

Testimony before
Senate Energy and Water Development Appropriations Subcommittee

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Mr. Chairman and Members of the Subcommittee:

I am Dallas Burtraw, a Senior Fellow at Resources for the Future in Washington DC. Let me thank you for the invitation to be here today. As for my background, I have a Ph.D. in economics from the University of Michigan. I have been working in areas related to the energy, environment, and cost benefit analysis for ten years at Resources for the Future (www.rff.org), which is a nonprofit, nonadvocacy research institution that specializes in issues related to energy, natural resources and the environment. The opinions I express are my own and not those of Resources for the Future, which takes no institutional position on regulatory or legislative matters.

With Joel Darmstadter and Karen Palmer, both Senior Fellows at Resources for the Future, and Jim McVeigh from Indiana University, we recently completed a study of renewable energy as a resource in electric power generation (“Winner, Loser or Innocent Victim: Has Renewable Energy Performed as Expected?”). Specifically, we studied the performance of renewable energy technologies with respect to specific goals often set forth as justification for public support over the last three decades. This study was supported and published by the Renewable Energy Policy Project (www.repp.org), and is forthcoming in the journal *Solar Energy*. I am thrilled to have the opportunity to share our insights. In my brief oral presentation, I would like to focus on the first four pages of my submitted testimony that captures the main thrust of our findings. I would additionally be pleased if the full report could be made part of the hearing record.

Americans have argued long, hard, and often loudly in the last three decades about where their energy should come from. Concerns about the environment, the economy, national energy security, equity, monopoly power, and the role of the public sector have fueled this debate. One outcome has been public policy and public-sector support—albeit sometimes faltering—for renewable energy technologies.

Nearly thirty years into this public discussion, however, the reality is that renewable technologies have failed to emerge as a prominent component of the U.S. energy infrastructure. This failure may have created the impression that these technologies have not met the goals and claims of proponents, and that therefore after several decades of support without success, it is time to *pull the plug* on renewables. We sought to investigate with some rigor the premise of this statement - that is, the notion that renewable technologies have been largely a disappointment.

We located about sixty studies authored over the last three decades and reviewed twenty-five of them in detail. We evaluated five technologies used to generate electricity: biomass, geothermal, solar photovoltaics, solar thermal, and wind. We also evaluated projections for conventional technologies. Our findings lead us to the conclusion that any argument that public policy support for renewable technologies should be ended because “past efforts have been unsuccessful” is based on a faulty premise. Evaluations of the available evidence indicate that renewable technologies have lived up to some significant expectations and public policy goals.

In general, *market penetration* has been lower than expected. However, the *cost* of renewable technologies also has been lower than expected, and, in several cases significantly lower, even when compared to what seemed initially to be the optimistic projections of advocates for renewable energy. But, which of these measures is of greater relevance?

The more important measure of success would seem to us to be the cost of electricity generation compared with the expectations that served as the justification for

public-sector support. This is remarkable, given that renewable technologies have not significantly penetrated the market, nor have they attracted large-scale investment and production that can contribute to technological development or economies of scale in production, as many analysts anticipated when forming their cost projections.

At the same time, we must recognize the failure of (nonhydroelectric) renewables to emerge more prominently in the energy portfolio for the nation. However, that fact has more to do with unrelated decline in the cost of conventional generation. Developments in conventional energy markets (notably the emergence of a competitive world oil market), the success of public policy initiatives (for example, deregulation of natural gas, oil pipelines and railroads - a major factor in reducing the cost of coal-fired generation), and prospectively, restructuring of the electricity industry, promise to keep the cost of generation from conventional technologies low. Thus, while changes in the regulation, technology, and market structure of fossil fuels have been mostly beneficial for electricity consumers, they have also been frustratingly disappointing for the fate of renewable technologies, which have had to compete in this changing environment. Hence renewables may be seen as a loser amid the widespread success of an array of public policies and favorable trends in energy markets.

Our findings have three implications. First, considered in tandem, projections of generation and cost are not necessarily more accurate for conventional generation than for renewable generation. Experience does not suggest that forecasts about the future of renewable generation are more uncertain than forecasts of conventional generation.

Second, the rate of technological change might be expected to be greater for an emerging technology than for a mature one. However, it is important to realize that such change continues as well for mature technologies. Indeed, the rate of improvement in relatively mature conventional technologies such as coal and gas-fired generation may accelerate in the increasingly competitive environment of wholesale and retail competition in the electricity industry.

Third, the declining price of conventional generation constitutes a shifting baseline against which renewable technologies will have to continue to compete. Collectively these regulatory, technological, and market structure changes have reduced generation costs for conventional technologies and have also led to a dramatic improvement in their environmental performance (especially that of newly constructed generation facilities).

We believe that this outcome should not necessarily be taken to signify that public-sector support for renewable technologies has been misplaced. After all, fire insurance is not judged a failure if the house does not burn down. A modest degree of public-sector support for renewable technologies may be viewed as prudent precaution against the risks associated with too narrow a portfolio of conventional energy resources, even if those risks ultimately turn out to have been misplaced. The possibility of greenhouse-induced global warming is, of course, one such contingency.

However, in providing public support for the future development of renewables, there are a few guidelines that we suggest in order to maximize the payoff on this investment, drawing loosely on lessons from the study of economics. One suggestion is to maintain a stable level of support if possible, and to smooth the transition in changing the level of funding. This reduces the cost of start-ups and shut-downs, and provides a more creative setting for research. Second, the allocation of research funds to specific projects should provide competitive incentives that reward the most promising ideas, and should reflect the judgement of independent reviewers.

A Survey of Studies

To better understand how renewables have fit into the energy picture thus far and where they might be headed, we evaluated five technologies used to generate electricity: biomass, geothermal, solar photovoltaics, solar thermal, and wind. We compared the

actual performance of each of these energy sources against past projections that helped shape public policy goals over the last three decades. These projections related to the future share of these renewable technologies in total electricity generation and also their future costs. We also compared their performances against that of conventional electric power generation, based on projections of its cost and contribution to energy over the same thirty-year period.

To make these comparisons, we identified about sixty previous studies of renewable energy sources. But because the rigor of analysis varied tremendously, we reviewed in detail twenty-five of them. We then constructed criteria and used them to evaluate each study in order to develop weights that were applied in an aggregate analysis. We did not adjust the projections for potential differences in their underlying assumptions. For example, some projections assumed sustained high levels of government support for renewables. To the extent that their optimism was off base, performance was judged weaker than projected.

Projected Cost: On the Money

Our findings document a significant difference between the success of renewable technologies in penetrating the U.S. electricity generation market and in meeting cost-related goals, when compared with historic projections. In general, renewable technologies have failed to meet expectations with respect to market penetration. They have succeeded, however, in meeting expectations with respect to their cost. For every technology analyzed, successive generations of projections of what they would cost in the future have either agreed with previous projections or been more optimistic (predicted even lower costs).

We measured market penetration—that is, the contribution of technologies to electricity supply—in terms of the total amount of electricity generated. We measured cost of electricity at point of production, which incorporates capital, fuel, and operation

and maintenance (O/M) costs, as well as expected lifetime and capacity factors. The total costs of production over the lifetime of the generating facility were amortized in a straight-line fashion (just as payments for a standard home mortgage would be). This annual cost was divided by the average annual amount of electricity produced over that lifetime to calculate the levelized cost of electricity generation (COE). Cost data are reported in constant 1995 dollars.

To display the findings, the projections are organized by the decade when the studies were written (1970s, 1980s, and 1990s). Some of these findings are discussed below. Note that some of the figures use a logarithmic scale to display results.

Wind

Production. In the 1970s, projections for **wind**-generated electricity capacity were high. But studies during the following decades offered projections that were lower by an order of magnitude, due in large part to declining fossil fuel prices. As shown in Figure 1, a large shift downward in projections of generation occurred after the 1970s. Projections of generation and capacity from the 1990s are consistent with those from the 1980s.

Figure 1

Costs. Figure 2 illustrates that optimistic projections of a decline in the cost of electricity generated by **wind** have been realized or exceeded over time. Some early projections assumed that the exhaustion of good resource sites would prevent costs from falling. This has not occurred, however, in part because the inventory of sites identified to have strong resources has expanded and in part because technological advances in wind turbine technologies (see the preceding article) have improved profitability at lower wind speeds. Wind has a current cost of about 52 mills/kWh (ten mills = one cent) at existing facilities, close to the average cost of generation from conventional sources.

Figure 2

Solar Thermal

Production. Solar thermal electricity production began in the late 1970s with a central station receiver in the desert of southern California. Solar thermal technology uses concentrated sunlight to heat a fluid, creating “steam” which in turn drives a turbine generator. Though expectations were high, reductions in public-sector financial incentives and government R&D spending hit this technology particularly hard. Viewing the median value of projections of generation chronologically in Figure 3 reveals a “fan diagram,” resulting from downward revisions of expected penetration. This pattern recurs in a similar way for **solar photovoltaic** production. Photovoltaic technology converts the energy inherent in the sun’s light directly into electricity. In subtler ways, the fan also plays out for other technologies when considering projections of production.

Figure 3

Costs. Few projections exist for the capital costs of solar thermal technology, and those we found varied greatly with regard to the type of technology modeled. Substantial variation was present also in the measure of COE. Projections from the 1970s for 1990 ranged from 36 to 198 mills/kWh. Figure 4 illustrates that the median projections for solar thermal have been tracked closely by the actual COE. Though not shown, the same applies for solar photovoltaic.

Figure 4

Other Technologies

Geothermal technology taps the intense amounts of heat that exist at varying depths below the earth’s surface to create steam and run a turbine generator. Biomass technology uses wood (plants) or waste products in combustion to create steam. Projections of electricity production from **geothermal** and **biomass** produced a much weaker version of the familiar fan diagram, that is, their expected levels of market penetration had to be

revised down, but not nearly as much as for the solar technologies. Recently, in fact, biomass production has *exceeded* projections.

Cost estimates for both technologies have fallen over time. Though reports from the 1970s forecast increasing costs for generating electricity from **geothermal** sources, technological advances have expanded the types of geologic settings that can be tapped. Recent projections suggest declining cost from 5.5 to 4 cents/kWh over the next twenty years.

Biomass costs have been as low as expected or lower, and projections have fallen over time. At about 70 mills/kWh, biomass costs slightly more than wind and geothermal. However, biomass is the largest provider of renewable energy, mainly because of its availability twenty-four hours a day (unlike the sun) and its ability to co-fire with traditional fossil fuels.

Projections by Affiliation

Overall, we detected little systematic difference among the sponsors and authors of the studies we reviewed with respect to their projections of costs, but we did detect a difference with respect to their treatment of market penetration.

To the extent that nongovernmental organizations (NGOs) historically have championed renewable technologies, they might be expected to have been the most optimistic about what renewables could do. We did not find this to be the case, however. For wind, geothermal, and biomass, NGOs were the most conservative in their projections of generation and capacity, and in each case they predicted performance levels below those actually realized.

Studies sponsored or conducted by government (more than half of our sample) and independent research organizations (including the national laboratories) tended to make the highest projections of production.

Studies by the Electric Power Research Institute usually, though not always, offered the most conservative projections across all technologies.

Conventional Generation

Projections for conventional technologies that we looked at included nonhydroelectric renewable technologies, which made up a very small part of total generation (at most 0.3 percent in 1982). They also included hydroelectric (14 percent), nuclear (13 percent), and fossil-fired power production (73 percent).

Production. Electricity sales increased by about 2.7 percent a year or about 80 percent overall from 1975 to 1997. From 1982 until now, government forecasts of 2 to 3 percent annual growth have been largely accurate. See Figure 5, which summarizes information from the Energy Information Administration's *Annual Energy Outlook* (AEO).

Figure 5

Costs. Projections in the 1980s significantly overestimated actual electricity costs. For example, a 1982 forecast anticipated that real electricity prices would rise by more than 8 percent during 1980–90; in fact, real prices *declined* by 10 percent. A 1984 forecast anticipated a real price decline during 1983–95 of around 5 percent. The actual decline over the period was more than 25 percent. The entire difference between the projected and actual energy prices in 1995 is attributable to the degree to which the fuel component of the price fell short of the forecast. In total, just over half of retail electricity cost is attributable to generation, and real generation costs in 1995 were about 44 percent below what had been forecast from a 1983 base.

Figure 6 indicates that the familiar fan diagram emerges especially clearly when viewing the projections compared with the actual value for the generation portion of retail price projections, here grouped by four-year increments.

Figure 6

What the Fans Imply

The fan diagram appears particularly prominently in projections of future generation for solar technologies, indicating the vast difference between the energy they were expected to deliver and the energy they actually did. A modest fan diagram appears for wind and geothermal, though both came close to meeting revised projections of generation from the 1980s and 1990s. The exception to this pattern was biomass, for which market penetration exceeded previous projections.

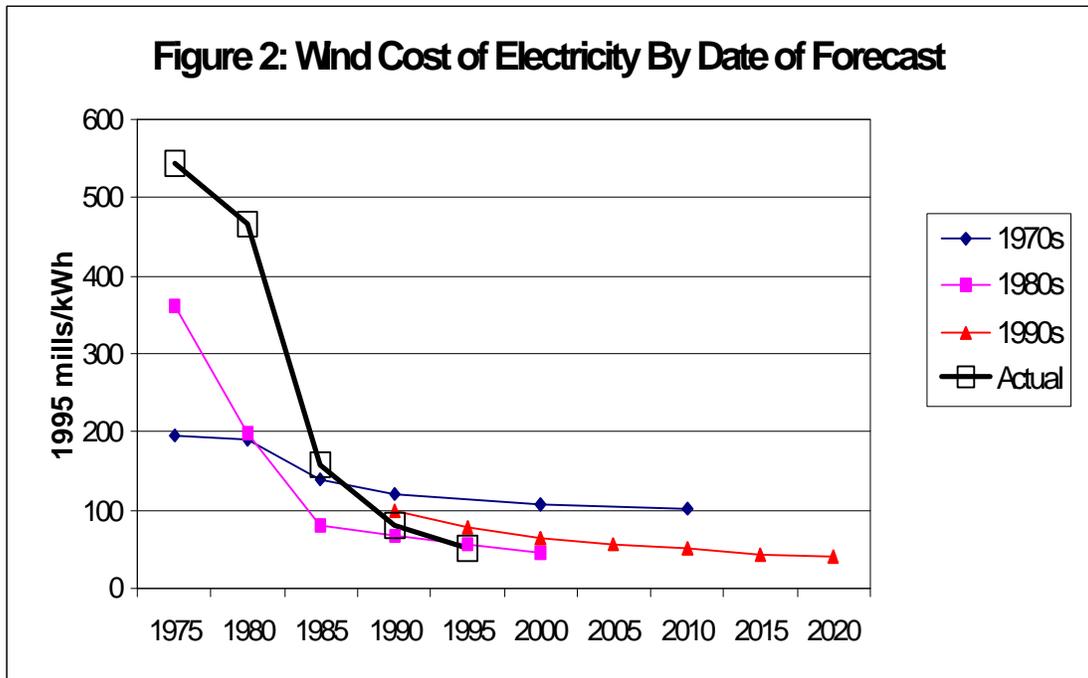
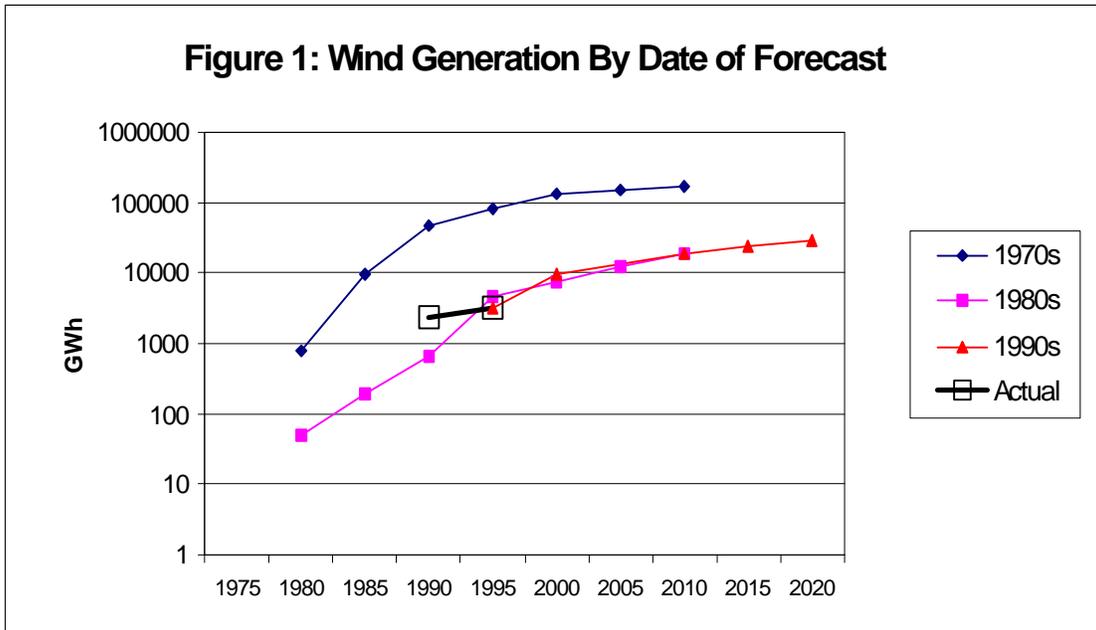
A different picture emerges, however, of cost projections for renewable technologies. In every case, successive generations of cost projections have either agreed with previous projections, or have declined relative to them. More important, in virtually every case the path of actual cost has equaled or been below the projections for a given period.

The story is reversed when it comes to projections about conventional technologies. With respect to generation, expectations generally were accurate. With respect to cost, projections were overestimated and successively revised, creating a fan diagram.

Conclusion and Further Information

In conclusion, we find that renewables have performed well relative to projections of cost of electricity production. However, we do not attempt to attribute the successful achievement of projected technological development and cost declines for renewables to a specific policy or other factor. Nor do we make a direct case for continued government support of these technologies. Nonetheless, these findings should be of interest in the policy debate about the possible future role of renewable energy technologies.

A full copy of the report can be obtained from Resources for the Future at: http://www.rff.org/disc_papers/PDF_files/9928.pdf, or from the Renewable Energy Policy Project at http://www.repp.org/articles/mcveigh/index_mcveigh.html.



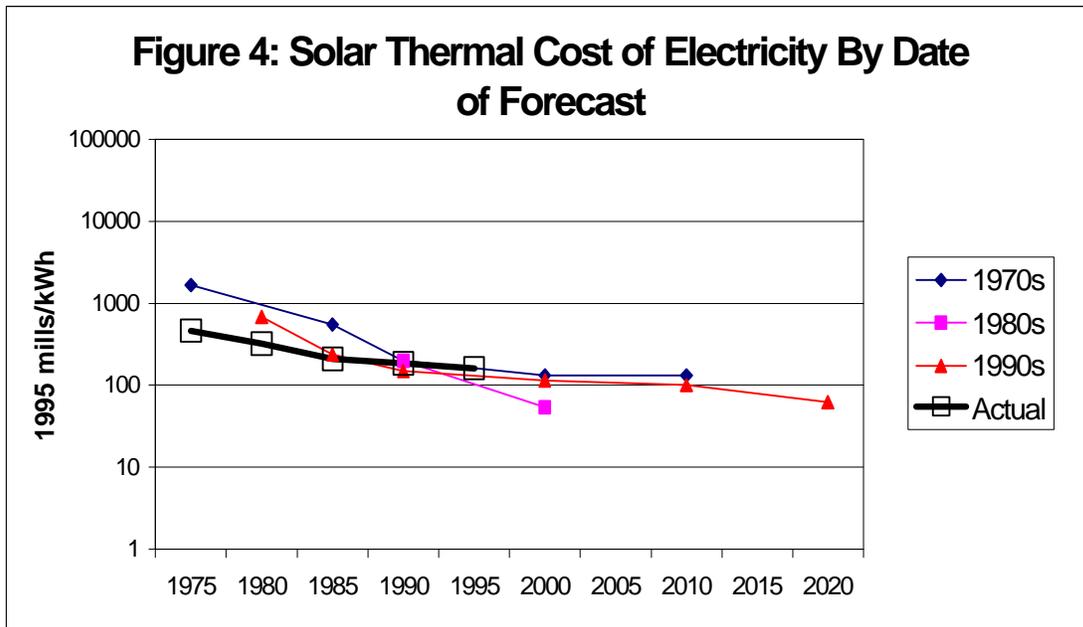
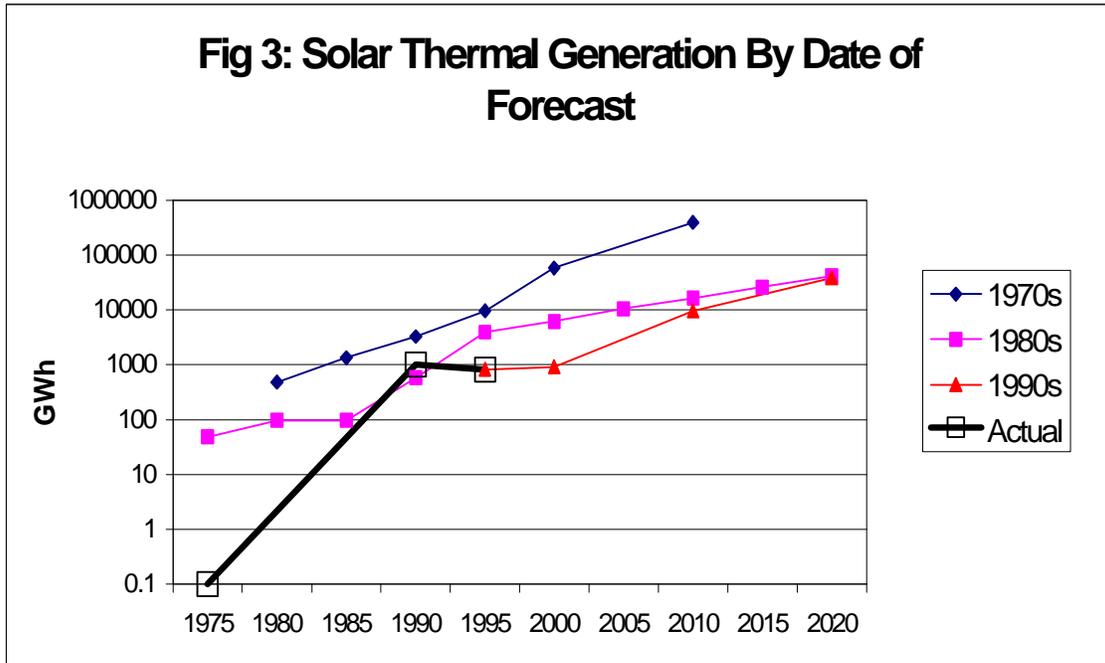


Figure 5: Conventional Generation (Retail Sales) by Date of Forecast

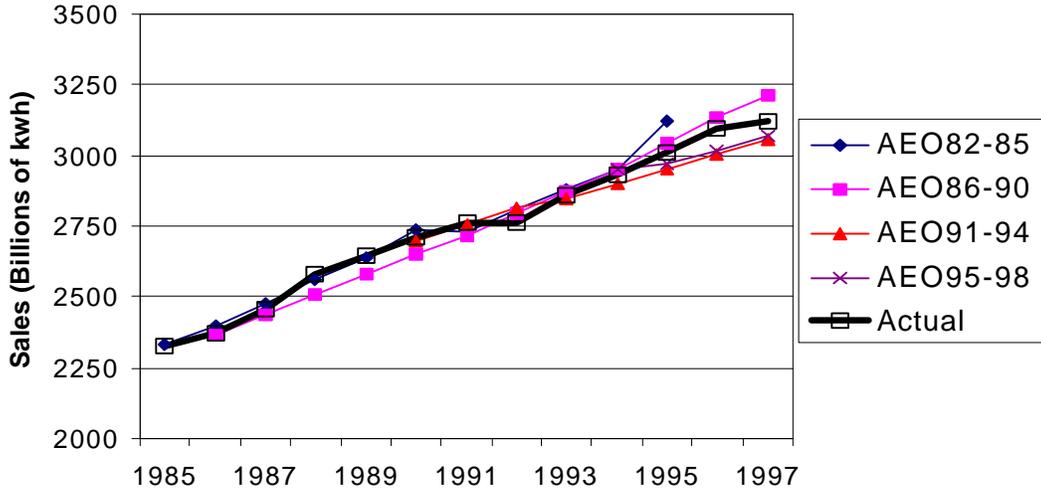


Figure 6: Conventional Generation Cost of Electricity (Retail Prices) by Date of Forecast

