Renewable Energy

Winner, Loser, or Innocent Victim?

by Dallas Burtraw, Joel Darmstadter, Karen Palmer, and James McVeigh

Predictions that wind, solar power, and other renewable energy sources would make a significant contribution to U.S. energy needs have proven faulty. But the performance of these technologies is higher—and the cost often lower—than predicted.

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 has 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.

Our findings lead us to a much less harsh conclusion, however. Evaluations of the available evidence indicate that renewable technologies have lived up to many significant expectations and public policy goals. If anything, these technologies may be victims of circumstance rather than poor performance. Their lack of commercial success may be ascribed largely to changing factors and outcomes unrelated to the merits they offer.

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). This success is remarkable, given that renewable

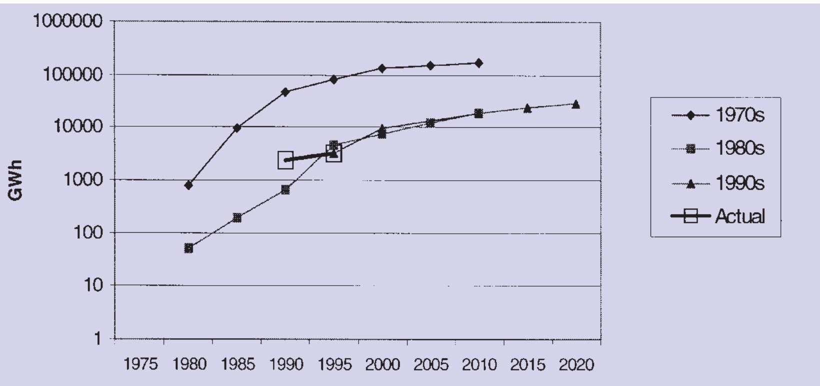

Figure 1. Wind Generation by Date of Forecast

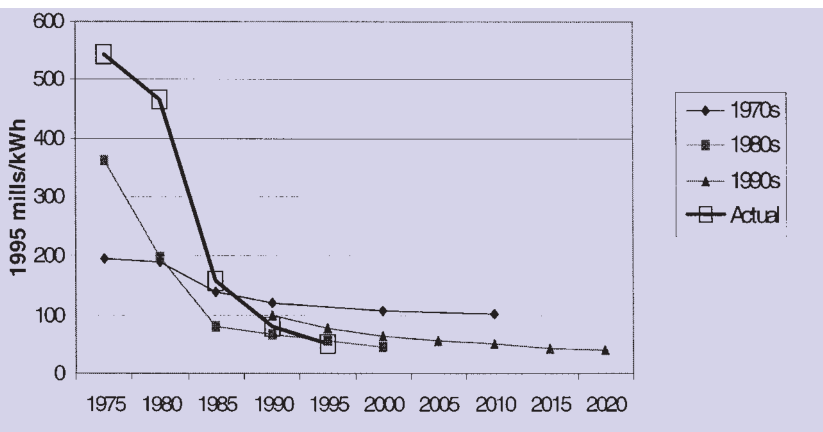

Figure 2. Wind Cost of Electricity by Date of Forecast

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.

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.

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 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.

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 the image of a fan. This "fan diagram" results from successive revisions downward of expected penetration. This pattern re-occurs 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.

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.

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 costs 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.

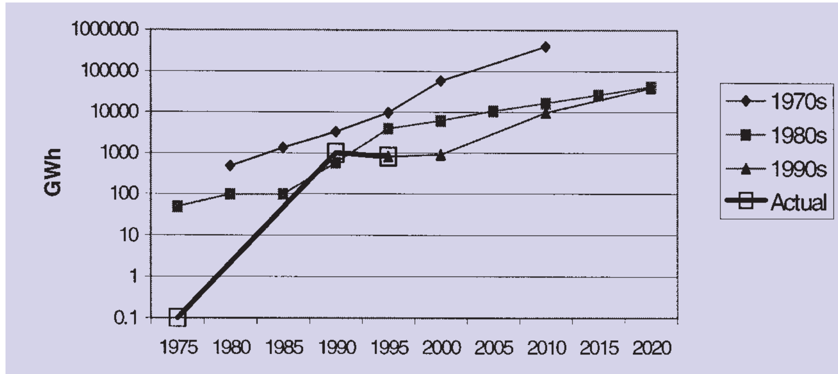

Figure 3. Solar Thermal Generation by Date of Forecast

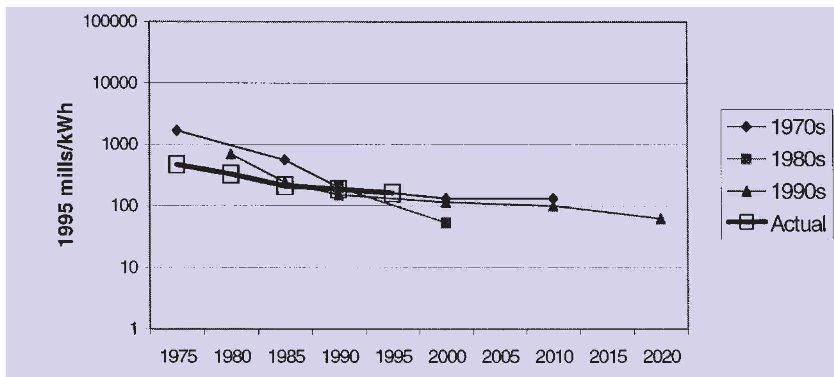

Figure 4. Solar Thermal Cost of Electricity by Date of Forecast

To the extent that nongovernmental organizations (NGOs) have historically 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.

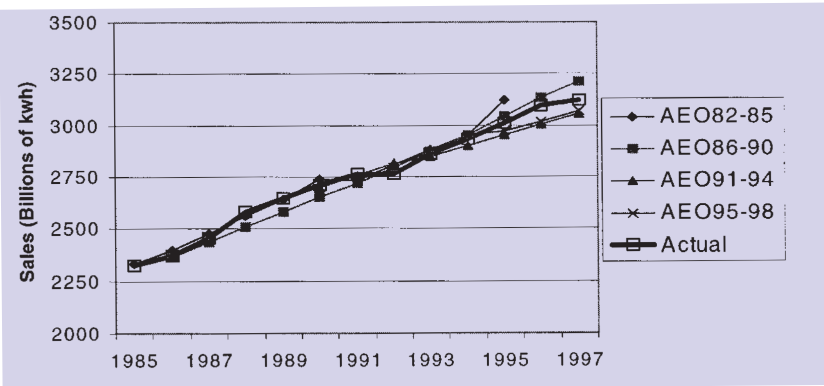

Figure 5. Conventional Generation (Retail Sales) by Date of Forecast

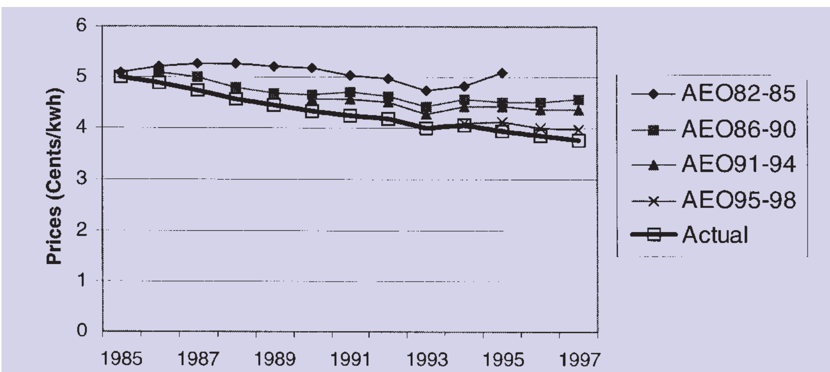

Figure 6. Conventional Generation Cost of Electricity (Retail Prices) by Date of Forecast

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).

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.

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.

These 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 for mature technologies. Indeed, the rate of improvement in relatively mature conventional technologies may accelerate in the increasingly competitive environment of wholesale and retail competition in the electricity industry. The cost threshold at which renewable generation may capture a larger share of the electricity market is likely to continue to move, posing ongoing challenges for the renewable industry.

Third, the declining price of conventional generation constituted a moving baseline against which renewable technologies had to compete. Energy policy initiatives—such as the 1978 Public Utility Regulatory Policies Act, which required utilities to use renewable and cogenerated power, and the deregulation of natural gas, oil pipelines, and rail industries—complemented technological and economic trends that directly affected conventional technologies. 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).

Victim of Happy Circumstance

The ultimate impacts of these changes in the regulation, technology, and market structure of fossil fuels have been mostly favorable 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 relative loser amid the widespread success of an array of public policies aimed at energy markets.

This outcome does not necessarily imply 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. And of course circumstances do change. Public-sector financial incentives for renewable technologies (as well as other energy technologies) can be viewed as precautions against rising energy prices and vulnerability to disruptions of foreign energy supply, as well as potential solutions to environmental problems associated with energy consumption.

Great Green Hope?

Any argument that public policy support for renewable technologies should be ended because "past efforts have been unsuccessful" is based on a faulty premise; such support should not be judged based on largely unrelated outcomes. The most 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. According to this measure, renewable technologies have met the goals set for them, and could emerge as an important contender in an ongoing struggle toward sound energy policy.

However, we do not attempt to attribute the successful achievement of projected technological development and cost declines for renewables to a specific government policy or any 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. Whether the level of public sector support has been adequate or should continue we leave to another investigation.

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