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Hearing on
Renewable Energy Tax Incentives:
How Has the Expiration of Key Incentives Affected the Renewable Energy Industry In the United States?

Renewable Energy Subsidies Should Be Abandoned

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The views expressed in this testimony are those of the author alone and do not necessarily represent those of the American Enterprise Institute.

Thank you, Mr. Chairman and distinguished members of this committee, for this opportunity to offer my perspective on the issues attendant upon the recent expiration of several tax incentives---subsidies---for renewable energy, energy efficiency, and biofuels. For the most part my comments will be oriented toward the issues raised by subsidies for renewable electricity, wind and solar power in particular, but are broadly applicable to the analysis of biofuels as well.

I begin with a summary of my testimony for the record. Section I discusses the inherent limitations of renewable electricity that public policies can overcome only at very substantial cost to the taxpayers and to the economy as a whole. Section II discusses the five central rationales that commonly are offered in support of subsidies for renewable power; these rationales are deeply flawed. Section III discusses recent developments in the market for natural gas---a direct competitor to renewable power technologies---and the attendant implications for the future competitiveness of renewable electricity. Section IV offers concluding observations on the economics and policy analytics of subsidies for renewable energy.

I will be very pleased to address any questions and observations that the Chairman and other members of this committee may have.

Summary

This testimony addresses the outlook for renewable energy in electricity generation as a substitute for such conventional fuels as coal and natural gas. The emphasis is on wind power, which in terms of projected generation capacity is by far the most important of the non-hydroelectric forms of renewable power. Some analysis of solar energy is presented also. The discussion examines as well the central arguments in favor of policies supporting the expanded use of renewables, and the implications of prospective supply and price developments in the market for natural gas.

Public policy support for renewable electricity has been substantial. This support has taken the form of direct and indirect subsidies, and requirements in a majority of the states that specific percentages of the market for electric power be reserved for electricity produced from renewable sources. Nonetheless, renewable power provides only a small proportion of electric power in the U.S., and official projections are for slow growth at most. This market resistance to investment in renewable generation capacity can be explained by the problems intrinsic to renewable power---that is, the inherent limitations on its competitiveness---that public policies can circumvent or neutralize only at very substantial expense. These problems uniformly yield high costs and low reliability for renewable power, and can be summarized as follows.

- The unconcentrated energy content of renewable energy sources.
- Location (or siting) limitations.
- Relatively low availability (“capacity factors”) over time combined with the intermittent nature of wind flows and sunlight.

The low energy content of sunlight and wind flows relative to that of fossil or nuclear fuels forces renewable technology to compensate by relying upon massive substitute investment in land and/or materials. Second, unlike conventional generation technologies, renewable generation is sharply constrained by siting problems because favorable sunlight and wind conditions are limited geographically, yielding large additional costs for transmission. Finally, capacity factors---essentially, the proportion of the year during which renewable facilities actually can generate power---are substantially lower for wind and solar facilities than is the case for most conventional generation, and the intermittent nature of sunlight and wind flows exacerbates this problem. These conditions result in a need for conventional backup generation capacity so as to preserve the stability of the electric grid and prevent power shortages; this need increases associated costs substantially. Moreover, in particular for wind power, actual power generation tends to be concentrated in off-peak periods---winds tend to blow at night and in the winter---so that the electricity produced from wind facilities tends to be less valuable than that produced from conventional sources.

The five central rationales commonly offered in support of subsidies and mandates for renewables can be summarized as follows.

- The “infant industry” argument: Renewables cannot compete with conventional electric generation technologies on an equal basis because scale and learning efficiencies can be achieved only with an expanded market share.
- The “level playing field” argument: Subsidies enjoyed by conventional technologies introduce an artificial competitive disadvantage for renewable technologies.
- A second “level playing field” argument: The adverse environmental effects (e.g., air pollution)---“externalities”---of conventional electricity generation create an additional artificial cost advantage for those technologies.
- The resource depletion (or “sustainability”) argument: Policy support for renewables is justified as a tool with which to slow the depletion of such conventional resources as natural gas and to hasten the development of technologies providing alternatives for future generations.
- The “green employment” argument: Policy support for renewables will yield expanded employment (and economic competitiveness).

These rationales are deeply problematic. The infant industry argument is inconsistent with the cost evidence for renewables and with the presence of an international capital market. The subsidies per kilowatt-hour enjoyed by renewables outweigh by far those bestowed upon conventional generation technologies, so that the first level playing field argument is unsupported by the evidence. With respect to the adverse environmental effects of conventional generation, the cost of conventional backup capacity made necessary by the unreliability of wind and solar generation is substantially greater than any artificial cost advantage enjoyed by conventional technologies as a result of negative external effects assumed not to have been corrected (“internalized”) by current policies. The depletion or sustainability criticism of conventional technologies is incorrect simply as a matter of basic economics, and is inconsistent with the historical evidence. Finally, the premise that expansion of renewable power will yield an increase in "green employment" confuses benefits for a particular group with costs imposed upon the economy as a whole, and fails to distinguish between employment growth in the aggregate and employment shifts among economic sectors. Moreover, the actual employment effect of expanded renewables subsidies is likely to be negative because of the inverse aggregate relationship between electricity costs and employment, and because of the adverse employment effects of the taxes needed to finance the subsidies. In short: The purported social benefits of policy support for renewables are illusory.

The market difficulties faced by renewables are likely to be exacerbated by ongoing supply and price developments in the market for natural gas, which will weaken further the competitive position of renewable power generation. At the same time, subsidies and mandates for renewables impose nontrivial costs upon the taxpayers and upon consumers in electricity markets. The upshot is the imposition of substantial net burdens upon the U.S. economy as a whole even as the policies bestow important benefits upon particular groups and industries, thus yielding enhanced incentives for innumerable interests to seek favors from government. As is the case in most contexts, the resource uses emerging from market competition, even as constrained and distorted by tax and regulatory policies, are the best guides for the achievement of resource allocation that is most productive. As federal policymakers address the ongoing issues and problems afflicting renewable electricity generation, the realities of this recent history provide a useful guide for policy reform. One such reform should be the abandonment of subsidies for renewable energy.

I. Inherent Limitations of Renewable Electricity

Renewable electricity---wind and solar power in particular---receives very large subsidies, both direct and indirect, from the federal and state governments. As discussed in section II, this policy support is far larger per kilowatt-hour, both on average and on the margin, than that enjoyed by such conventional electric generation technologies as coal, natural gas, nuclear fuels, or hydroelectric facilities. Moreover, a majority of states has mandated some form of guaranteed market shares for renewable electricity. This political support for renewable power is substantial, broad-based, bipartisan, and longstanding.

Nonetheless: Renewable electricity generally, and wind and solar power in particular, is very high cost and is likely to remain so for the foreseeable future because of three central factors discussed below. As a result, they have achieved only small market shares. Renewable electricity generation from all non-hydroelectric sources was only 3.6 percent of total U.S. generation in 2010. The Energy Information Administration estimated in 2007 that the proportion in 2030 would be that very same 3.6 percent. The EIA more recently has increased that projection to 11 percent.

But it is not clear what changes in important parameters have yielded that increase in the projected market share over the course of only a few years. No sound rationale, whether economic or technological, can explain this change in the official wisdom. Quite to the contrary: Both economic and technological factors suggest strongly that wind and solar power will remain uncompetitive, heavily dependent upon subsidies both direct and indirect, and small relative to the electricity market as a whole.

The implementation of energy policies in the U.S. for decades has pursued energy sources defined in various ways as alternative, unconventional, independent, renewable, and clean, in an effort to replace such conventional fuels as oil, coal, and natural gas. These longstanding efforts without exception have yielded poor outcomes, in a nutshell because they must swim against the tide of market forces. That is why the only reliable outcome has been one disappointment after another, and there are powerful reasons to predict that the same will prove true with respect to the current enthusiasm for renewable electricity.

Policy preferences for renewable electricity at both the federal and state levels are substantial, in the form of both direct and indirect financial subsidies, and other forms of support as well.[1] The relative magnitudes of the federal subsidies given various forms of electricity, as estimated by the Energy Information Administration, are instructive.[2] For 2010, nonhydroelectric renewable power generation, again, was 3.6 percent of all generation; but it received 53.5 percent of all federal financial support for the electric power sector. Wind power, providing 2.3 percent of generation, received 42 percent of such support. This combination of substantial policy support and meager market competitiveness suggests the presence of important impediments to the growth of renewable power. The technical literature reveals three central problems that have not received widespread attention in the popular discussion; they can be denoted as:

- The unconcentrated energy content of renewable energy sources.
- Location (or siting)---that is, geographic---limitations and resulting transmission costs.
- Relatively low availability ("capacity factors") over time combined with the intermittent nature of wind flows and sunlight.[3]

Unconcentrated Energy Content.[4] The energy content of wind flows and sunlight, which varies depending upon air speed and sunlight intensity, is far less concentrated than that of the energy contained in fossil or nuclear fuels. In order to compensate for this physical characteristic, large capital investments in land and/or

[1] For a detailed list of such policies, see the database at http://www.dsireusa.org/.
[2] U.S. Energy Information Administration, *Direct Federal Financial Interventions and Subsidies In Energy In Fiscal Year 2010*, July 2011, at http://www.eia.gov/analysis/requests/subsidy/pdf/subsidy.pdf, Tables ES4 and ES5.
[3] The capacity factor for a generation facility (or technology) is its actual production over a given time period divided by its theoretical maximum production over that time period.
[4] The energy content of different fuels varies greatly. Per unit of fuel---tons of coal, millions of cubic feet of natural gas, wind speeds in miles per hour, an hour of sunlight---this variation can be thought of usefully as the degree of concentration of the energy content of a particular energy source.

materials must be made to make renewable generation even technically practical in terms of generating nontrivial amounts of electricity. A wind farm would require 500 wind turbines of 2 MW each to provide a theoretical generation capacity of 1000 MW. Since the wind turbines must be spaced apart to avoid wake effects (wind interference among the turbines), a 1000 MW wind farm even in principle would require on the order of 48,000-64,000 acres (or 75-100 square miles) of land. With an assumed capacity factor for a typical wind farm of, say, 35 percent[5], reliable wind capacity of 1000 MW would require an amount of land (perhaps at different locations) on the order of two to three times that rough estimate. In contrast, a 1000 MW gas-fired plant requires about 10-15 acres; conventional coal, natural gas, and nuclear plants have capacity factors of 85-90 percent.

The same general problem afflicts solar power. The energy content of sunlight, crudely, is about 150-400 watts per square meter, depending on location, of which about 20-30 percent is convertible to electricity, depending on the particular technology. Accordingly, even in theory a square meter of solar energy receiving capacity is enough to power roughly one 100-watt light bulb, putting aside such issues of sunlight intensity and the like. This problem of land requirements for solar thermal facilities is of sufficient importance that most analyses assume a maximum plant capacity of 50-100 MW, which, conservatively, would require approximately 1250 acres, or 2 square miles.

In short: Transformation of the unconcentrated energy content of wind and sunlight into a form useable for modern applications requires massive capital investment in the form of both land and wind turbines and solar receiving equipment. This means that the energy that can be extracted from renewable sources, relative to that from conventional forms, by its very nature is limited and expensive.

Siting Limitations and Transmission Costs. Conventional power generation plants can be sited, in principle, almost anywhere, and such fuels as coal and natural gas can be transported to the generation facilities. This means that investment planning decisions can optimize transmission investment costs along with the other numerous factors that constrain and shape generation investment choices, among them land costs, environmental factors, reliability issues, transmission line losses, and the like. Wind and solar sites, on the other hand, must be placed where the wind blows and the sun shines with sufficient intensity and duration. (Photovoltaic installations, suitable for small applications, face the transmission problem either not at all or to a far smaller degree than solar thermal plants, but still are constrained by the intensity of sunlight.) Because appropriate sites are limited, with the most useful (i.e., lowest cost) ones exploited first, the successive (or marginal) cost of exploiting such sites must rise, so that even if wind and solar technologies exhibit important scale economies in terms of capacity and/or generation costs, scale economies may not characterize a broader cost calculation including the cost of finding and using particular sites.

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[5] For standard assumptions on capacity factors for the various generation technologies, see Energy Information Administration, "2016 Levelized Cost of New Generation Resources from the *Annual Energy Outlook 2010*", at http://www.eia.doe.gov/oiaf/aeo/pdf/2016levelized_costs_aeo2010.pdf. The assumed capacity factor for onshore wind generation in that analysis is 34.4 percent.

In other words, scale economies are unlikely to be available at the industry level even if they are present at the project (or the turbine or parabolic dish) level. This reality is consistent with a time series of capacity factors for 1998-2009 published recently by the Energy Information Administration. The capacity factors for non-hydroelectric renewables declined almost monotonically from 57.0 percent to 33.8 percent over that period, suggesting that as renewables capacity has expanded it has been forced onto increasingly unfavorable sites.

Because conventional generation investments can optimize transmission costs and other reliability factors more easily than is the case for wind and solar capacity, it would be surprising if such costs were not higher for the latter. This general condition is exacerbated by the physical realities that wind conditions are strongest in open plains regions, while solar generation in general requires regions with strong sunlight and, for thermal solar plants, sizeable open areas. For the U.S., the best wind capacity sites are in a region stretching from the northern plains down through Texas, and the best thermal solar sites are in the southwest. The U.S. simply lacks significant east-west high-voltage interconnection transmission capacity to transport such power to the coasts. One national study of this problem notes that "wind development will require substantial additions to the nation's transmission infrastructure… due to the locational dependence of wind resources [and] the relatively low capacity factor of wind plants…"[6]

Some analyses of these transmission costs are available. One survey of 40 transmission studies for wind projects conducted during 2001-2008 finds a median transmission cost of $15 per megawatt-hour. The survey was limited to studies of transmission requirements for multiple new wind plants with a combined capacity greater than 300 MW. An analysis by the California Public Utilities Commission concludes that implementation of a 20 percent renewable electricity standard (or requirement) for the state by 2020 would impose a need for four new major transmission lines at a cost of about $4 billion, while a 33 percent standard would require seven new lines at a cost of $12 billion. For that 33 percent requirement, the assumptions in the CPUC study suggest transmission costs of about $6.39 per megawatt-hour, a figure that is implausibly low. A study done for the National Renewable Energy Laboratory examined the transmission requirements and attendant costs for four alternative wind capacity scenarios for the Eastern Interconnection (the continental U.S. east of the Rocky mountains, minus Texas, plus parts of southeastern Canada). This study reports a cost of wind "integration" of about $5 per megawatt-hour; but other data in the study suggest transmission costs of about $17 per megawatt-hour, a figure roughly comparable to the $15 median reported in the survey noted above.

A comprehensive comparison of various cost categories across generation types has been published by the Energy Information Administration. The data show that conventional generation---coal and natural gas combined cycle---has transmission costs

[6] Andrew Mills, Ryan Wiser, and Kevin Porter, "The Cost of Transmission for Wind Energy: A Review of Transmission Planning Studies," Lawrence Berkeley National Laboratory, LBNL-1471E, February 2009, p. vii, at http://eetd.lbl.gov/EA/EMP/reports/lbnl-1471e.pdf.

of about $3.60 per megawatt-hour, less than half those of wind generation ($8.40) and about a third those of thermal solar generation ($10.40). These projections for transmission costs are consistent with the hypothesis that wind and solar power are highly constrained in terms of capacity factors and sites, and so impose higher transmission costs than is the case for conventional generation.

Low Availability and Intermittency. Electric energy in large amounts cannot be stored at low cost in batteries due to technological limitations; only indirect storage in the form of water in dams is economic. This reality means that the production and consumption of electricity in a given power network must be balanced constantly in order to prevent blackouts, and more generally to preserve system reliability. Because unexpected surges in demand and/or outages of generating equipment can occur, backup generation capacity must be maintained; such backup capacity is termed the "operating reserve" for the given network. This operating reserve is of two types; the first is the "spinning reserve," that is, generators already connected to the network, the output of which can be increased by raising the torque applied to the generating turbines. The typical system requirement is that spinning reserves be 50 percent or more of total operating reserves. The second component of operating reserves is the supplemental reserve, which comprises generation capacity that can be brought on line within five to ten minutes and/or electric power that can be obtained quickly from other networks or by withholding power being distributed to other networks. Additional reserve capacity often is provided by generators that require up to an hour to come on line; this backup capacity is not included in measures of the operating reserve for a system because of the length of time required for availability.

Electric supply systems respond to growing demands ("load") over the course of a day (or year) by increasing output from the lowest-cost generating units first, and then calling upon successively more-expensive units as electric loads grow toward the daily (or seasonal) peak. Because of the uncertainties caused by the unreliability of wind and sunlight, most electric generation capacity fueled by renewable energy sources cannot be assumed to be available upon demand; system planning and optimization cannot assume that such power will be available when it is expected to be most economic. Accordingly, it cannot be scheduled (or "dispatched"). Instead, it requires backup generation capacity to preserve system reliability.

And so the cost of that needed backup capacity becomes a crucial parameter usually not mentioned in public discussions of wind and solar power. One study, using figures from the California Independent System Operator, projects that an increase in California renewable generation capacity between 2009 and 2020 would be about 17.7 gigawatts (GW) for a 20 percent renewable requirement, and about 22.4 GW for the 33 percent requirement.[7] The projected needs for backup capacity (of varying types) are, respectively, 0.8 GW (or 4.5 percent) and 4.8 GW (or 21 percent).

[7] See KEMA, Inc., "Research Evaluation of Wind Generation, Solar Generation, and Storage Impact on the California Grid," June 2010, p. 1, at http://www.ovcr.ucla.edu/uploads/file/CA%20Energy%20Commission_PIER%20Final%20Project%20Report_June%202010.pdf.

What would that backup power cost? U.S. wind and solar generation capacity in 2009 was about 34,000 MW. If we assume, conservatively, that this renewable capacity has required investment in backup capacity of about 3 percent (rather than 4.5 percent), that requirement would be about 1000 MW. Cost estimates published by the EIA suggest that this backup capacity has imposed fixed capital and operations and maintenance costs of about $1.7 billion, variable operating costs of approximately $2.00-$4.50 per megawatt-hour, and total costs per megawatt-hour of about $368.[8]

That rough estimate is likely to be biased downward. Because state renewables requirements require system operators to take renewable power when it is available, conventional backup generation must be cycled---that is, in effect turned on and off---in coordination with the availability of the renewable generation. In particular for coal-fired generation, but also for gas combined-cycle backup generation, this means that the conventional assets cannot be operated as efficiently as would be the case were they not cycled up and down in response to wind or solar generation conditions. A recent study of the attendant emissions effects for Colorado and Texas found that requirements for the use of wind power impose significant operating and capital costs because of cycling needs for backup generation---particularly coal plants---and actually exacerbate air pollution problems.[9]

The EIA estimates wind (onshore) and solar costs in 2016 at about $149 and $257-396 per megawatt-hour, respectively; if we add the rough estimate for backup costs, the total is about $517 for wind and $625-$764 for solar generation. The EIA estimates for gas- or coal-fired generation are about $80-$110 per megawatt-hour.[10] Accordingly, the projected cost of renewable power in 2016 including the cost of backup capacity is at least five times higher than that for conventional electricity.

At the same time, outages of wind capacity due to weak wind conditions are much more likely to be correlated geographically than outages of conventional plants, for the obvious reason that weak winds in part of a given region are likely to be observed in tandem with weak winds in other parts of that region. Because appropriate regions for thermal solar sites and photovoltaic systems are concentrated geographically, the same correlation problem is likely to affect solar electric generation as well.

The higher cost of electricity generated with renewable energy sources is only one side of the competitiveness question; the other is the value of that generation, as not all electricity is created equal. In particular, power produced at periods of peak demand is more valuable than off-peak generation, whether during a given daily cycle or across annual seasons. In this context, wind generation in particular is problematic because in

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[8] EIA, *Electricity Market Module*, release date April 2010, p. 91 (Table 8.2), at http://www.eia.gov/oiaf/aeo/assumption/pdf/electricity.pdf#page=3.

[9] See Bentek Energy, *How Less Became More: Wind, Power and Unintended Consequences In the Colorado Energy Market*, April 16, 2010, pp. 25-33, at http://www.wind-watch.org/documents/wp-content/uploads/BENTEK-How-Less-Became-More.pdf.

[10] See EIA, *op. cit.*, fn. 5.

general there is an inverse relationship between the daily hours of peak demand and wind velocities, and between peak summertime demands and peak wintertime wind velocities: Winds tend to blow at night and in the winter.

II. The Central Rationales for Renewables Subsidies: A Critique

The central arguments in support of subsidies for renewable power are numerous and varied, but generally fall into the following categories:

- Renewable energy as an "infant industry";
- Leveling the playing field: offsets for the subsidies enjoyed by conventional generation;
- The adverse environmental effects of conventional generation;
- Resource depletion or "sustainability"; and
- Renewable electricity as a source of expanded "green" employment.

The Infant Industry Argument. This argument begins with the assumption that new technologies often cannot compete with established ones because the available market at the beginning is too small for important scale economies to be exploited, and because the downward shifts in costs that might result from a learning process cannot be achieved without substantial expansion in market share. Accordingly, policy support for expansion of the newcomers' share of the market is justified as a tool with which to allow the achievement of both scale and learning efficiencies.

One obvious problem with this argument is that the market for electric power already has several competing technologies, each of which began with a small market share virtually by definition. More generally, many industries employing competing technologies are characterized by the presence of scale economies and/or learning efficiencies; but market forces operating through domestic and international capital markets provide investment capital in anticipation of future cost savings and higher economic returns. Accordingly, the infant industry argument is a *non sequitur*: The market can foresee the potential for scale and learning efficiencies, and invest accordingly. There is no efficiency rationale for subsidies or other policy support.

In any event, the narrower issue is whether important learning and/or scale efficiencies remain available to be exploited for cost reductions for wind or solar generation. The pattern of average costs over time, controlling for the size of projects, should yield inferences about the remaining importance of learning efficiencies; if the infant industry argument is correct, we should observe in the data over the last decade or two declining costs for renewable electricity. For wind generation, the Department of Energy reports data on average project cost per MW over time, beginning in the early 1980s.[11]

[11] See Department of Energy, "2009 Wind Technologies Market Report," August 2010, at Figure 27, at http://www1.eere.energy.gov/windandhydro/pdfs/2009_wind_technologies_market_report.pdf.

These data show a rough pattern of declining average costs from the 1980s through about 2001, and then rising average costs through 2009: from about $4800 per MW in 1984 to about $1300 per MW in 2001, and rising to about $2100 in 2009, all in constant year 2009 dollars. Since these data are weighted by capacity, the rising average costs per wind MW after 2000-2001 suggest that further learning efficiencies no longer are available to be exploited, unless, perhaps, future technological advances are made.[12]

Other DoE data are available on average costs by project size for wind projects installed in the 2007-2009 period.[13] The short time period reduces the likely impact of learning efficiencies, yielding important information about the availability of scale economies. The data show that scale economies are important only for small wind projects (about $2700 per MW for projects smaller than 5 MW), and that average costs either constant or slightly increasing (about $1800-$2000 per MW) characterize projects larger than about 20 MW or thereabouts.

Reliable time-series data on costs for photovoltaic and thermal solar systems are more difficult to find in the literature; perhaps the only consistent series is provided by the EIA for 2000-2009.[14] These data show a decline in costs per MW for both photovoltaic and thermal systems early in the decade, suggesting the exploitation of learning efficiencies, and, perhaps, the use of more suitable sites. The data show also an increase in costs per MW after 2002; this suggests that no further learning efficiencies are available to be exploited and/or that the problem of rising site costs is significant.[15] On the other hand, a different data analysis for photovoltaics only, published by the DoE, shows a decline in the capacity-weighted average installed cost between 1998 and 2008, from $10.80 per watt (2008 dollars) to $7.50 per watt.[16] In short: The data are mixed in the case of solar generation systems. The "infant industry" assumption of significant learning and/or scale economies as a barrier to adoption of renewable technologies at best is far from obviously correct; the bilk of the available data suggest that it is incorrect.

<u>*Leveling the Playing Field.*</u> The second central argument made in favor of policy support for renewables is essentially a level-playing-field premise: Because conventional generation benefits from important tax preferences and other policy support, renewables cannot compete without similar treatment. A recent EIA analysis presents data from

[12] Note that an assumption of future technological advances does not imply enhanced future competitiveness, in that technological advances are likely affect conventional and renewable technologies alike.
[13] *Ibid.*
[14] Energy Information Administration, *Electricity Market Module* discussions within the "Assumptions" chapters, various years, at http://www.eia.gov/oiaf/archive.html.
[15] For photovoltaic systems, capacity costs fell from $5386 per MW in 2000 to $4744 in 2002, and then increased steadily to $6239 in 2009. For thermal systems the figures were $3679 in 2000, $3194 in 2002, and $5237 in 2009.
[16] Department of Energy, "Solar Technologies Market Report," January 2010, at Figure 3.9, at http://www1.eere.energy.gov/solar/pdfs/46025.pdf.

which federal subsidies and support per kilowatt-hour produced by different technologies can be compared.[17] These data are presented in Table 1.[18]

Table 1
FY2010 Electricity Production Subsidies and Support per megawatt-hour
(year 2010 dollars)

Fuel/Technology	Dollars per megawatt-hour
Natural Gas, Petroleum Liquids	0.63
Coal (pulverized)	0.64
Hydroelectric	0.84
Biomass	2.00
Nuclear	3.10
Geothermal	12.50
Wind	52.48
Solar	968.00

These data show that federal solar and wind subsidies in fiscal year 2010 were far higher---by two or three orders of magnitude---than those enjoyed by fossil fuels, nuclear, or hydroelectric generation. Accordingly, it is clear that solar and wind technologies are not at a competitive disadvantage because of average subsidies enjoyed by conventional generation; quite the reverse is true.

A more direct calculation of marginal subsidies and support has been reported by Metcalf, yielding estimates of effective marginal tax rates on investments in alternative electric generation technologies. Computation of such effective marginal tax rates incorporates the many subsidies and preferences that affect choices among those alternatives, and so offers a direct test of the degree to which federal policies favor given technologies over others.[19] Table 2 summarizes his findings, which are for 2007.

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[17] See the EIA data at http://docs.wind-watch.org/US-subsidy-2010.pdf.

[18] Other things held constant, subsidies that affect the marginal (or incremental) cost of generation or the per-unit prices received by particular technologies are likely to affect market prices, even under standard rate-of-return regulation, and so might create a competitive disadvantage for other technologies not receiving equivalent treatment. An example is the per-unit production tax credit for renewable power. Other credits might improve profitability without affecting marginal costs or prices directly; investment tax credits for renewables are a good example. The latter would attract additional investment into the industry over time, thus perhaps affecting market prices, but that price effect would be felt by all producers regardless of which actually received the subsidy. At the same time, even such subsidies as the latter would serve to reduce or eliminate whatever competitive disadvantages confront renewables as a result of policies in support of conventional generation.

[19] See Gilbert E. Metcalf, "Investment in Energy Infrastructure and the Tax Code," in Jeffrey R. Brown, ed., *Tax Policy and the Economy, Volume 24*, Chicago: University of Chicago Press Journals, 2010, pp. 1-33. See also Gilbert E. Metcalf, "Federal Tax Policy Towards Energy," NBER Working Paper No. 12568, October 2006, at http://www.nber.org/papers/w12568.pdf; and Gilbert E. Metcalf, "Taxing Energy In the United States: Which Fuels Does the Tax Code Favor?", Manhattan Institute Center for Energy Policy and the Environment, Report No. 4, January 2009, at http://www.manhattan-institute.org/html/eper_04.htm.

Table 2
Metcalf Findings on Effective Marginal Tax Rates For Electric Generation Investment
(percent)

Technology	Current Law	No Tax Credits	Economic Depreciation
Coal (pulverized)	38.9	38.9	39.3
Gas	34.4	34.4	39.3
Nuclear	-99.5	32.4	-49.4
Solar Thermal	-244.7	12.8	-26.5
Wind	-163.8	12.8	-13.7

Source: Metcalf (2010), *op. cit.*, fn. 19.
Note: Current law is as of 2007.

The three columns present the Metcalf calculations of effective marginal tax rates under current law (as of 2007), under a regime without production and investment tax credits, and with economic depreciation assumed in place of accelerated depreciation, respectively.[20] Under current law, solar thermal and wind generation investments receive large net percentage marginal subsidies (negative effective marginal tax rates) far larger than those enjoyed by nuclear investments; and coal and gas investments face effective tax rates greater than zero. If the tax credits are assumed away, solar thermal and wind investments face effective tax rates roughly one-third those of the other technologies. If economic depreciation replaces accelerated depreciation, nuclear investment enjoys a negative effective marginal tax rate (tax subsidy) larger (in absolute value) than those for solar and wind investments; but coal and gas investments face effective marginal tax rates of over 39 percent.

The Metcalf calculations of effective marginal tax rates under current law suggest strongly that the "offsetting subsidy" rationale for public support for solar and wind investments is weak: Coal and gas investments face positive effective marginal tax rates, and new nuclear investment no longer is a serious competitive threat.[21] Moreover, the effective subsidies enjoyed by solar and wind generation are far greater than those needed to level the playing field with respect to nuclear generation.[22]

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[20] Metcalf uses an exponential depreciation rate rather than straight-line depreciation as an approximation of economic depreciation over the lives of given investments.

[21] The last nuclear generation reactor to begin operation is the Watts Bar-1 plant in Tennessee, which began commercial operation on May 27, 1996. See EIA at http://www.eia.gov/cneaf/nuclear/page/operation/statoperation.html. However, the Tennessee Valley Authority has announced plans to complete Watts Bar-2.

[22] The playing field is biased in favor of renewables for two additional reasons, the first of which is the implicit subsidy for backup generation capacity and transmission costs: Such costs are a direct effect of investment in renewable capacity, but are spread across electricity consumption from all sources. The Federal Energy Regulatory Commission, in a recent case involving the Midwest Independent Transmission Operator, ruled that the transmission costs attributable to wind generation may be allocated to consumers regardless of the amount of wind power actually consumed by any given ratepayer. This ruling essentially

<u>*Adverse External Effects of Conventional Generation.*</u> A negative "externality" is an adverse effect of economic activity the full costs of which are not borne by the parties engaging directly in the activity yielding the adverse effect. A simple example is the emission of effluents into the air as a byproduct of such industrial processes as power generation. There is no dispute that power generation with fossil fuels imposes adverse environmental effects in the form of sulfur dioxide, nitrogen oxides, mercury, particulates, and other effluents. Accordingly, the EPA and the states have established detailed programs for defining emission standards and for implementing attendant investment and enforcement programs.

If the negative externalities yielded by conventional generation are not internalized fully by current environmental policies---that is, if buyers and producers are not confronted with the full costs of the environmental costs that they impose on others---then the costs of conventional generation as perceived by the market would be (artificially) lower than the true social costs. At the same time, the unreliable nature of wind and solar generation imposes a requirement for costly backup capacity, as discussed above.[23] And so the question to be addressed is as follows: Given the magnitude of those externalities as estimated in the technical literature, are the additional (or marginal) costs of backup capacity imposed by renewable generation sufficient to offset any artificial cost advantage enjoyed by conventional generation?

A number of analyses of the externality costs of U.S. electricity generation were conducted during the 1980s and 1990s. These studies differ somewhat in terms of methodology and focus, but offer a range of estimates useful in terms of the question addressed here. In summary: The estimated externality costs for coal range from 0.1 cents per kilowatt-hour to 26.5 cents per kilowatt-hour. For gas generation, the range is 0.1-10.2 cents per kilowatt-hour. For oil, nuclear, and hydro generation, the respective ranges are 0.4-16.5 cents per kilowatt-hour, 0-4.9 cents per kilowatt-hour, and 0-2.1 cents per kilowatt-hour.

The highest estimated figure for coal generation is 26.5 cents per kilowatt-hour, or $265 per megawatt-hour. From the discussion above, a conservative estimate of the cost of backup capacity for existing wind and solar generation is about $368 per megawatt-hour, or roughly 37 cents per kilowatt-hour. Accordingly, if all conventional generation were coal-fired, existing wind and solar capacity imposes a backup cost "externality"

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spreads such costs across the entire grid; accordingly, the transmission costs associated with wind generation are not reduced but instead are hidden somewhat from calculations of the marginal cost of wind power. See the FERC Conditional Order, Docket No. ER10-1791-000, December 16, 2010, at http://www.ferc.gov/whats-new/comm-meet/2010/121610/E-1.pdf. Second, public subsidies for renewable power, whether in the form of direct outlays or indirect tax preferences, impose costs upon the private sector larger than the subsidies themselves, because of the excess burden (or "deadweight losses") imposed by the tax system. Essentially, the private sector becomes smaller by more than a dollar when it is forced to send a dollar to the federal government. For a nontechnical discussion, see Martin A. Feldstein, "The Effect of Taxes on Efficiency and Growth," *Tax Notes*, May 8, 2006, pp. 679-684.

[23] See the discussion *supra.*, pp. 8-10.

about 39 percent higher than the environmental externality costs of conventional generation under the implausible assumption that none of the conventional externalities have been internalized under current environmental policy.

But in fact coal generation is a bit less than 45 percent of total U.S. generation; gas generation is about 23 percent, nuclear generation is about 20 percent, hydroelectric generation is about 7 percent, and renewables and other miscellaneous technologies make up the rest. If we use those figures and the highest estimates by fuel type noted above to compute a weighted-average externality cost for nonrenewable generation, the externality cost per conventional kilowatt-hour is about 15.5 cents, or $155 per megawatt-hour. If we use instead the midpoints of the externality ranges listed above, the weighted average externality cost is 7.8 cents per kilowatt-hour, or $78 per megawatt-hour. Relative to the backup cost "externality" ($368 per megawatt-hour) imposed by wind and solar investments alone, those figures are sufficiently low to cast substantial doubt upon the externality argument for renewables subsidies: Current environmental regulation must internalize some substantial part of conventional externalities, and federal and state subsidies, both explicit and implicit, and requirements for minimum market shares for renewables also have the effect of offsetting any artificial cost advantage enjoyed by conventional generation as a result of uninternalized externalities.

Note that in terms of economic efficiency, subsidies for renewables intended to offset the (assumed) uninternalized external costs of conventional generation are a "second-best" policy at best. Such subsidies would reduce the (inefficient) competitive advantage of conventional generation yielded by the presence of some social costs unreflected in prices; but they would not improve the efficiency of costs or prices for conventional generation. And by biasing the perceived costs and prices of renewable generation downward, the subsidies would result in a total electricity market that would be too large. In short: The externality argument in favor of policy support for renewable electricity generation is exceedingly weak, far more so than commonly assumed.

The Resource Depletion or "Sustainability" Argument. "Renewable" energy has no uniform definition; but the (assumed) finite physical quantity of conventional energy sources is the essential characteristic differentiating the two in most discussions. In a word, conventional energy sources are depletable. In contrast, sunlight and wind flows replenish themselves, a central component of "sustainability," perhaps a broader concept, which has been defined by the Environmental Protection Agency as "the satisfaction of basic economic, social, and security needs now and in the future without undermining the natural resource base and environmental quality on which life depends."[24]

As an aside, the energy content of sunlight and wind is finite, regardless of self replenishment. They contain only so much convertible energy, and they are not always available. Moreover, the same is true for the other resources---materials, land, etc.---upon which the conversion of such renewable energy into electricity depends. In any event, the basic "sustainability" concept seems to be that without policy intervention, market forces will result in the depletion (or exhaustion) of a finite resource.

[24] See the EPA discussion (February 2001) at http://epa.gov/sustainability/basicinfo.htm.

Accordingly, subsidies and other support for renewable power generation are justified as tools with which to slow such depletion and to hasten the development of technologies that would provide alternatives for future generations.

That argument is deeply problematic. Putting aside the issue of whether government as an institution has incentives to adopt a time horizon longer than that relevant for the private sector, the profit motive provides incentives for the market to consider the long-run effects of current decisions. The market rate of interest is a price that links the interests of generations present and future. If a resource is being depleted, then its expected future price will rise, other things held constant. If that rate of price increase is greater than the market interest rate, then owners of the resource have incentives to reduce production today---by doing so they can sell the resource in the future and in effect earn a rate of return higher than the market rate of interest---thus raising prices today and reducing expected future prices. In equilibrium---again, other factors held constant---expected prices should rise at the market rate of interest.[25] Under market institutions, it is the market rate of interest that ties the interests of the current and future generations, by making it profitable currently to conserve some considerable volume of exhaustible resources for future consumption.[26] Because of the market rate of interest, market forces will never allow the depletion of a given resource.

Accordingly, the market has powerful incentives to conserve, that is, to shift the consumption of some resources into future periods. That is why, for example, not all crude oil was used up decades ago even though the market price of crude oil always was greater than zero, which is to say that using it would have yielded value. In short, the "sustainability" argument for policy support for renewable electricity depends crucially upon an assumption that the market conserves too little and that government has incentives to improve the allocation of exhaustible resources over time. That is a dual premise for which the underlying rationale is weak and with respect to which little persuasive evidence has been presented.

"Green Jobs": Renewable Power As A Source of Expanded Employment. A common argument in support of expanded renewable power posits that policies in support of that goal will yield important benefits in the form of complementary employment growth in renewables sectors, and stronger demand in the labor market in the aggregate. Both of those premises are almost certainly incorrect.

The employment in renewables sectors created by renewables policies actually would be an economic cost rather than a benefit for the economy as a whole. Suppose that policy support for renewables (or for any other sector) had the effect of increasing the demand for high-quality steel. That clearly would be a benefit for steel producers, or

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[25] In reality the long run prices of most exhaustible natural resources have declined (after adjusting for inflation), in large part because of technological advances in discovery, production, and use.

[26] Strictly, speaking, it is not the price of the resource that should rise at the market rate of interest; instead the total economic return to holding the resource for future use should equal the market rate of interest. That economic return includes expected price changes and capital gains, expected cost savings, and the like.

more broadly, for owners of inputs in steel production, including steel workers. But for the economy as a whole, the need for additional high-quality steel in an expanding renewable power sector would be an economic cost, as that steel (or the resources used to produce it) would not be available for use in other sectors. Similarly, the creation of "green jobs" as a side effect of renewables policies is a benefit for the workers hired (or for those whose wages rise with increased market competition for their services). But for the economy as whole, that use of scarce labor is a cost because those workers no longer would be available for productive activity elsewhere.[27]

There is the further matter that an expansion of the renewable electricity sector must mean a decline in some other sector(s), with an attendant reduction in resource use there; after all resources in the aggregate are finite. If there exists substantial unemployment, and if labor demand in renewables is not highly specialized, a short-run increase in total employment might result. But in the long run---not necessarily a long period of time---such industrial policies cannot "create" employment; they can only shift it among economic sectors. In short, an expanding renewables sector must be accompanied by a decline in other sectors, whether relative or absolute, and creation of "green jobs" must be accompanied by a destruction of jobs elsewhere. Even if an expanding renewables sector is more labor-intensive (per unit of output) than the sectors that would decline as a result, it remains the case that the employment expansion would be a cost for the economy as a whole, and the aggregate result would be an economy smaller than otherwise would be the case.[28] There is no particular reason to believe that the employment gained as a result of the (hypothetically) greater labor intensiveness of renewables systematically would be greater than the employment lost because of the decline of other sectors combined with the adverse employment effect of the smaller economy in the aggregate. There is in addition the adverse employment effect of the explicit or implicit taxes that must be imposed to finance the expansion of renewable power.

Because renewable electricity generation is more costly than conventional generation, policies driving a shift toward heavier reliance upon the former would increase aggregate electricity costs, and thus reduce electricity use below levels that would prevail otherwise. The 2007 EIA projection of total U.S. electricity consumption in 2030 was about 5.17 million gWh.[29] The latest EIA projection for 2030 is about 4.31 million gWh, a decline of about 16.6 percent.[30] The change presumably reflects some combination of assumptions about structural economic shifts, increased conservation,

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[27] Considerable employment would be created if policies encouraged ditch-digging with shovels (or, in Milton Friedman's famous example, spoons) rather than heavy equipment. Such employment obviously would be laughable, that is, an obvious economic burden. There is no analytic difference between this example and the "green jobs" rationale for renewables subsidies.

[28] Many advocates of renewables subsidies assert that solar and wind power is more labor intensive than conventional generation. The assumption of greater labor intensity for renewable power production is dubious: The operation of solar or wind facilities does not employ large amounts of labor, and it is far from clear that construction of solar or wind facilities is more labor intensive than construction of conventional generation facilities.

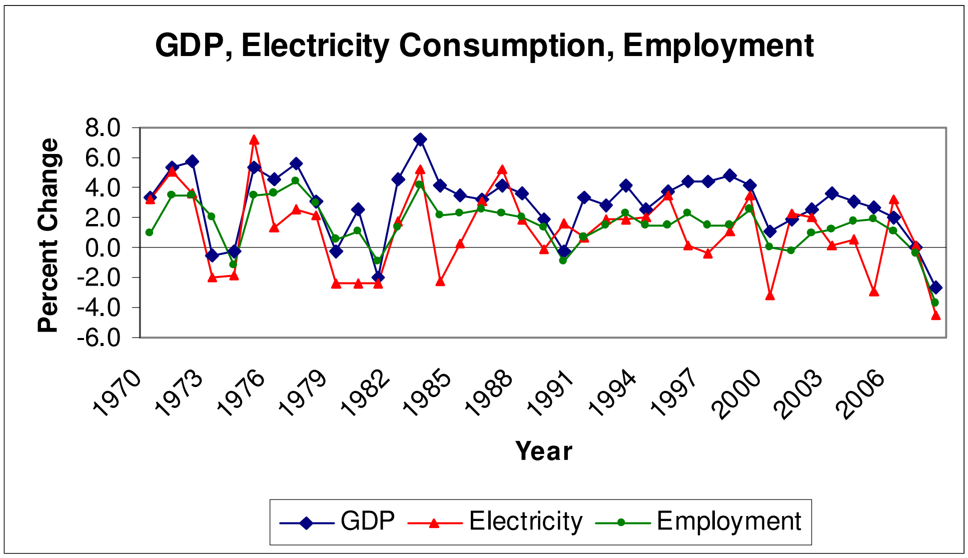
[29] See EIA at http://www.eia.doe.gov/oiaf/archive/aeo07/aeoref_tab.html, at Table 2.

[30] See EIA at http://www.eia.gov/forecasts/aeo/tables_ref.cfm, at Table 8.

substitution of renewables for some conventional generation, and a price increase from about 8.8 cents per kilowatt-hour to 9.0 cents (in 2009 dollars).

It would be surprising if that reduction in total U.S. electricity consumption failed to have some employment effect. Figure 1 displays data on percent changes in real GDP, electricity consumption, and employment for the period 1970 through 2009.[31]

Figure 1



It is obvious from the aggregate trends that electricity use and labor employment are complements rather than substitutes; the simple correlation between the percent changes for the two is 0.61, meaning, crudely, that a percent change in one tends to be observed with a 0.61 percent change in the other, in the same direction. The simple GDP/electricity and GDP/employment correlations are 0.67 and 0.85, respectively.

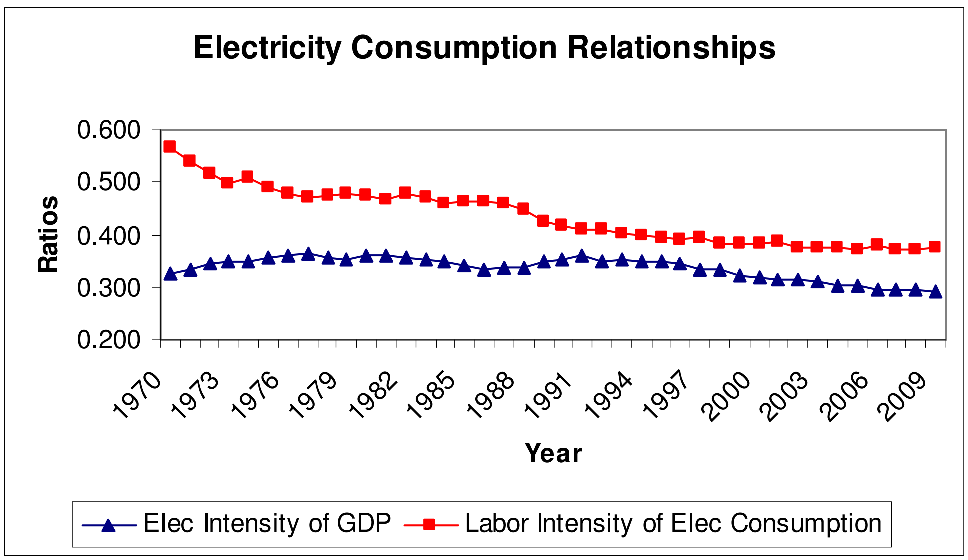
The correlations by themselves are not evidence of causation, the determination (or refutation) of which requires application (and statistical testing) of a conceptual model. But the data displayed in Figure 1 make it reasonable to hypothesize that the higher costs and reduced electricity consumption attendant upon expansion of renewable generation would reduce employment; and they certainly provide grounds to question the common assertion that policies in support of expanded renewable electricity generation would yield increases in aggregate employment as a side effect, putting aside whether such increases would be a net economic benefit for the economy as a whole.

[31] Sources: For real GDP, see Bureau of Economic Analysis at http://www.bea.gov/national/nipaweb/SelectTable.asp?Popular=Y, and author computations; for civilian employment, see Bureau of Labor Statistics at http://www.bls.gov/cps/cpsaat1.pdf; and for electricity consumption, see EIA at http://www.eia.doe.gov/emeu/aer/pdf/pages/sec8_5.pdf.

It certainly is possible that the historical relationship between employment and electricity consumption will change. Technological advances are certain to occur; but the prospective nature and effects of those shifts are difficult to predict.[32] The U.S. economy may evolve over time in ways yielding important changes in the relative sizes of industries and sectors; but, again, the direction of the attendant shifts in employment and electricity use is ambiguous.

But there exists no evidence with which to predict that a reduction in electricity consumption would yield an increase in employment. Like all geographic entities, the U.S. has certain long-term characteristics---climate, available resources, geographic location, trading partners, *ad infinitum*---that determine in substantial part the long-run comparative advantages of the economy in terms of economic activities and specialization. Figure 2 presents the historical paths of the electricity intensity of U.S. GDP (kilowatt-hour per dollar of output) and of the labor intensity of U.S. electricity consumption (employment per kilowatt-hour).[33]

Figure 2



During 1970-2009, the electricity intensity of GDP has increased and declined over various years, but for the whole period has declined slightly at a compound annual rate of about 0.3 percent. The labor intensity of U.S. electricity consumption---in a sense, the employment "supported" by each increment of electricity consumption---has declined

[32] Note that greater energy "efficiency" in any given activity can yield an increase in actual energy consumption, if the elasticity of energy demand with respect to the marginal cost of energy use is greater than one. If, for example, air conditioning were to become sufficiently "efficient" in terms of energy consumption per degree of cooling, it is possible that air conditioners would be run so much that total energy consumption in space cooling would increase. A tax, on the other hand, whether explicit or implicit, increases the price of energy use, and so unambiguously reduces energy consumption.

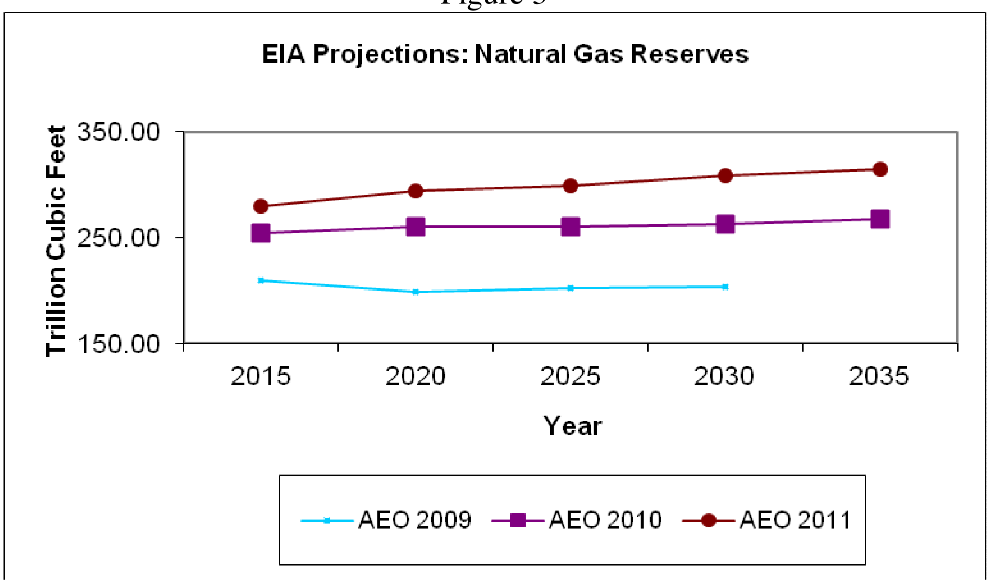
[33] Sources: See fn. 31.

more-or-less monotonically over the entire period, at an annual compound rate of about 1.05 percent.[34] This may be the result largely of changes in the composition of GDP (toward services), and perhaps the substantial increase in U.S. labor productivity in manufacturing. But these data do not suggest that a reduction in electricity consumption would yield an increase in aggregate employment; instead, they suggest the reverse. In short, while the employment/electricity relationship may have declined over time, there is no evidence that it is unimportant in an absolute sense, and it is far from inverse.

III. Implications of Recent Developments in the Market for Natural Gas

Recent technological advances in the production of natural gas from shale formations and from coal beds have increased estimated natural gas reserves sharply.[35] Figure 3 illustrates the resulting sharp increase over the last two years in projected gas reserves. Between the 2010 and 2011 EIA estimates, projected natural gas reserves through 2025 have increased about 15 percent. The 2011 projection is about 17 percent higher for 2030 and for 2035.[36]

Figure 3



[34] These data in Figure 2 were scaled upward by a factor of 10 for ease in presentation.
[35] For a brief discussion, see EIA, "What Is Shale Gas and Why Is It Important?," at http://www.eia.gov/energy_in_brief/about_shale_gas.cfm.
[36] See EIA at http://www.eia.gov/oiaf/archive/aeo/aeoref_tab.html, at Tables 13 and 14; and EIA at http://www/eia.gov/forecasts/aeo/tables_ref.cfm, at Tables 13 and 14.

As a result, the EIA has reduced its projections of future prices for natural gas delivered for electric generation. Between the two sets of projections (2010 and 2011), prices fall by about 15-23 percent over the period 2015-2035.[37]

Drawing the obvious conclusion, the 2011 EIA projection of combined cycle gas capacity for 2035 is about 6 percent higher than that made a year earlier. *But the projections of non-hydroelectric renewable capacity in 2030-2035 fall by about 16-21 percent over the course of only one year.*[38] These EIA projections of capacity investment in substantial part reflect the fact that gas and renewable generation technologies are substitutes, and the projected decline in delivered gas prices exacerbates the inherent competitive disadvantages borne by renewable technologies.

IV. Concluding Observations

As a crude generalization, the experience in Europe in the context of renewable electricity can be summarized as high costs combined with low reliability.[39] That is the U.S. experience as well, an outcome unavoidable given the basic economic realities afflicting wind and solar power electric generating technologies. Accordingly, renewable power generation has achieved only a small market share in the U.S., and official projections are for slow growth at best, notwithstanding large subsidies and other policy support.

This market resistance to investment in renewable generation capacity can be explained by the problems intrinsic to renewable power---that is, the inherent limitations on its competitiveness---that public policies can circumvent or neutralize only at very substantial cost. Those problems can be summarized as:

- unconcentrated energy content;
- siting constraints and resulting high costs for transmission; and
- the costs created by low capacity factors, the intermittent nature of wind flows and sunlight, and the resulting need for backup capacity.

Moreover, the five central analytic arguments that dominate the political/policy support for renewables are highly problematic: The "infant industry argument is inconsistent with the cost evidence on renewables. The subsidies enjoyed by renewables

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[37] *Ibid.*

[38] For the capacity projections in the 2010 *Annual Energy Outlook*, see http://www.eia.gov/oiaf/archive/aeo10/aeoref_tab.html, at Table 9. For the capacity projections in the 2011 *Annual Energy Outlook* (early edition), see http://www.eia.gov/forecasts/aeo/tables_ref.cfm, at Table 9.

[39] See Kenneth P. Green, "The Myth of Green Energy Jobs: The European Experience," American Enterprise Institute, Energy and Environment Outlook No. 1, February 2011, at http://www.aei.org/docLib/EEO-2011-02-No-2-g.pdf. See also Kenneth P. Green, "On Green Energy: A Dutch (Re)Treat," *The American*, April 10, 2011, at http://www.american.com/archive/2011/april/on-green-energy-a-dutch-re-treat. For an analysis of capacity factors for UK wind generation even lower than expected, see A*nalysis of UK Wind Power Generation: November 2008 to December 2010*, John Muir Trust, March 2011, at http://www.jmt.org/assets/pdf/wind-report.pdf.

outweigh by far those bestowed upon conventional generation technologies. The costs of backup capacity made necessary by renewable power---an "externality" that renewable power imposes upon the electric system writ large---are greater than any negative externalities created by conventional generation and assumed not to have been corrected by current policies. And the "sustainability" and "green employment" rationales are exceedingly weak.

These realities suggest that the purported social benefits of policy support for renewables are illusory. Moreover, ongoing supply and price developments in the market for natural gas are likely to weaken further the competitive position of renewable power generation. At the same time, the subsidies and mandates that have been implemented in support of renewable electricity impose nontrivial costs upon the taxpayers and upon consumers in electricity markets. The upshot is the imposition of substantial net costs upon the U.S. economy as a whole even as the policies bestow important benefits upon particular groups and industries, thus yielding enhanced incentives for innumerable interests to seek favors from government. As has proven to be the case in most contexts, the outcomes of market competition, even as constrained and distorted by tax and regulatory policies, are the best guides for the achievement of resource allocation that is most productive. As federal policymakers address the ongoing issues and problems afflicting renewable electricity generation, the realities of this recent history provide a useful guide for policy reform.