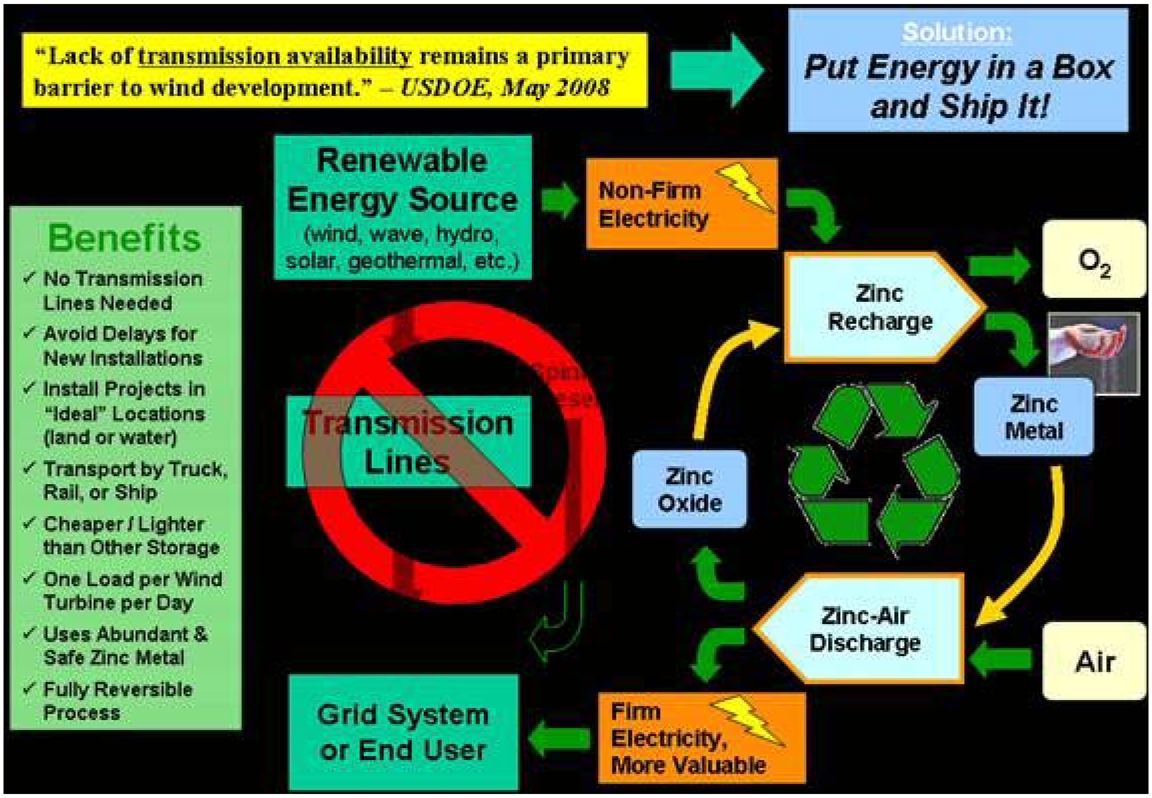

Figure 3. A Different Model for Transporting Renewable Energy to Market.

Economic Performance Targets

The economic requirements (financial requirements might be a better term) of this wireless-transport system are in two critical aspects. The first is the value of saving power lines. The question is "Is it less costly to transport the power by lines or by electric powered vehicles?" To analyze this, the cost of power transport by lines needs to translated to a cost per MWh of power transported per mile. The Miles, Wiser, Porter report [3] showed a median cost to transport power of $15/MWh. Their study actually shows a range from nearly 0$/MWH to as high as $79/MWh. We use the $15 figure here to illustrate; however, it may be more useful in the field as a means to select which projects are best suited to this approach.

The report does not directly connect distance to the cost per mile. An article in Wind Power Monthly noted that America [4] has a great amount of good wind power potential that is 50 to 150 miles from existing transmission lines. The midpoint of 100 miles is used here. This gives a cost of $0.15 per MHh delivered. The wireless-transport system thus has a bogie of $0.15 per MWh to beat.

Additionally, the cost of generating and storing the energy must be considered. Table 6 builds a benchmark price that the wireless-transport system must beat. Table 5 shows that the current wholesale price is $57.20 per MHh. This price is virtually certain to rise as carbon emissions costs are included. As an estimate of those costs, the $19.77 current European trading price is used. Noting that 55% of US electricity is currently produced using coal, which emits one ton of CO_2 per MWh gives a conservative figure of $10.87 of increased cost/price of electricity on the wholesale markets. This figure could be higher if other CO_2 emitting electricity sources such as natural gas and oil are considered. Consequently, the benchmark price for production and storage is about $68; the wireless-transport system needs to be able to produce at less than this cost.

Table 5: Benchmark Price

Average Wholesale Price of Electricity (per kWh) (2007)	$0.0572
Average Wholesale Price of Electricity (per MWhr) (2007)	$57.20
Carbon Emmissions Current Trading Price (Europe)	$19.77
Coal fraction of all USD Electricity	55%
Cap & Trade Effect	$10.87
Conservative Price Target	$68.07

The Match of Our Technology with the Economic Requirements

The transportation cost is analyzed in Table 6. In Table 6, the owning and operating cost is assumed to be about $40 per hour of operation of the electric-powered truck. This is a typical number for conventional transport; electric transport should actually compare favorably to this figure. O&O cost per round trip total to about $160 for a truck that would deliver over 14 MWh to the Power Grid. This translates to a very favorable $0.11 per MWh per mile.

Table 6: Transport Cost

O&O / Hour of Operation	$40.00
Line Length Saved (miles)	100
Miles of Truck OPNS	200
Miles/Hour Operation	50
Number of Hours	4
O&O Cost/Truck Round Trip	$160.00
Truck Payload (Tons)	30
Storage Device Energy Metric	
(MWh/Tonne)	0.60
Conversion to Ton	1.1
(MWh/Ton)	0.55
Discharge Efficiency	86.6%
MWh Delivered/Ton	0.47
Total MWh Delivered	14.17
Transport Cost/MWh Delivered	$11.29
Transport Cost/MWh/mile	$0.11

Table 7 pulls together cost information of generation of electricity at high quality wind sites ($20/MWh) and the costs of using power storage both to firm the wind (arbitrage prices) and transport power by electric vehicles. The analysis shows about a $44 per MWh cost of production with a $4 cost advantage over lines. In brief, the pwer can be produced and delivered to the Grid for well below the benchmark of $68/MWh and at prices similar to current prices. This would be of enormous advantage in dealing with CO2 emissions costs.

Table 7: Generation & Storage Cost

Average Cost of Electricity (per kWh)	$0.020
Average Wholesale Price of Electricity (per MWhr)	$20.00
Carbon Emmissions Current Trading Price (Europe)	$19.77
Percentage COP2 Emission	0%
Cap & Trade Effect	$0.00
Generation Cost	$20.00
Cost per MWh Storage	$150,000
Storage System Life (Charge-Discharge Cycles)	10,000
Cost per MHw Stored	$15.00
MWh Input Requirement for 1 MWh Stored	1.15
Generation Cost/MWh stored	$23.09
Total Cost/ Stored MWh	$38.09
Discharge Efficiency	0.87
Total Cost/MWh Delivered	$43.99
Adjustment for Transmission Advantage	$4.00
Cost Achievement	**$39.99**

Summary

This process has the potential for being cost competitive, especially when carbon costs are considered. It is nearly perfectly green (with no fossil fuel backup being required for the wind power, and no fossil fuels being required for transport). Not all aspects of the gains were considered in this report. For example, the report did not evaluate the gains to investors and to society of being able to bring wind on line years sooner than with power lines and their associated legal, regulatory, and public hearing requirements. This would of special concern given President Obama's goal of 20% of US electric power being renewables by the year 2020.

References

1. **NPR.org**.

2. American Wind Energy Association.

3. Andrew Mills, Ryan Wiser and Kevin Porter; *The Cost of Transmission for Wind Energy: A Review of Transmission Planning Studies*, Ernest Orlando Lawrence Berkley National Laboratory, February, 2009.

4. "Shell bets big on American wind and contemplates storing Texas wind energy in salt caverns", *Wind Power Monthly*, February, 2009.