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Science article is *wrong* in claiming that wind energy is cheaper than coal and could easily replace 59% of US coal-fired electricity generation

An article, *Exploiting Wind versus Coal*, appearing in the August 24, 2001, issue of *Science* magazine falsely claims that wind energy is now cheaper than coal for generating electricity and that, by substituting wind energy, the US could easily shut down 59% of American's coal-fired electric generation and meet Kyoto Protocol targets.

There are two basic ways to look at this highly misleading article:

- Cheer for the false conclusion that "the cost of wind energy is now less than that of coal." That would mean that there is no longer *any* rationale for extending all the federal and state subsidies for wind energy – the real costs of which are shifted from wind developers and hidden in other peoples' tax bills and in consumers' monthly electric bills.
- Catalog the faulty assumptions and slight of hand used by the authors in coming up with their conclusions about the number of windmills required, the relative cost, and the ease with which the US could replace 59% of coal fired electric generation with wind energy.

Summary

The authors of the article, Stanford University engineers Mark Z. Jacobson and Gilbert M. Masters, relied on an old ploy when making cost comparisons. That is, they inflated the cost estimates for the energy source (coal) that they *don't like* (i.e., including estimates for externalities) and avoided counting comparable costs associated with the technology they *do like* (wind energy).

However, one doesn't even need to look at the authors' cost estimates to find the flaws in the assumptions and calculations used in their analysis. For example:

- The authors assert that between 214,000 and 236,000 wind turbines (each with a rated capacity of 1,500 kilowatts – kW) could be substituted for 59% of US reliance on coal for electric generation and, the authors claim, meet Kyoto Protocol targets.
- In fact, it would take about 294,500 of the very tall 1,500 kW windmills to meet the authors' unrealistic target -- instead of the 214,000 to 236,000 they estimate. In addition, It would take an additional 71,000 of the 1,500 kW windmills to replace the annual increase in coal-fired generation that EIA expects to occur by 2010 – raising the total number of windmills to nearly 366,000!

Correcting the authors' assumptions and arithmetic isn't the only problem with their claims. The authors failed to address the real world problems of:

- Finding sites for 214,000 huge (each 300 ft. tall) scenery impairing windmills -- let alone the more accurately calculated 366,000 windmills that would be needed.
- Adding thousands of miles of transmission lines to move that electricity from the windmills to the places where electricity is used.
- Providing backup generation for such a large amount of wind-generated electricity, recognizing the inherent intermittence, unpredictability and unreliability of wind energy.

Details

The remainder of this paper catalogs some of faulty assumptions and calculations and slight of hand used by the authors in attempting to support their conclusions.

1. **Familiar ploy.** The authors used the all-too-familiar ploy in their economic analysis of inflating the estimated cost of the technology and fuel that they *don't* like and avoided mentioning costs associated with the technology they *do* like. Specifically, they have.

   a. Assigned health and environmental externality costs of $0.02 to $0.043 per kWh to the costs of electricity from a "new coal power plant," raising what they claim is a generation cost of $0.035 to $0.04 to achieve a "total cost" of $0.055 to $0.083 per kWh.

   b. Assumed that there are no externality costs associated with wind energy, despite the fact that windmills have significant environmental externality costs -- including but not limited to noise, bird mortality, scenic impairment and property value impairment.

   c. Ignored other costs associated with wind energy due to its intermittence, variability and unreliability since wind availability and speed varies widely and is difficult to predict on a time scale required by managers of electric power grids. *Extra* costs associated with wind energy include:
      1) Providing backup power from reliable generating plants to supply electricity when the wind is not blowing or not at speeds required to produce the electricity that is needed.
      2) Building transmission capacity to move electricity from remote areas where huge windmills might be acceptably located to places where it is used.
      3) Losses of electricity ("line losses") when it moves over transmission lines.

2. **Correcting the authors' assumptions and calculations**

   a. **Annual capacity factors.** A 1,500 kW wind turbine, if it could operate at its full rated capacity for a year (8760 hrs), would produce 13,140,000 kWh of electricity.[2] The authors – using only engineering calculations suggest that such a turbine would produce

4,700,000 to 5,200,000 kWh of electricity a year, implying capacity factors in the range of 35.8% to 39.6%.[3] Such capacity factors exceed real world experience – which is 30% or less. The authors apparently have failed to consider such factors as:

1) Wind conditions at turbine sites that are less than their engineering estimate,
2) Planned and unplanned outages for maintenance and repair, and
3) Performance deterioration over time or due to such things as bugs encrusted on blades[4], which sharply reduce electricity output.

If the turbine actually achieved a 30% annual capacity factor, the output would be 3,942,000 kWh.[5] Thus, by using an engineering calculation the authors have overestimated likely annual output from a 1,500 kW turbine by 19% to 32%.

b. Replacing 59% of coal-fired generation with windmills. Using their inflated electricity output numbers, the authors calculate that the US could build 214,000 to 236,000 windmills to replace 1,890,000,000,000 kWh of coal-fired generation. They apparently used an estimate of 1999 US coal-fired generation. (EIA reports that 1999 coal-fired generation was 1,884,322,000,000kWh.[6])

1) *Bringing numbers up to date.* For 2000, EIA reports that coal-fired generation was 1,967,726,000,000 kWh – 4.1% above the number used in the authors' calculations. So, the next adjustment needed in the authors' calculations is to increase the number of windmills that would have to be built by 4.1% to catch up with actual year 2000-electricity generation.[7]

2) *Continuing increase in coal-fired generation.* The next adjustment that is needed in the authors' calculations is to provide windmills to cover the expected increases in coal-fired generation. In it's latest forecast, EIA shows that total annual US electricity generation will grow by about by 800,000,000,000 kWh by 2010, of which EIA expects 281,000,000,000 kWh to be generated by coal-fired plants.[8]

c. Correcting the number of windmills required to achieve the authors' objectives. Once the capacity factor and kWh of coal-fired capacity numbers are corrected, it is possible to come up with the number of windmills that would be required to achieve the author's apparent objectives; i.e., replace 59% of current coal-fired generation and avoid any increase in coal-fired generation.

As demonstrated in the table that is attached, the number of 1,500 kW windmills that would be required is **NOT** 214,000 or 236,000. Instead, the number would be 365,794, more than 50% greater than the authors claimed.

2. Real problems with wind energy ignored by the authors

The authors have ignored very real problems associated with the use of windmills to generate electricity, including the facts that:

- Windmills are huge structures that generate very little electricity.[9] Many of the windmills now being built in the US are around 300 feet tall – equal to the height of the US Capitol building and about twice the height of the Statue of liberty.
- Scenery impairment by the huge structures is a serious problem for many people.
- Windmills are not "good neighbors" and, therefore, are only appropriate for remote areas. For example:
  - They present noise problems. A utility in Wisconsin has decided to buy up neighboring properties because of complaints about unusual noise, even though the windmills met prescribed noise standards when built.
  - Neighboring property owners, particularly residential properties, fear value loss.
  - Many areas where building windmills may otherwise be appropriate (the Plains states are often cited) do not have existing transmission lines nearby. The small, intermittent and unreliable electricity output would militate against adding the costly transmission lines that would be needed. Furthermore, potentially appropriate sites are often long distances from where electricity is needed and would, therefore, involve significant electricity line losses and high cost to transmit the electricity over long distances.
  - Providing backup power is often costly because electricity from windmills is intermittent, unreliable and unpredictable. Since electricity must be available on demand, other generating capacity must be immediately available to fulfill demand. This so-called "firming service" can be expensive.[10]

It should also be noted that the above analysis does not address other important matters that should be taken into account including the impact on investment or employment in existing coal-fired generating plants and the coal supply industry.

It should also be noted that, despite hundreds of millions of tax dollars spent by the US Department of Energy for wind energy R&D, most wind turbines being installed in the US (and around the world) come from non-US companies, principally Denmark companies.

3. Are the Authors' Financial Cost Numbers Accurate?

A detailed assessment of the authors' direct wind energy cost assumptions is not possible at present since reliable data on wind energy costs are not publicly available. Also, the data relied on by the authors apparently are in an article that is still "in preparation."

In fact, the actual costs of wind farms – as well as their actual output once in operation -- vary widely among "wind farm" projects. Capital costs vary widely among "wind farms" for a variety of reasons, including but not limited to the number, type and cost of turbines involved, cost of substations and meteorological towers, electrical connections, control room and other capital items, site conditions, need for adding transmission lines, source of financing, federal and state tax shelters and other subsidies. Operation and maintenance costs (O&M) also vary widely among projects.

All that can be stated at this point is that the authors' estimates *appear* low. Ideally, the US Department of Energy would conduct or arrange for a *thoroughly independent* study to catalog actual costs for a representative number of "wind farms." Such a study should *not* be done by wind (or other) advocates in DOE or its national labs. Perhaps it could be done under contract by a truly independent accounting firm that had no ties to DOE, its laboratories or other contractors, other advocacy groups or existing wind farm developers. Conflicts of interest would have to be avoided if the data is to be credible and accepted as valid by all concerned about wind energy development.

The authors assume overall capital costs for a 1,500 kW of $1,500,000 or $1,000 per kWh. This is close to the number ($983 in 1999$ for a plant coming on line in 2004) used by EIA as an overnight capital cost assumption for its Annual Energy Outlook 2001.[11] The authors assume 6% to 8% "interest" – which costs would actually depend on financing arrangements (e.g., debt-equity) -- and $18,000 to $30,000 per year in O&M charges.

It's unclear whether the authors' estimates take into account the generous federal and state tax shelters and other subsidies now available to wind energy developers. Existing federal tax shelters alone are huge. They include a $0.017 cent per kWh production tax credit for production during the first 10 years of project life and 5-year double declining balance accelerated depreciation for capital costs. A spokesman for BP Solar recently reported that the value of these two federal tax shelters alone is equal to 42% of project costs.[12] Some states provide additional subsidies that are financed from tax revenues or from taxes (often called "public benefit charges") added to customers' monthly energy bills.

All federal and state subsidies for wind farm developers merely shift costs from the wind farm developer and "hide" them in tax bills paid by remaining taxpayers or in monthly bills of electricity users.

Conclusions, in Brief

The Jacobson – Masters article published by Science magazine in its August 24, 2001 issue:

- Substantially underestimates the number of windmills that would be needed to replace the 59% of US existing coal-fired electricity generation that the authors say would be necessary to meet Kyoto Protocol targets.
- Uses an inconsistent approach when comparing costs of energy sources, adding estimates of externality costs for one source while ignoring such costs in others.
- Ignores significant costs that must be incurred to increase the use of wind energy.
- Ignores scenic impairment and other environmental costs of wind energy.
- Ignores the difficulty of finding acceptable, useable sites for the nearly 366,000 huge windmills that would be required.
- Relies on capital and operating cost estimates of unknown validity.

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The preceding self-financed analysis is provided in my role as a citizen, consumer and taxpayer and is not on behalf of any client or other interest.

Attachment: Table showing calculations

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[2] 1,500 kilowatts (kW) times 8760 hours per year = 13,140,000 kilowatt-hours (kWh).
[3] 4,700,000 kWh divided by 13,140,000 kWh = capacity factor of 35.8%; 5,200,000 kWh divided by 13,140,000 = capacity factor of 39.6%.
[4] Corten, Gustave P. & Herman F. Veldkamp, Nature, Vol. 412, July 5, 2001, pp. 61-62.
[5] 1,500 kW rated capacity x 8760 hours in year times 30% = 3,942,000.
[6] US Energy Information Administration, *Monthly Energy Review*, Table 7.2.
[7] Ibid.
[8] US Energy Information Administration, Annual Energy Outlook 2001, Table A8.
[9] To illustrate, a 555,000 kW gas-fired generating plant that was opened in California on July 9, 2001 will produce more electricity in a year than was produced in 1999 by all of California's 13,000+ windmills. Many of California's windmills were built in the 1980s and are smaller than those being built today.
[10] A representative of the Northwest Power Planning Council reported at the National Renewable Energy Laboratory's Analysis Forum held in Golden, Colorado on August 13-14 that Bonneville Power Authority charges $0.028 per kWh as a "firming charge" for wind energy suppliers. This information has not been separately verified.
[11] US Energy Information Administration, *Assumptions to the Annual Energy Outlook 2001*, p. 69.
[12] NREL Analysis Forum, Golden, Colorado, August 13, 2001.

Attachment A

Corrections of Jabobson – Masters Calculations of the Number of 1,500 kW Windmills Required to Replace 59% of US Coal-fired Generation

	Kilowatt-hours of Coal-fired generation To be replaced		
Authors' capacity factor assumptions		35.8%	39.6%
Authors' calculations of kWh output		4,700,000 kWh	5,200,000 kWh
Authors' estimates: replace 59% of 1,890,000,000,000 kWh or	1,115,100,000,000		
Authors' calculations of number of 1,500 kW wind turbines required		236,000	214,000
Adjust numbers for actual 2000 coal-fired generation (1,967,726,000,000 kWh x 59%)	1,160,958,300,000		
Wind Turbines required using actual 2000 Generation and authors' Capacity factor assumptions		247,012	223,261

More Realistic Capacity Factor		30%
Annual output from 1,500 kW wind turbine Using realistic capacity factor		3,942,000 kWh
Number of wind turbines required to replace year 2000 coal-fired generation using 30% capacity factor (i.e., 1,160,958,300,000 divided by 3,942,000		294,510 turbines
EIA's expected increase in annual coal fired generation by 2010	+ 281,000,000,000 kWh	
Number of windmills needed to cover the increase In coal-fired generation expected by EIA (i.e., (281,000,000,000 kWh divided by 3,942,000 kWh – assuming 30% capacity factor)		+ 71,284 turbines
Total kWh that would have to be replaced to achieve the authors' objectives, including avoidance of increase in annual coal-fired generation expected by EIA by 2010	1,441,958,300,000 kWh	
Total number of 1,500 kWh windmills that would be required to offset the above kWh of coal-fired electricity generation (i.e., 1,441,958,300,000 divided by 3,942,000)		365,794 turbines