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FEDERAL ENERGY SUBSIDIES: NOT ALL TECHNOLOGIES ARE CREATED EQUAL

by Marshall Goldberg

Wind, solar and nuclear power received approximately $150 billion in cumulative Federal subsidies over roughly fifty years, some 95% of which supported nuclear power. Perhaps more significant, nuclear power received far higher levels of support per kilowatt-hour generated early in its history than did wind or solar. *Federal Energy Subsidies* also provides a qualitative accounting of Federal involvement in hydropower development.

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A Message from the Staff of the Renewable Energy Policy Project

Each month, regulators relinquish to market forces a smidgeon more control over the American electric sector. Some observers celebrate this "restructuring" as a rejection of governmental meddling, heralding vitality, innovation and efficiency. Yet, these changes reflect a hidden irony: today's market for cheap power results in part from substantial investment by the federal government in innovative technology.

The Energy Information Administration foresees 1,000 new American generating stations totaling 300 gigawatts by 2020. Ninety percent will employ combustion turbines (or combined-cycle units, which pair combustion and traditional steam turbines) fueled by natural gas. Along with deregulation of the natural gas supply sector during the 1980s, combustion turbines' success seems to demonstrate the superiority of free-market energy solutions.

In fact, the combustion turbine represents a sustained investment by the federal government in research and development, albeit applied indirectly. Its pedigree traces back to jet engines. For decades, utility managers found generating units based on jet technology cheap, but inefficient and unreliable. Largely through government-funded R&D on combustion turbines for aircraft use, the technology improved. Reportedly, the Defense Department invested an average of $425 million per year in jet engine R&D from the mid-1970s to the mid-1980s, reaching $750 million annually in the late 1980s. In the 1990s, the independent power sector used these cheap, effective, government-enabled "aeroderivative" turbines to challenge the dominance of established utilities—in effect, to blow apart the rationale for regulated monopolies in electric power generation by demonstrating the effectiveness of competition.

Gas turbines and other technologies demonstrate that generation is no longer a "natural" monopoly. Yet, they raise a deeper question, one often ignored amidst the hullabaloo of restructuring: who should undertake similar long-term, potentially system-shattering research? Researchers Robert Margolis and Daniel Kammen have shown that energy firms typically invest rather little in R&D—some 0.5% of revenues, compared to 10% in high tech industries such as telecommunications—and that the energy sector's total R&D investments plummeted between 1980 and 1996, even as R&D investments in the economy as a whole soared. Alarmingly, rising competition has impelled many electric companies to crop R&D budgets further, and to focus on conservative innovations able to pay off in the short term.

One can exaggerate the role of subsidies. REPP's work over the past five years shows that building strong markets for clean energy will require many actions by many actors: wheelbarrows of federal money are not sufficient, and may in some cases be counterproductive. Rather, targeted financial support and R&D must be combined with other more subtle measures, such as standard-setting, government purchases, insurance guarantees, and so on. Indeed, many common technologies, including the fax machine, the cellular telephone and the computer benefited from similar government actions.

In short, the case of the combustion turbine, when added to the data collected in the following research report, suggests two key points: it requires a great deal of money to establish an energy technology; and few have reached maturity without substantial public sector investment. In a proposed second part of this investigation, we will explore the federal role in developing other electricity generation technologies, including the combustion turbine. With this information, we hope to tackle the key questions related to subsidies: Do subsidies work? Are there better ways to support long-term technology development? And, what happens when subsidies outlive their purpose?

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FEDERAL ENERGY SUBSIDIES: NOT ALL TECHNOLOGIES ARE CREATED EQUAL

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EXECUTIVE SUMMARY

Federal Energy Subsidies provides a historical accounting of federal government subsidies to nuclear, wind, photovoltaic, and solar thermal electricity generating technologies. Also provided is a less complete accounting of federal subsidies for hydroelectric power. In addition to identifying the actual dollar amounts of the subsidies during the last 60 years, the report offers new insights on how these subsidies have fared relative to each other. A simple message emerges from *Federal Energy Subsidies*: it takes a substantial amount of money, invested over several years, to bring an electricity generation technology to maturity.

This analysis comes at a time when citizens and policymakers alike are debating the environmental impacts of energy use, the role in the American economy of corporate welfare, and appropriate levels of government spending. It provides pertinent information for the ongoing debate regarding the government's influence on energy markets, its support for nuclear power, and, more recently, the notion that renewables are heavily subsidized and receiving preferential treatment.

The report concludes that federal support for nuclear power has far surpassed support for renewables, and that over the long term this public investment correlates with increasing electricity generation by the nuclear sector—although, of course, the increase in nuclear generation reflects several factors in addition to federal investment.

From 1943 through 1999, cumulative federal government subsidies to these electricity-generating technologies (excluding hydropower) totaled almost $151 billion (in 1999 dollars). This figure includes all direct program budgetary outlays, plus several of the most notable off-budget subsidies and policies, including tax credits and incentive payments for renewable energy, as well as nuclear liability limitations. The nuclear industry received $145.4 billion, or over 96 percent of the subsidies. Those to photovoltaic and solar thermal power accounted for a cumulative total of $4.4 billion, while wind technology received $1.3 billion.

Data on early expenditures for hydropower are incomplete. This reflects both the scarcity of archived generation and investment data on hydropower—the development of which began in the 1890s—and the complex historical context of federal hydropower development. In particular, federal hydropower facilities often formed part of larger projects with multiple goals, including flood control, river navigability, regional development, and stimulation of the local and national economies. For this reason, it is difficult to attribute a specific portion of federal investment for power generation. Nevertheless, to assist in further investigations, the figure of $1.6 billion can be given for a set of straightforward subsidies to hydropower.

Analyses of subsidies during the first 15 years of federal support versus electricity generated reveals surprising differences. Notably, commercial, fission-related nuclear power development received subsidies worth $15.30 per kilowatt-hour (kWh) between 1947 and 1961. This compares with subsidies worth $7.19/kWh for solar and 46¢/kWh for wind between 1975 and 1989. In their first 15 years, nuclear and wind technology produced roughly the same amount of energy (2.6 billion and 1.9 billion kilowatt-hours, respectively), but

Federal Energy Subsidies represents the first portion of a proposed two-part study designed to gather primary data and provide a new historical perspective on federal subsidies that influenced the development and viability of electricity generating technologies. This part focuses on nuclear, hydropower, wind, photovoltaics, and solar thermal electric technologies. Included is cumulative historical spending for each of the technologies. A second report, pending funding, may include coal, natural gas, petroleum, and other renewable technologies. While identifying the extent of actual subsidies is the key goal, gaining a broader understanding of how these subsidies compare to each other is also important.

the subsidy to nuclear outweighed that to wind by a factor of over 40, at $39.4 billion to $900 million. It may be that this differential contributed to a more mature nuclear sector, as reflected in its much more rapid growth; by 1999, nuclear generation totaled 727.9 billion kWh annually, while wind generation totaled 3.5 billion kWh.

When cumulative subsidies and electricity generation for all years are accounted for (that is, through 1999), subsidies to the development of commercial, fission-related nuclear power results in a subsidy cost of 1.2¢/kWh. This compares with a subsidy cost of 51¢/kWh for solar and 4¢/kWh for wind. As these numbers suggest, greater generation from nuclear power swamps the greater absolute subsidies to that technology. Again, it seems that larger early investment in nuclear power paid off in subsequent years.

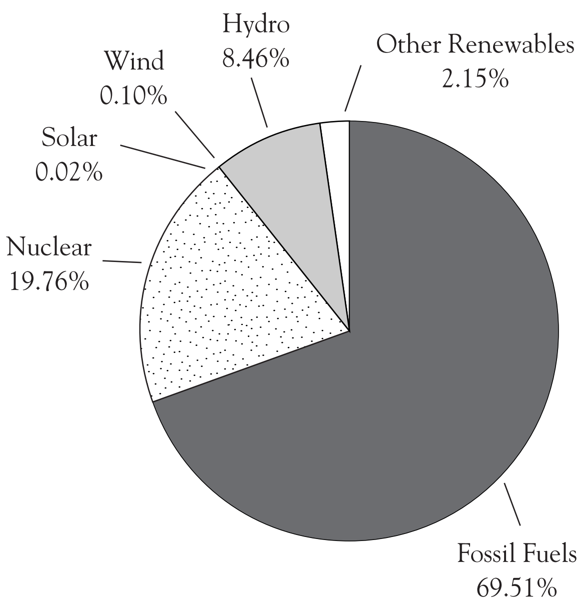
In short, subsidies have played an important role in the development of the technologies examined in the report. The study points to the need to reevaluate energy subsidies in light of larger energy and environmental goals.

FEDERAL ENERGY SUBSIDIES: NOT ALL TECHNOLOGIES ARE CREATED EQUAL

by Marshall Goldberg[1]

Since 1970, energy supply disruptions, expanded awareness of environmental degradation, and concerns about corporate welfare and budget deficits have all spurred debate on the use of appropriate energy resources and public funding of market interventions. Despite subsidies to all energy resources, some claim that renewable energy technologies are heavily subsidized, especially given the size of the industry and its modest share of electricity generation.

Figure 1. 1999 Resource Share of Electricity Generation



In 1999, fossil fuels and nuclear reactors provided the largest share of U.S. electricity, accounting for 3,289 billion kilowatt-hours, or just over 89 percent of total U.S. electric power industry net generation. (See Figure 1.) Hydropower supplied almost 9 percent, wind was 0.1 percent, solar provided 0.02 percent, and all other renewable sources accounted for a combined total of just over 2 percent of electricity generation.[2]

This current resource mix in part reflects historically low fossil fuel prices that do not account for environmental impacts. Possibly more significant, it may reflect government policies and subsidies to encourage development of these technologies and the related industries. In fact, during the last 20 years more than a dozen studies on energy-related subsides, some as recent as 1998 and 1999, have been completed by government agencies and private organizations alike to quantify these benefits.

The results are startlingly different—with benefits ranging from just over a billion dollars to hundreds of billions of dollars, primarily because each study takes a somewhat unique perspective on what factors to include. (See Appendix B for a partial listing of studies on subsidies and a summary of results.) Nevertheless, it is clear that government policymakers have treated energy technologies and related industries inequitably.

PART I. SCOPE OF THE REPORT

What Are Energy Subsidies?

While energy subsidies may be defined informally as any action that affects the development and allocation of energy technologies and resources, this study uses a more limited definition. It includes direct and off-budget expenditures, revenue losses, and implied subsidies by the federal government that directly target commercial development and adoption of the four technologies being considered.

Direct subsidies include actual expenditures by federal agencies and commissions for research and development and oversight activities beginning in 1947 and running through 1999. Off-budget subsidies include preferential or targeted actions (those not applied equally to all energy technologies) by the federal government—outside the conventional budgetary process—designed to enable or encourage industry development and/or adoption of specific technologies. This includes production and investment tax credits and implied subsidies from insurance premium savings from liability limitations for nuclear activities. It also includes savings or revenue losses associated with government financing of power assets of federal dams and transmission-related facilities at low interest rates.

While many past studies are informative and comprehensive, it is still difficult to compare their results or to combine disparate data to develop a complete picture of the impacts of energy policies and energy subsidies over time. For example, some studies include estimates for direct government expenditures for all forms of energy. Others limit their scope to one type of technology such as coal, nuclear, or renewables, and may or may not quantify a vast array of subsidies or market interventions.

Despite the particular focus, all but a few of the studies rely on data contained in previous studies and limit the scope of analysis to a single year. This comes as no surprise, given the federal government's extensive role in developing energy resources and the daunting task (both in time and money) of sorting though all economic interactions and analyzing the pertinent data.

Methodology

Preliminary research confirmed the complexity of issues pertaining to energy policy and technology development. At the same time, there was a general lack of available data in many instances, especially on past hydropower expenditures and generation. Despite these limitations, the research and analysis undertaken here presents pertinent information for the ongoing debate about the government's influence on energy markets and for an evaluation of whether renewable energy technologies have in fact been heavily subsidized.

For spreadsheets of energy and subsidy data developed for this report, see the REPP Web site at <www.repp.org>.

Table 1 identifies the combination of direct and off-budget subsidy categories included in this study. Appendix A provides more detail on the types of subsidies included and not included in the analysis, along with the resources and data used to derive the subsidy estimates.

Military and Space-related Research and Subsidy Issues

The analysis here is limited to civilian and commercially oriented expenditures. There is broad general agreement that military and space-related R&D activities (that is, fundamental breakthroughs and designs) contributed to commercialization of electricity generating technologies, especially nuclear reactors and photovoltaic panels. There is insufficient information to quantify these benefits, however.[3] For this reason, no military or space-related expenditures are included in this analysis. Nevertheless, the difficulty of arriving at an estimate is not grounds for assuming that the government spent nothing on breakthrough technologies. Military and space programs undoubtedly played a valuable role in developing energy technologies.

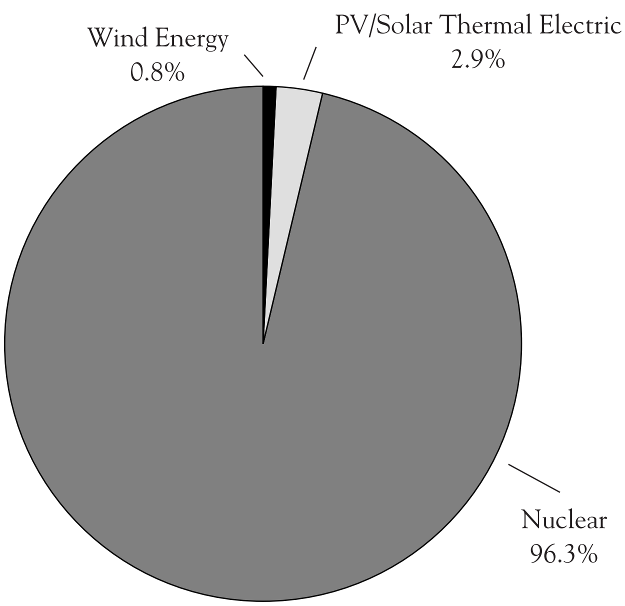
PART II. SUBSIDY ESTIMATES

This section considers the basic underlying question, What are the actual dollar values of federal subsidies to development of civilian/commercial nuclear (fission-related), photovoltaic, solar thermal, wind, and hydro electricity generating technologies? (Due to the lack of complete data on past expenditures and generation for hydropower, the subsidy data gathered for this technology are reported at the end of the section, separate from the other technologies, and are not compared with the other technologies.)

Table 1. Subsidies Included in Analysis

Subsidy Category	Technology Affected
Direct budget subsidies	
Agency expenditures (Department of Energy, Energy Research and Development Administration, Atomic Energy Commission and Nuclear Regulatory Commission): R&D, demonstration, technical and production assistance, regulatory oversight and engineering and marketing activities, and so on from 1947 to 1999	Nuclear, photovoltaic, solar thermal electric, wind, hydropower
Indirect budget subsidies	
Limitation on nuclear liability (Price-Anderson Act): estimated insurance premium savings, 1959-99	Nuclear
Technology investment and production credits (Investment and Production Tax Credits and Renewable Energy Production Incentive): estimated revenue losses, 1980-99	Photovoltaic, solar thermal electric, wind
Interest rate discounts: estimated revenue losses, 1943-99	Hydropower

Figure 2. Technology Share of Subsidies



Federal subsidies to nuclear, photovoltaic, solar thermal electric, and wind electricity technologies and to the industries as a whole totaled $150.98 billion between 1947 and 1999 (in 1999 dollars). Figure 2 illustrates the respective share of the total subsidies for each technology. As Table 2 indicates, when all "off-budget" subsidies to the nuclear industry are also accounted for, the nuclear industry received a combined total of $145.36 billion, just over 96 percent of the total subsidies evaluated in this study. In 1998, cumulative subsides to nuclear power had an equivalent cost of $1,411 per household.[4]

Even without the off-budget subsidies for nuclear, which total almost $30.3 billion, the direct subsidies to this technology are still significantly larger than any of the other technologies analyzed, separately or combined. In fact, in no single year did the direct subsides for solar and wind combined exceed 50 percent of that year's subsidies to nuclear (ranging from a low of 4.4 percent in 1975 to a high of 46.5 percent in 1998). When all subsidies are included (direct and off-budget), subsides for solar and wind never exceed 24 percent of annual subsidies to nuclear.[5]

In 1998, cumulative subsides to nuclear power had an equivalent cost of $1,411 per household.

Among the technologies evaluated, combined photovoltaic and solar thermal electric technologies were a distant second to nuclear in the amount of subsidies received. They account for a cumulative total of $4.42 billion, or 2.9 percent of total subsidies. Despite the grouping of the photovoltaic and solar thermal electric technologies, which was necessary due to a lack of detailed data on solar "off-budget" subsidies, each of the individual technologies still received

Table 2. Cumulative Federal Subsidies for Select Electricity Generating Technologies, 1947-99

Category	Subsidy (billion 1999 dollars)	Share of Total (percent)
Direct program (on-budget only)		
Nuclear	115.07	95.4
All solar	4.37	3.6
Photovoltaics	2.45	2.0
Solar thermal electric	1.92	1.6
Wind	1.12	0.8
Total direct program budget	120.56	100.0
Direct program plus off-budget		
Nuclear	145.36	96.3
All solar	4.42	2.9
Photovoltaic	n.a.	n.a.
Solar thermal electric	n.a.	n.a.
Wind	1.20	0.8
Total direct plus off-budget	150.98	100.0

Table 3. Cumulative Direct and Off-Budget Federal Subsidies for Select Electricity Generating Technologies, 1947-99

Category	Subsidy (billion 1999 dollars)	Share of Total (percent)
Direct program budget subsidies	120.56	79.85
Off-budget subsidies	30.42	20.15
Limited nuclear liability (Price-Anderson Act): Estimated insurance premium savings, 1959-1999	30.29	20.06
Technology investment tax credits (Production Tax Credits and Renewable Energy Production Incentive): Estimated revenue losses, 1980-1999	0.13	0.09
Photovoltaic and solar thermal electric	0.05	0.03
Wind	0.08	0.05
Total direct and off-budget subsidies	150.98	100

larger subsidies than wind, which received only a cumulative total of $1.2 billion.

Table 3 indicates that cumulative off-budget subsidies to all technologies totaled $30.42 billion between 1947 and 1999. This represents just over 20 percent of total subsidies. Looking at the subsidies in more detail, off-budget subsidies to the nuclear industry represent 20 percent of all subsidies (but 99.6 percent of all off-budget subsidies).[6] Tax and production credits for wind totaled only $80 million—0.05 percent of total subsidies and 0.3 percent of all off-budget subsidies. Similarly, tax and production credits for photovoltaic and solar thermal were significantly less than nuclear subsides, at $50 million.

Data on early expenditures for hydropower are incomplete. This reflects both the scarcity of archived generation and investment data on hydropower—which was developed starting in the 1890s—and the complex historical context of federal hydropower development. In particular, federal hydropower facilities, on which construction began in the 1930s, often formed part of larger projects with multiple goals, including flood control, river navigability, regional development, and stimulation of the regional and national economies.[7]

Furthermore, diverse agencies carried out the construction of dams and transmission facilities for federal hydropower, including the Bureau of Reclamation, the Army Corps of Engineers, and the various Power Marketing Administrations. Surviving budget and financing documentation often lacks the detail necessary to separate costs and do a head-to-head comparison with the other technologies examined here. For these and other reasons, it remains difficult to attribute a specific component of federal investment for hydropower generation. Nevertheless, to facilitate future research, a set of straightforward subsidies to hydropower can be identified.[8]

As Table 4 indicates, hydropower received subsidies of just under $1.6 billion between 1943 and 1999 (in 1999 dollars). This includes $159.4 million in direct program expenditures between 1976 and 1999 and just under $1.4 billion in interest rate discounts on debt not yet repaid.

PART III. NEW INSIGHTS ON SUBSIDIES

Although energy subsidies can and do serve many policy purposes, the most basic relate to furthering the development and commercialization of technologies deemed to be in the public interest. At the same time, subsidies can lower prices artificially and help bolster support, for investment purposes and for public acceptance.[9] Nevertheless, subsidy programs—like much public policy—tend to undervalue environmental impacts. Thus the subsides, especially those that outlive their intended purpose, may act against the public interest. With this in mind, the subsidy estimates and historic cost and generation data for the respective technologies can be compared over time to gain new insights on policy choices.

Comparing Subsidy Costs Per kWh of Generation

The subsidy cost per kWh was calculated using cumulative subsidy costs and cumulative generation, including all years since the subsidies began. Subsequently, two levels of sensitivity were run for each

Table 4. Cumulative Direct and Off-Budget Federal Subsidies for Hydropower Technologies, 1943-99

Category	Subsidy (billion 1999 dollars)	Share of Total (percent)
Direct program budget subsidies, 1976-99	0.159	10.22
Off-budget interest rate discount: Estimated revenue loss, 1943-99	1.400	89.78
Total direct and off-budget subsidies	1.559	100

technology. The first level of analysis looked at the subsidy cost per kWh of electricity generation after 15 years of subsidies. This time period relates roughly to the number of years subsides were provided to the nuclear industry to get the first commercial plants up and running, and the point when the began generating significant amounts of electricity. As Table 5 indicates, the first 15 years of subsidies (1947–61) to commercial nuclear reactors resulted in a subsidy cost of $15.30 per kWh.[10]

For solar and wind technologies, the first 15 years refers to the period of 1975 through 1989. Both wind and solar have considerably lower subsidy costs compared with nuclear during this development stage: 46¢ per kWh for wind and $7.19 per kWh for photovoltaic and solar thermal combined. (Again, due to the lack of complete data on early generation and subsidies, no estimates on hydropower are made here.)[11]

During the early development phase of nuclear, nuclear plants generated a cumulative total of 2.6 billion kWh. Despite the large differences in subsidies, this total is comparatively close to a total of 1.9 billion kWh for wind and 0.5 billion kWh for solar during their initial 15 years, both representing significantly smaller capacity plants and substantially smaller cumulative subsidies. Notably, the cumulative investment in nuclear power over this early period was

Table 5. Comparison of Cumulative Electricity Generation Subsidy Costs

Category	Nuclear	Solar	Wind
15 Years of Subsidies	1947-61	1975-89	1975-89
Cumulative Subsidy (bill. 1999 dollars)	$39.4	$3.4	$0.9
Cumulative Generation (billion kWh)	2.6	0.5	1.9
Subsidy per kWh (1999 dollars)	$15.30	$7.19	46¢
25 Years of Subsidies	1947-71	1975-99	1975-99
Cumulative Subsidy (bill. 1999 dollars)	$76.0	$4.4	$1.2
Cumulative Generation (billion kWh)	114.6	8.6	32.9
Subsidy per kWh (1999 dollars)	66¢	51¢	4¢
53 Years of Subsidies	1947-99	1947-99	1947-99
Cumulative Subsidy (bill. 1999 dollars)	$145.4	$4.4	$1.2
Cumulative Generation (billion kWh)	11,679.5	8.6	32.9
Subsidy per kWh (1999 dollars)	1.2¢	51¢	4¢

Notes: Cumulative subsidies based on analysis of U.S. Government budget documents and other resources noted in this study. Data for solar includes both photovoltaic and solar thermal electric resources. For more detail, see text.

Figure 3. Nuclear Technology Costs

far greater than the investment in wind and solar during a corresponding period: $39.4 billion for nuclear compared with $3.4 billion for solar and $900 million for wind power.

The second sensitivity run analyzed the subsidy cost per kWh of electricity for the first 25 years, to capture some of the technology and industry advances inherent in emerging technologies. A similar pattern emerged. The subsidy cost to nuclear, estimated at 66¢ per kWh, although significantly lower than the 15-year estimate, is still about 30 percent higher than solar and just under 16 times greater than the subsidy for wind. Again, the results indicate that despite lower monetary subsidies, the solar and wind technologies appear to be making significantly greater advances when compared with nuclear during the same stage of development. Nevertheless, it is also clear that between the fifteenth and twenty-fifth year of subsidy support, nuclear generation increased to an extent not matched by wind or solar power.

Finally, looking at cumulative subsidies and electricity generation for all years, nuclear power, based on data for 53 years, had the lowest subsidy cost—1.2¢ per kWh. This compares with wind (a 25-year analysis) cumulative subsidy costs of 4¢ per kWh, and solar (also a 25-year analysis) cumulative subsidy costs of 51¢ per kWh. These cumulative results must be tempered somewhat by the large discrepancy in number of years analyzed, which allows for significantly greater generation, the maturity of nuclear technology, policy situations surrounding commercial development of nuclear power, and the large differences in subsidy amounts designed to encourage new generating resources.[12]

Of course, this form of analysis cannot show a causal link between subsidies and generation, but only a stronger or weaker correlation. That is, it is possible to hypothesize that disproportionately high subsidies to nuclear power in its early years paid off later in the form of much higher generation— in 1999, for instance, nuclear generation totaled 727.9 billion kWh, while wind generation totaled 3.5 billion kWh. However, this analysis can provide only circumstantial evidence for broader examinations of that question. A similar caveat holds true for the discussion of subsidies and electricity price.

Comparing Electricity Costs Over Time

Subsidy costs per kWh provide many interesting insights into the benefits and costs to date of the technologies considered here. A useful set of data also can be derived by determining how technology costs have changed over time. Despite the dramatically smaller level of subsidies for renewables compared with nuclear power, levelized costs for solar and wind-generated electricity dropped dramatically between 1980 and 1995.[13] On the other hand, nuclear costs have risen rather than fallen over time.

As Figure 3 illustrates, in parallel with the large subsidies received by the nuclear industry between 1970 and 1995 (and the preceding 24 years), levelized costs per kWh increased by almost 130 percent (in 1999 dollars).[14] In 1970, nuclear power cost approximately 4¢ per kWh. By 1995, 25 years later, per kWh costs had risen to more than 9¢.

As Figure 4 illustrates, levelized costs per kWh (in 1999 dollars) for renewable technologies declined continuously between 1980 and 1995. During the 16-year period of analysis, photovoltaic costs dropped 84 percent, from $1.52 to 25¢ per kWh; solar thermal electric costs declined 50 percent from 36¢ to 18¢ per kWh; and wind costs decreased 93 percent, from 86¢ to 6¢ per kWh.[15]

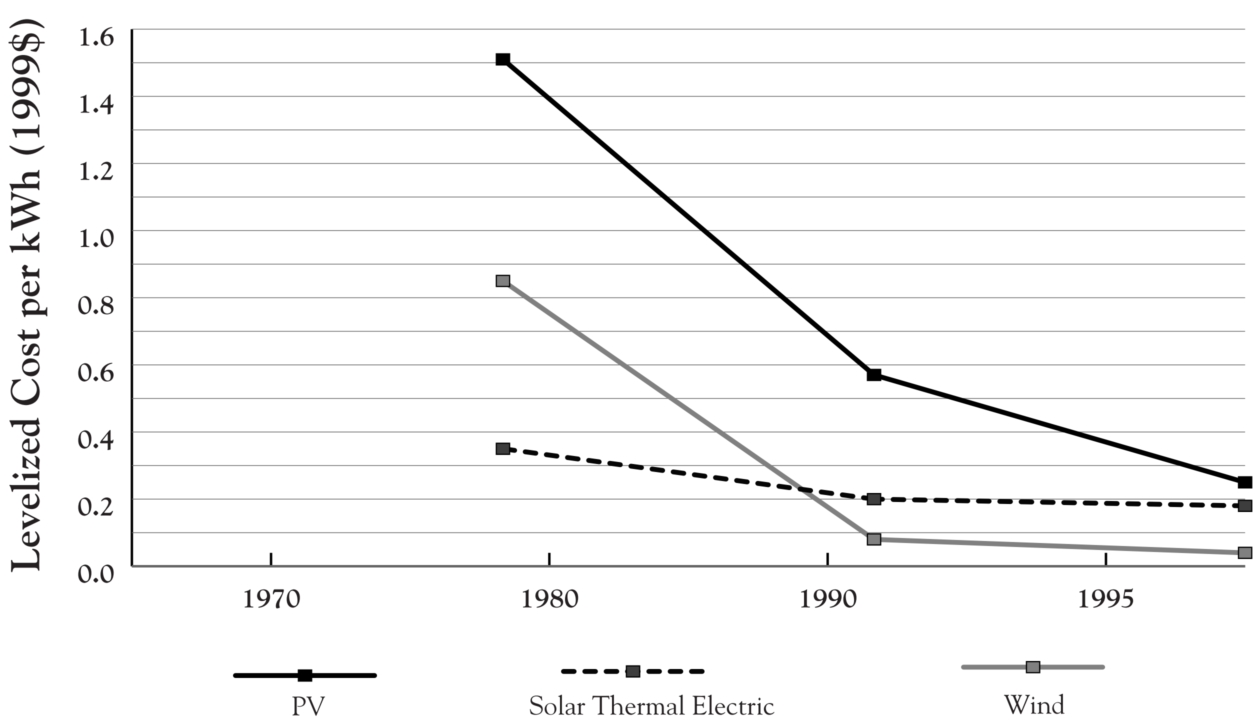
PART IV. SUMMARY AND CONCLUSIONS

There have been great discrepancies in federal support for electricity generating technologies over the last 60 years. In comparing subsidies for nuclear, photovoltaics, solar thermal, and wind, it is clear that the nuclear industry received more than 96 percent of almost $151 billion in subsidies identified. Photovoltaics and solar thermal received the second largest subsidy, a total of $4.4 billion. Wind received a total of $1.2 billion. While hydropower is not included in the total of $151 billion due to incomplete data, this technology received at least $1.6 billion.

The relatively small subsidies provided to the renewable technologies, combined with the strong government initiative beginning in the 1950s and 1960s to advance nuclear energy, correspond with the balance of these technologies in today's mix of electricity generating resources. Nuclear reactors account for the largest share of non-fossil electricity in the United States, at approximately 20 percent of total electricity generated in 1999. This was considerably greater than hydro (8.5 percent), solar (0.02 percent), or wind (0.1 percent).

Although significantly lower than in previous years, direct budgetary funding for nuclear power in 1999 still easily surpassed subsidies to wind, solar, and hydro. In 1999, direct budgetary subsidies to nuclear totaled $326 million (and $685 million with off-budget subsidies). In comparison, direct budgetary subsidies for photovoltaics were $72.2 million, while solar thermal electric received $17.0 million (a combined total of $91.9 million with off-budget subsidies).

Figure 4. Renewable Technology Costs



Wind received $34.8 million ($38.4 million with off-budget subsidies) and hydro received $3.25 million (and just over that figure with off-budget subsidies).

It is important to note that the mere existence of government support is neither good nor bad: the value of subsidies depends on public policy goals. There is no place for simplistic arguments that "they got theirs, and now we want ours." Rather, the research to this point suggests that policymakers should ask:

- Does this subsidy match the general goals of public policy?
- Is this subsidy intended only to bring the technology to maturity, or is there a sound rationale for continued support?

In short, it takes a good deal of investment to bring an energy technology to maturity. In the technologies investigated here, much of that investment has come from the public sector. Future research needs to continue examining subsidies in historical context, so that policymakers can assess them in terms of their purpose, success, and compatibility with public support and policy needs.

APPENDIX A: SUBSIDIES INCLUDED AND NOT INCLUDED IN THE ANALYSIS

This Appendix provides an overview of the direct and off-budget subsidies included and not included in the analysis. Data sources are noted, as are methodologies where appropriate.

Direct Program Budget Subsidies

Direct program budget subsidies (expenditures) for solar electric, wind, and hydropower technologies were derived from program-specific budgetary data provided by the Department of Energy (DOE), and a review of the Energy Research and Development Administration (ERDA) and DOE budgets covering the period between 1974 and 1999, contained in U.S. government budget documents.[16] The subsidies include expenditures for research and development activities, demonstration projects, technical and production assistance, engineering, marketing activities, and others [would these include grants to non-profits to analyze policy and technology issues?]. Every effort has been made to ensure the expenditure estimates are "net" of any offsetting revenues collected for specific services or programs. In other words, non-federal funds (collections or receipts), such as fees paid by utilities to the federal government for uranium fuels, have been deducted from total expenditures.

Hydropower

Although the use hydropower in the United States dates back to the 1800s, the circumstances surrounding its early and more recent commercial development by the federal government make it difficult to derive direct expenditure estimates. For instance, most of the spending on hydropower projects undertaken by the U.S. Army Corps of Engineers and the Bureau of Reclamation in the 1930s and 1940s was considered supplemental to the primary purpose of building dams for irrigation, flood control, and public water supply, among other uses.

As hydro resources became a desirable electricity generating option, the Tennessee Valley Authority and the federal Power Administrations were formed to administer the operations and market the power.[17] The actual construction and power-related expenses for the dams were financed through federal appropriations, with debt repayment tied to long-term, low-interest government loans. Since the power-related expenditures are to be repaid, these are not treated as a direct subsidy.[18] As a result, the direct expenditures for more recent hydropower activities (a total of $159.4 million) are derived from DOE and ERDA program budgetary data for the period 1974 through 1999.

Nuclear

Expenditures related to nuclear fission (a total of $115.1 billion) are also derived from the DOE and ERDA non-defense/military budgets. Expenditures from the Atomic Energy Commission (AEC) and Nuclear Regulatory Commission (NRC) budgets are included. DOE and ERDA budgets for civilian nuclear power covered the period between 1974 and 1999. AEC budgets covered 1947 through 1973, and NRC budgets covered 1974 through 1999. These subsidies include expenditures for civilian fission reactor research and development, fuel cycle research and development, uranium enrichment, waste disposal, decommissioning activities, and regulation and oversight to protect the public's health and safety, among others.[19]

For budgetary line items where civilian versus military-related expenditures were not clearly allocated (such as raw materials, biology and medicine, administration, and security, among others), the allocation is based on the percentage of reactor development costs attributed to civilian fission reactors for each year. These ranged from a low of approximately 25 percent to just over 54 percent.

Off-Budget Subsidies

The term "off-budget" refers here to preferential government policies targeting specific technologies and designed primarily to reduce technology costs and encourage industry development. These policies typically take the form of tax credits (not direct outlays), such as the applicable investment and production tax credits for solar and wind technologies. These credits are viewed as revenue losses to the government, the functional equivalent of non-taxed direct expenditures. However, two other forms of subsidy are also included—insurance liability limitations for the nuclear industry, and savings from low-interest loans for hydropower dam and transmission system construction.

Developing estimates for these off-budget subsidies was somewhat more problematic than estimating the direct subsidies. This is in part because government analysts simply do not perform much of the analysis or track much of the data, but also due to the unavailability and/or lack of detailed reporting.

Consequently, generating the off-budget estimates necessitated analysis of a greater variety of resources. These included, among others, energy-related tax data reported in U.S. government budget documents noted earlier, DOE information, numerous Energy Information Administration (EIA) publications, personal communications with solar and wind industry representatives, information on insurance liability limitation methodologies for nuclear, and estimates of investment and interest rate subsidies for hydro and renewables derived from previous studies.

Investment and Production Tax Credits and Production Incentive Payments

Investment tax credits and production credits designed to benefit only renewable technologies (here, solar and wind electricity generation) include the Renewable Energy Production Incentive (REPI) authorized under the Energy Policy Act of 1992 (EPAct) and two New Technology credits. These include the Investment Energy Tax Credit, established by the Energy Tax Act of 1978, and the Production Tax Credit (PTC), authorized under EPAct.[20]

The Production Tax Credit (or the Section 45 credit, as the Department of Treasury refers to it) is available to wind and closed-loop biomass power facilities owned by private companies that pay income tax. The credit initially ran from January 1, 1994, through July 1, 1999; recent legislation extended it to 2001. Although no closed-loop biomass projects have claimed the credit, it has proved important to many wind projects under way.

REPI provides for a production incentive payment to qualifying electricity facilities (solar, wind, geothermal, or biomass) owned by state and local government entities and not-for-profit electric cooperatives, which do not pay income tax and would not qualify for the PTC. The 1.5¢ payment per kilowatt-hour (1993 dollars indexed to inflation) is available for the first 10 years of operations commencing between October 1, 1993, and September 30, 2003. The availability of these credits is subject to federal government appropriations (that is, an amount is budgeted) and may technically be considered a program expenditure similar to direct expenditures. However, due to the production-dependent nature of the expenditure, it is listed here as an off-budget subsidy.[21]

The investment energy tax credit, or business energy tax credit, provides for a 10-percent credit on investment in or purchase of solar or geothermal energy property. Solar property includes solar electricity generation, heating, cooling, or hot water systems. This credit is limited to commercial entities. The credit was initially established through the Energy Tax Act of 1978 (at which time it also included credits for wind). It was revised in 1986 by the Tax Reform Act of 1986 (at which point wind credits were eliminated) and then permanently installed in 1992 through EPAct.

Cumulative tax investment credits for solar ($51.8 million in 1999 dollars) and wind ($54.5 million in 1999 dollars) were problematic, since no detailed accounting is available documenting the amount of credits claimed. Deriving the investment credits for each of these technologies required analyzing investments made for the respective technologies. Numerous studies were reviewed and industry representatives contacted. The studies had limited data and representatives provided only "ballpark" estimates; these served as a preliminary check. To derive the investment pattern for solar, data on domestic shipments of photovoltaic and solar thermal collectors from EIA survey data were studied.[22] For wind, the investment pattern is based on analysis of capacity additions and construction costs. These methodologies provide reasonable approximations of industry investments and credits given the limited data available.

Price-Anderson Act

The Price-Anderson Act of 1959 initially limited the financial liability of the nuclear industry to $560 million per accident.[23] The act included power plant operators and others involved in the handling or transport of nuclear-related materials. Subsequent amendments increased industry liability to $7 billion per accident. Passage of the initial liability limitation not only had the effect of reducing industry insurance premiums, but was perhaps the pivotal point in enabling the creation of the civilian nuclear industry. The limit on liability enabled private to raise money from investors and increase the likelihood of suppliers entering the industry.

The importance of the Price-Anderson Act is evident from testimony provided during hearings on the bill that led to it in 1956 and 1957. For instance, the Edison Electric Institute noted "We would…like to state unequivocally that in our opinion, no utility company or group of companies will build or operate a reactor until the risk of nuclear accidents is minimized."[24] In the same hearings, Charles Weaver, vice president of reactor manufacturer Westinghouse, stated "Obviously we cannot risk the financial stability of our company for a relatively small project no matter how important it is to the country's reactor development effort, if it could result in a major liability in relation to our assets." General Electric, another key player in reactor development at the time, expressed similar unwillingness to participate in the industry in the absence of liability limits.[25]

Later reports by the NRC and the General Accounting Office both acknowledge that the large financial risks associated with developing commercial nuclear power required federal participation, and this liability limitation was, in fact, a subsidy to the nuclear industry.[26]

To calculate the liability limitation subsidy, an annual estimate of insurance premium savings and the numbers of reactors in operation was used. The most widely used and accepted risk analysis methodology to derive these savings from the Price-Anderson Act was developed by economists Jeffrey Dubin and Geoffrey Rothwell in 1990.[27] Based on this, an implied subsidy value of $59.96 million each year was calculated for each reactor before 1989, and $21.72 million for each reactor for each year thereafter (in 1985 dollars). Based on a more recent analysis of Dubin and Rothwell's work by economists Anthony Heyes and Catherine Liston-Heyes, more conservative estimates of $13.32 million per reactor per year before 1989 were used, and $2.32 million per reactor per year thereafter (in 1985 dollars).

According to Heyes and Liston-Heyes, Dubin and Rothwell "misinterpret the terms of the industry's insurance arrangements" in their analysis. In interpreting the analysis, Heyes and Liston-Heyes found that Dubin and Rothwell's equations only "cover the full amount of damages for—and only for—an accident that inflicts total damage within those limits [$1 million and $160 million]." On the contrary, the coverage (and subsequent analysis) should reflect that insurers cover the first $160 million of any damage done by an accident, regardless of how big the accident is.[28]

Interest Rate Discounts

Estimates for hydropower subsidies (a total of just under $1.6 billion) were made by adapting and updating the low estimates for hydropower interest rate subsidies contained in *Federal Energy Subsidies: Energy, Environmental, and Fiscal Impacts*, prepared by Douglas N. Koplow for The Alliance to Save Energy.[29]

The subsidies for hydropower are derived from low interest rates charged by the U.S. Government on loans to construct and operate electricity generation assets on federal dams.[30] These include loans to the Tennessee Valley Authority and the federal Power Administrations during the last 50–60 years. The lower interest payments to the U.S. Treasury, due to the lower-than-market interest rates on the loans, in effect represent a revenue loss to the government. The resulting lower costs for hydropower in turn helped make hydro a more desirable generating option.

The interest rate subsidy for debt less than 30 years old is calculated as the difference between the interest rates charged at the time of debt and the government borrowing cost in the year of issue. For debt older than 30 years, the subsidy is calculated as the current government cost of funds (U.S. Treasury long-term bond rates) minus the interest rate on debt still outstanding. The U.S. Treasury long-term bond rates are used as a conservative estimate of the government's cost of funds.

Where applicable, every effort was made to net out cross-subsidies (that is, subsidies to other energy resources, such as nuclear and subsidies to irrigation). If the study's higher subsidy estimates had been used (which use the weighted average long-term bond rate on new power, gas, and light bonds calculated by Moody's bond rating service), the subsidy would be approximately 30 percent higher.

Subsidies Not Included in the Analysis

A number of energy-related policies and subsidies have not been evaluated or included in this analysis. Had they been included, the subsidy estimates, primarily for nuclear power, would have been significantly higher.[31] Among others, the subsidies not include are:

- price guarantees,
- discovery and production bonuses for high-grade uranium ore (designed to stimulate the domestic uranium industry),
- tax depreciation savings from the accelerated cost recovery system on property,
- costs related to environmental externalities,
- subsidies from state or local programs,
- tax exemptions for industrial development bonds, and
- general investment tax credits available to all industries.

In addition, the study excludes all expenditures for fossil fuels and other renewable programs such as solar heating and cooling in buildings, biomass, alcohol fuels, and geothermal, among others, and all other nuclear-related activities. Nuclear activities not included in this study include fusion research, weapons research and development, physical research (such as high energy physics, thermonuclear research, chemistry, and metallurgical research), development of isotopes and peaceful uses of nuclear explosives, and oversight by agencies not specifically noted.

APPENDIX B: OTHER STUDIES OF FEDERAL ENERGY SUBSIDIES

Analysts have undertaken a number of studies on federal government subsidies to the energy industry during the last 20 years. Each study defined subsidies (that is, what was quantified and what was not) somewhat differently. And most looked at only a single year. The following table provides a brief summary of subsidy estimates from six comprehensive studies. While all include direct government program-related expenditures, the extent to which other "off-budget" subsidies are included varies significantly, as do the reporting years and the results. The reader is advised to consult the respective studies for more detail and a greater understanding of what is and is not included in the respective estimates. All costs are given in 1999 dollars to provide a consistent basis for comparing data with the current study.

Study	Findings (in 1999 dollars)
Pacific Northwest Laboratory, *An Analysis of Federal Incentives Used to Stimulate Energy Production*, prepared for DOE (Richland, WA: February 1980)	Multiyear (1933–78) cumulative estimates for all fuel types, including direct expenditures, tax credits, loans, bonds, trust funds. Subsidies identified: nuclear $48.1 billion; hydro $38.7 billion; oil $282.8 billion; coal $26.7 billion; natural gas $33.3 billion; electricity $147.7 billion; total $577.3 billion.
Richard Heede, Richard E. Morgan, and Scott Ridley, *The Hidden Costs of Energy* (Washington, DC: Center for Renewable Resources, October 1985)	Estimates for 1984 for all fuel types, including direct program expenditures, tax expenditures, loans and loan guarantees, bonds. Subsidies identified: nuclear $23.8 billion; hydro $3.6 billion; oil $13.1 billion; coal $5.2 billion; natural gas $7.1 billion; electricity $9.6 billion; total $67.7 billion.
Douglas Koplow, *Federal Energy Subsidies: Energy, Environmental, and Fiscal Impacts*, App. B, Vol. I (Washington, DC: The Alliance to Save Energy, 1993)	Estimates for 1989 for all fuel types, including direct expenditures, tax credits, liability limitation, regulation, loans, trust funds, and excise taxes. Subsidies identified: nuclear fission $6.7–14 billion; other nuclear $500 million; hydro $500–800 million; oil $7.2–11.6 billion; coal $7.3–10.6 billion; natural gas $2.8–5.6 billion; renewables $2.0–2.9 billion; efficiency $200 million; total $28.1–47.7 billion.
Energy Information Administration, *Federal Energy Subsidies: Direct and Indirect Interventions in Energy Markets*, SR/EMEU/92-02 (Washington, DC: DOE, 1993)	November 1992 estimates for all fuel types, including direct program expenditures, tax expenditures, trust funds, excise taxes. Subsidies identified: nuclear $1.0 billion; oil –$1.8 billion (incl. –$3.6 billion excise taxes collected for specific activities, without offsetting liabilities); coal $1.2 billion; natural gas $1.3 billion; renewables (including hydro) $1.0 billion; efficiency $740 million; electricity $2.1 billion; total $5.7 billion.
Management Information Services, *Federal Incentives for the Energy Industries* (Washington, DC: 1998)	Multiyear (1950–97) cumulative estimates for all fuel types, including direct program expenditures, tax expenditures, regulation, grants and loans. Subsidies identified: nuclear $63.5 billion; oil $283 billion; coal $70.7 billion; natural gas $75.9 billion; renewables (including hydro) $93.6 billion; total $586.8 billion.
Energy Information Administration, *Federal Financial Interventions and Subsidies in Energy Markets 1999: Primary Energy*, SR/OIAF/99–03 (Washington, DC: DOE, September 1999)	FY 1999 estimates for all fuel types, including direct program research and development expenditures, tax expenditures, trust funds, excise taxes. This study excludes programs that cover end-use energy and electricity. Subsidies identified: nuclear $640 million; oil $312 million; coal $489 million; natural gas $1.2 billion; mixed oil, gas, coal $205 million; renewables (including hydro) $1.1 billion; electricity $73 million (for advanced turbine technology, with other generation technology distributed by fuel type); total $3.95 billion.

1 The author would like to thank Kevin Bell, Karl Gawell, Larry Goldstein, Jan Hamrin, David Kline, Doug Koplow, Alan Miller, Kevin Porter, Roby Roberts, Adam Serchuk, Christopher Sherry, Virinder Singh, and Carl Weinberg for reviewing early drafts of this material. Special thanks also go to Joe Galdo at the Department of Energy for helping to identify informational resources. The statements contained in this paper remain the responsibility of the author, and do not necessarily reflect the views of the reviewers, REPP, or the REPP Board of Directors.

2 Other renewables includes electricity generation from geothermal, plant material, municipal solid waste, wood, and other waste. See U.S. Department of Energy (DOE), Energy Information Administration (EIA), *Monthly Energy Review,* DOE/EIA-0035(2000/03) (Washington, DC: March 2000), p. 97.

3 For example, one study contends that "the unique importance of the...[naval program's construction of a nuclear fleet] was in its establishment of a broad technical base which would be critical to the later development of commercial nuclear power," but does not go on to quantify that importance; Office of Economic Analysis, *Federal Support for Nuclear Power: Reactor Design and the Fuel Cycle*, Energy Policy Study 13, DOE/EIA-0201/13 (Washington, DC: DOE, February 1981), p. 8. Although it is not included in the current study, spending on naval reactor development by the Atomic Energy Commission alone is estimated at almost $8 billion (1999 dollars) between 1955 and 1973. Similarly, there is broad qualitative agreement that the early commercialization of photovoltaics was spawned by successes in the U.S. space program in the late 1950s. For a narrative account, see John Perlin, *From Space to Earth: The Story of Solar Electricity* (Ann Arbor, MI: AATEC publications, 1999), pp. 41–48.

4 This estimate for nuclear is derived by dividing the cumulative subsidy between 1947 and 1998 by the total number of U.S. households in 1998 ($144.7 billion / 102.5 million = $1,411 per household). This compares with a solar cost of $42 per household, a hydropower cost of $15 per household, and a wind cost of $11 per household. The household data are derived from the U.S. Bureau of the Census, *Statistical Abstract of the United States: 1999* (Washington DC: 1999), p. 61.

5 See Appendix B for more detail on annual subsidy values for the respective technologies.

6 This estimate is derived using a revised methodology for calculating nuclear plant subsidies from Anthony Heyes and Catherine Liston-Heyes, "Subsidy to Nuclear Power Through Price-Anderson Liability Limit: Comment," *Contemporary Economic Policy* 16 (January 1998), and historical nuclear plant data from the DOE, op. cit. note 3, Table 8.2 page 112.

7 Based on the National Inventory of Dams, compiled by the U.S. Army Corps of Engineers, the primary purposes for dam construction fall into seven main categories (along with the percentage of dams developed for that purpose): recreation (35 percent), stock pond (18 percent), flood control (15 percent), public water supply (12 percent), other (7 percent), and power generation (2 percent). Note that these percentages refer to the number of dams, not their size or cost. This information was adapted from the U.S. Department of Energy, Office of Power Technologies, Hydropower Program Web site, <www.inel.gov/national/hydropower/facts/benefit.htm>.

8 See Appendix B for more detail on what is included in this estimate and sources of data from other studies.

9 For more on the effectiveness of public policy in lowering unit production costs through market transformation programs aimed at increasing production volume, see Richard Duke and Daniel Kammen, "The Economics of Energy Market Transformation Programs," *The Energy Journal* 20 (1999), pp. 15–64.

10 This calculation is based on the following formula: cumulative subsidies / cumulative net kWh generated = subsidies per kWh. Cumulative electricity generation is based on analysis of data contained in EIA, *State Energy Data Report 1996*, DOE/EIA-0214(96) (Washington, DC: February 1999); DOE, op. cit. note 3; EIA, *Renewable Energy Annual 1998*, DOE/EIA-0603(98)/1 (Washington, DC: December 1998); and EIA, *Annual Energy Review 1998*, DOE/EIA-0384(98) (Washington, DC: July 1999).

11 As noted, hydropower was in many ways a mature technology when the federal government began its development in the 1930s. Thus our subsidy estimate may not represent the true first years of development, nor, as noted, is it a necessarily complete accounting of subsidies.

12 As noted elsewhere, early commercialization efforts for nuclear power were also in part the result of other influences, such as an attempt to make nuclear weapons more acceptable in the 1950s and 1960s.

13 See, for example, James McVeigh et al., *Winner, Loser or Innocent Victim: Has Renewable Energy Performed as Expected?* (Washington, DC: REPP, 1999), which notes that the cost of wind and solar power has dropped faster than virtually all projections made over the years.

14 The rise in average costs per kWh appears to be the result of a number of factors including age of plant, rising fuel costs, increases in operation and maintenance costs, decommissioning costs, and costs associated with stricter regulation due to safety and environmental concerns. Among others, see EIA, *An Analysis of Nuclear Power Plant Operating Costs*, SR/OIAF/95-01 (Washington, DC: April 1995).

15 Data for this analysis are derived from a number of sources, including: Ronal W. Larson, Frank Vignola, and Ron West, *Economics of Solar Energy Technologies* (Boulder, CO: American Solar Energy Society, December 1992), pp. 43–44; Office of Utility Technologies, *Technology Characterizations* (Washington, DC: DOE, May 1994); National Renewable Energy Laboratory, *Photovoltaics: The Power of Choice*, DOE/GO-10096-017 (Golden, CO: DOE, January 1996), p. 9; and Charles Komanoff and Cora Roelofs, *Fiscal Fission: The Economic Failure of Nuclear Power*, prepared for Greenpeace, December 1992), pp. 74–75.

16 See Office of Management and Budget, *Budget of the United States Government* (Washington, DC), for all years beginning in 1947 and the *Appendix* for each year. Spreadsheets containing historic program budget expenditure data for renewables were obtained from the Department of Energy, as were program specific data from Program Managers.

17 These include the Bonneville Power Administration, the Western Area Power Administration, the Southeastern Power Administration, and the Alaska Power Administration.

18 The costs associated with the lower than market rate interest loans are treated as off-budget subsidies rather than direct subsidies in this analysis.

19 Waste disposal and decommissioning activities only account for expenditures through 1999. No allowance is made for possible underfunding of future activities. Based on analysis of DOE and Energy Research and Development Administration budget documents (which include separate categories for Nuclear Waste

Disposal and the Uranium Enrichment and Decontamination Fund), cumulative fees collected for these categories currently exceed expenditures.

20 Data for this analysis derived from the Office of Management and Budget, *Budget of the United States Government Fiscal Year 2000* (Washington, DC: 2000), and previous years; personal communications with Treasury Department representatives and industry representatives; and a review of a number of studies conducted during the last 20 years.

21 For more information on REPI, see the U.S. Department of Energy, Office of Power Technologies, Web site at <www.eren.doe.gov/power/repi.html>.

22 See EIA, *Renewable Energy Annual 1998,* op. cit. note 11, Table 11.

23 For a broader discussion of the Act, see, among others, U.S. Nuclear Regulatory Commission, *The Price-Anderson Act—The Third Decade, Report to Congress*, NUREG-0957 (Washington, DC: December 1983); Dan R. Anderson, "The Price-Anderson Act: Its Importance in the Development of Nuclear Power," *CPUC Annals* 30 (University of Wisconsin-Madison: December 1977); and Comptroller General, *Nuclear Power Costs and Subsidies,* EMD-79-52 (Washington, DC: U.S. General Accounting Office, June 1979).

24 See Elmer L. Lindseth, *Hearings Before the Joint Committee on Atomic Energy on Governmental Indemnity for Private Licensees and AEC Contractors Against Reactor Hazards*, 84th Congress, 2d Session (Washington, DC: 1956), p. 182, cited in Anderson, op. cit. note 24, p. 254.

25 See Charles H. Weaver, *Hearings Before the Joint Committee on Atomic Energy on Governmental Indemnity for Private Licensees and AEC Contractors Against Reactor Hazards*, 84th Congress, 2d Session (Washington, DC: 1956), p. 110, cited in Barry P. Brownstein, "The Price-Anderson Act: Is It Consistent With A Sound Energy Policy?" Cato Institute, *Policy Analysis* 36 (17 April 1984).

26 See, among others, Comptroller General, op. cit. note 24.

27 See Jeffrey A. Dubin and Geoffrey S. Rothwell, "Subsidy to Nuclear Power Through Price-Anderson Liability Limit," *Contemporary Policy Issues* 3 (July 1990), pp. 73–79.

28 For the revised methodology and a more detailed discussion of the reasons behind the revision, see Heyes and Liston-Heyes, op. cit. note 7, pp. 122–24. If we had used the Dubin and Rothwell methodology in our analysis, we would have arrived at a cumulative subsidy of $183.6 billion (in 1999 dollars).

29 See Douglas N. Koplow, *Federal Energy Subsidies: Energy, Environmental, and Fiscal Impacts*, App. B, Vol. I (Washington, DC: The Alliance to Save Energy, April 1993), pp. B4-81–B4-89 and accompanying tables.

30 Although not included in the analysis, further perspective on the magnitude of subsidies not quantified for hydro is possible. According to a recent study, through 1995 the U.S. Government had cumulatively invested more than $62 billion in assets used in part or in total for power generation—a large portion of which went to hydropower—at the Tennessee Valley Authority and the five Power Marketing Administration. Of this total, approximately $10 billion was invested in inactive nuclear projects. See Congressional Budget Office, *Should the Federal Government Sell Electricity?* (Washington, DC: November 1997), pp. 9, 47, and 61.

31 For a more detailed subsidy discussion and estimates for some of the subsidies included and excluded in this study, see the studies cited in Appendix A.

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