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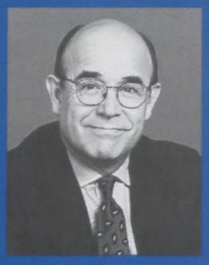
RESOURCES

RESOURCES FOR THE FUTURE RESEARCH THAT MAKES A DIFFERENCE



Paul R. Portney

World Wide Web

All the world's a web, as Under Secretary of State for Global Affairs Frank Loy suggests in this issue of *Resources*. The former RFF board member says solving global problems like ozone layer depletion and climate change means looking beyond the borders of our own countries—and our own mindsets—for international solutions.

At the annual RFF Council meeting in April similar observations were made, as J.W. Anderson notes. But if global interconnectedness sometimes seems overwhelmingly complex, technology has given us powerful new tools to help understand these ties. As one participant notes, the Internet's instant global communication capacity promises to shape green politics, too.

Joy Hecht likewise points to the Internet's importance in her update on efforts to incorporate environmental considerations into national income accounts. She notes the need for international accord on methodology in this area though, like Frank Loy, she knows that building such a broad consensus is a daunting task. Away from the global conference table, meanwhile, she tells us about environmental accounting activities going on in individual countries.

Kate Probst and Tom Beirele also take a comparative look at several countries in their study of hazardous waste programs. In a subtler way, such comparisons also inform the sneak preview David Simpson gives of the new RFF book on productivity change in U.S. natural resource industries. Among other things, he and his colleagues sought to understand why some countries are better than others at making the most of their natural resources. One factor may be how well equipped a nation is to capitalize on technology, which can compensate for depletion of easily accessible reserves and keep extraction and production costs down.

The implications of cost control through technological breakthroughs are far reaching, as Dallas Burtraw indicates in his feature on the status of renewable energy sources. Rosy predictions that we would pay less and less to buy electricity produced by sun, wind, and other renewables came true. Yet we are powering up with them far less than even the glummest prognosticator imagined. Apparently that's because conventionally generated electricity remains far cheaper than anybody ever dreamed—which brings us back to a nation's ability to use new technologies to control costs.

Of course the world has been shrinking for a long time. As the interweave tightens, we need more help from each other to unravel the strands of the problems that entangle us. At RFF we are grateful to those who understand how much we need their support to study the natural resources and environment on which we all depend.

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GOINGS ON

Healthy trading

Letting electric utilities bank and trade sulfur dioxide emissions hasn't threatened human health and the environment the way critics thought it would, especially in the Northeast. On the contrary, RFF researchers found it to be a boon to health—not only in the East as a whole—but even in New York State, where public acrimony has been high enough for one politician to liken the effects of acid rain caused by sulfur dioxide emissions to "airborne terrorism."

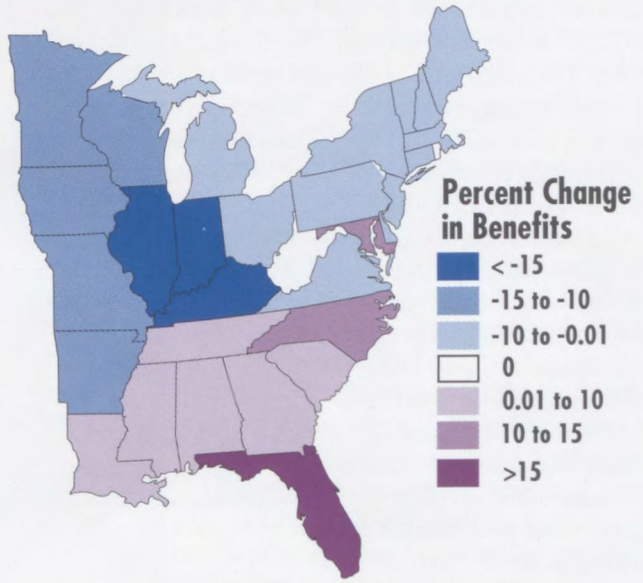
Instead of the fallout critics feared (both literally and figuratively), trading has reduced SO_2 emissions in most states outside the Ohio Valley. Lowered emissions in the more populous East translates into less chronic disease and premature death from breathing bad air; in the Northeast it means less deposition of sulfur (acid rain). Banking surplus allowances also appears beneficial, though the resulting geographic pattern of emissions changes is not simple to follow.

These findings are detailed in a study that Senior Fellow **Dallas Burtraw** and UC–Berkeley graduate student **Erin Mansur** recently completed in which they assessed effects of SO_2 trading at the state level. Using a computer model of the utility industry called the Tracking and Analysis Framework, they looked at changes in the location of emissions, the atmospheric concentrations and deposition of pollutants, and public health benefits from reduced exposure to sulfur dioxide and particulate matter.

Based on their model, in the year 2005 trading is expected to lead to health benefits nationwide of about $125 million; it is expected to lead to regulatory compliance cost savings of $531 million.

Download a copy of "The Effects of Trading and Banking in the SO_2 Allowance Market" (RFF Discussion Paper 99-25) at *http://ww.rff.org/disc_papers/PDF_files/9925.pdf*. To order by mail, see page 22.

Percent Change in Title IV Baseline Benefits Attributable to Trading for 2005



Based on RFF Research, the map shows the health benefits expected to result from sulfur dioxide emissions trading, as a portion of the overall health benefits to result from Title IV of the Clean Air Act.

Keeping cost estimates in the ballpark

Bureaucrats tend to overestimate the cost of proposed environmental and occupational health regulations—and for good reason, a recent RFF study shows. For example, unforeseen technological innovation often follows after a regulation's implementation, making it cheaper to reduce pollution. But although costs are frequently overestimated, so are benefits.

For example, overstating baseline conditions—say, the amount of emissions that would occur without a new rule—can skew estimates of both costs and benefits upward, a surprisingly common outcome.

In addition, agencies often make an upper bound estimate of compliance costs, rather than so-called "best" estimates of what is likely. And on its way to becoming final, a rule itself can change, invalidating the assumptions that were the basis for the original estimate.

These are the underlying reasons for the overestimation tendency that **Winston Harrington**, **Richard D. Morgenstern**, and **Peter Nelson** found after comparing forecasted costs with observed outcomes for more than two dozen regulations.

Unlike the few earlier efforts on the subject, the RFF examination was limited exclusively to cost estimates by government agencies, which included EPA, OSHA, and international and state regulatory bodies.

As the researchers note, inaccurate cost estimation misrepresents the true social burden of regulation, and may lead to bad policymaking and reduced public confidence in the regulatory process.

Economic incentive policies seem to be especially prone to cost overestimation, the researchers report, although their sample was small. This finding could be of particular relevance to the debate on climate change policy, since most proposals have an important economic-incentive component.

Download a copy of "On the Accuracy of Regulatory Cost Estimates" (RFF Discussion Paper 99-18) at *http://www.rff.org/disc_papers/PDF_files/9918.pdf*. To order by mail, see page 22.

GOINGS ON

The joy of flex

Touting the "joy" of flexibility in the climate change debate, RFF President **Paul R. Portney** filled his listeners in on the meaning of some climate policy terms of art at the Energy Information Administration late in March. As the keynote speaker at EIA's "National Energy Modeling System/Annual Outlook Conference," Portney also took the opportunity to call attention to a proposal for "early action" to reduce U.S. greenhouse gas emissions beginning in 2002.

Strong signals in early action

RFF researchers have put forward a proposal for mandatory greenhouse gas emissions reductions in the United States during the period 2002–2008, using an auctioned emissions permit trading system. Unlike other proposals that emphasize voluntary participation, this one would require permits for supplies of domestic and imported fossil fuels.

However, the reductions in emissions that the researchers propose are modest. Total U.S. emissions of carbon dioxide would be capped at 1996 emissions levels (or about 1,460 million tons of carbon). Compared with the deeper cuts proposed under the Kyoto Protocol, the amount is about 10 percent greater than 1990 levels and about 10 percent less than carbon emissions are forecast to be in 2002 (20 percent below the forecast for 2008).

To limit the cost of meeting the proposed goal, the researchers have built a "safety valve" into their system. If the price of a permit rose above $25/ton in 2002, the government would offer extra permits—as many as desired—at that price. The safety valve price would go up 7 percent per year above inflation during 2002–2008. This rise would be equivalent, Portney said, to a $0.06/gallon hike in gasoline prices and a $0.005/kwh increase in electricity prices in 2002.

The proposal is designed to be equitable. Since it would increase household costs for energy and other goods, three-quarters of the revenues raised in the first year would be returned directly to consumers in the form of a rebate. The remaining 25 percent would be given to states as block grants to address such concerns as the vulnerability of low-income households and certain industries.

At the conference, Portney pointed out what he thought were several attractive features of the proposal. Its modesty alone, he remarked, might give it a chance of being adopted since the safety valve ensures against skyrocketing costs.

If, Portney explained, energy conservation is as inexpensive as some say it is, the trigger price would never be set off. If the opposite turns out to be true, a number of extra tons of emissions would have to be sold. Either way, he continued, a lot would be learned about carbon mitigation costs, just as a lot was learned about sulfur abatement costs through the 1990 amendments to the Clean Air Act. The education is important, Portney emphasized, given the wildly divergent estimates of carbon abatement costs heard today.

PHOTODISC, INC

Implementation of the proposal would signal in a measured way the need to pay closer attention to energy conservation opportunities and would send a message to those who allocate research and development dollars, he said. It would also show developing countries that the United States is willing to act first to curb emissions.

Finally, Portney concluded, the proposal would give us valuable experience in how a greenhouse gas trading system would work. Such experience would stand the United States in good stead if Kyoto goes into effect, whether in its current or a renegotiated form.

RFF researchers **Raymond Kopp**, **William Pizer**, and **Michael Toman** devised the proposal, together with **Richard Morgenstern**, a former visiting scholar at RFF.

Download a copy of "The Joy of Flexibility: U.S. Climate Policy in the Next Decade" at *http://www.weathervane.rff.org/refdocs/portney_flex.pdf.*

Download "A Proposal for Credible Early Action in U.S. Climate Policy," at *http://www.weathervane.rff.org/features/feature060.html*

Mother Nature Necessitates Invention

And Technology Buoys Industry

by R. David Simpson

The United States remains competitive in world resource markets, despite geological disadvantages and a relatively long history of depletion. American ease with innovation helps explain why.

A generation ago, some prognosticators warned that Americans should brace themselves for an era of scarcity. The natural resources we depended on for food, clothing, shelter, and energy were dwindling, they claimed. But after years of resource use, the specter of scarcity remains just that. In fact, it has faded somewhat. Natural resources are neither scarce nor expensive and their price tags have declined—as much as 40 percent in the past forty years.

Prices have declined because the costs of producing natural resources have dropped. Costs have dropped because improvements in technology have more than offset the effects of depletion. Technological innovation, then, is something of a savior for America's consumers and natural resource producers, helping to make the latter strong competitors on the international market. Even copper mining is flourishing, though it seemed doomed as an American enterprise not long ago.

How exactly has technology controlled costs? With support from the Alfred P. Sloan Foundation, researchers at RFF have been exploring this question as part of a study of productivity change in four U.S. natural resource industries: coal mining, oil and gas exploration, copper mining, and forestry. In conducting the research, we performed individual case studies first and then a statistical analysis of productivity trends in the four industries. Thus we took both "bottom up" and "top down" approaches.

The record of productivity growth in U.S. natural resource industries is mixed, and does not lend itself to easy interpretation. Changes in market conditions and regulation in the 1970s apparently had some temporary negative effects on productivity. Superimposed on these temporary phenomena may be the effects of the gradual depletion of more easily accessible reserves. There is, however, a long-run trend working in the opposite direction: the introduction and adoption of improved production technologies have offset the effects of depletion. One can never be sure that such a trend will continue. Our findings published in *Productivity Change in Natural Resource Industries* identify three factors that explain how and why technology has kept natural resources relatively cheap and plentiful in the United States, however, and suggest that the same factors will continue to be important in the future.

Origins of Innovation

First of all, necessity does appear to be the mother of invention. Were it not for new technologies, extraction costs would go up as the most accessible reserves went down. The viability of companies or even whole industries depends on continuing technological progress.

Second, new inventions are rarely the results of immaculate conceptions. If necessity is their mother, then the general state of technology might be said to be their father, determining the set of innovations possible. Furthermore, breakthroughs come at the end of what can be a long gestation period that often involves cross-fertilization. New machinery and processes are rarely truly novel, consisting rather of recombinations of existing technologies.

Third, a nation's legal, political, and social institutions play a crucial role in encouraging solutions to be conceived in the first place and then husbanded through to maturity. How well a society nurtures invention makes a big difference in how much of it occurs. The United States, for example, offers a much more "innovation-friendly" environment than many of its competitors.

Winnowing Waste

Perhaps the best example we found of necessity mothering invention is something called the solvent extraction-electrowinning (Sx-Ew) process in copper mining. In the 1970s, U.S. mining companies had to reduce costs if they were to survive competition from foreign suppliers. Developing the Sx-Ew technology was an important component of the latter strategy. It enabled copper companies to "mine" the waste streams from their earlier operations; now they could extract enough copper from mine tailings to make them viable ore sources.

Just how much American copper companies have relied on the more intensive working of existing mines is striking. Annual U.S. copper production increased by more than 40 percent between the 1970s and 1990s. But new mines were few and only accounted for some 3 percent of U.S. copper production in 1995.

Similarly, a dwindling supply of trees has driven innovation in the forestry industry. Earlier improvements in harvesting technology made it possible to eliminate large swathes of forest closest to centers of population and industry. Once the most easily accessible forests were gone, setting out for increasingly rare and inaccessible virgin forest was not an attractive option. Not only are these remote areas costly to harvest, they are increasingly in demand as preserves for recreation and biodiversity conservation. Often it has become more profitable to replant and manage previously harvested areas instead. More and more, trees are being grown on plantations and treated like crops. They are being harvested in areas best suited for forestry and not simply reproduced where they stood in the past.

Increments and Complements

Among our case studies, use of three-dimensional seismology in petroleum exploration and development probably best illustrates how incremental progress has enhanced the applicability of a new technology. The way in which the technique is used today likewise shows how innovation depends on the technologies generally available in the economy, as well as those being employed in particular industries. The principles underlying 3D seismology have been known for close to a century, but its practical application had to await development of high-speed parallel computing. Absent the ability to compile and interpret extremely large amounts of data, the technique, which involves the use of sound waves to map out the shape and location of underground geological formations, was far too slow and costly to apply in practice.

Today, 3D seismology is widely used in conjunction with directional drilling and in deepwater extraction operations. These three technologies are highly complementary. Having precise information about reservoir shape and location is less valuable if the technology is not available to enter a reserve from the optimal angle. This entry is precisely what directional drilling allows. Similarly, deepwater drilling is an extremely expensive process. It would not be economical were it not possible to obtain surveys sufficiently accurate to ensure a high probability of success, which 3D seismology allows.

Complementary innovations have had reinforcing and enabling effects in all of the industries that we have studied. Plantation forests, which are themselves innovations, are profiting from biotechnological breakthroughs and from techniques first developed for agricultural crops and animal husbandry. As forestland is more and more at a premium, investments in genet-

Impacts on Innovation

Most people would agree that new types of machines are innovations. But what about new management practices? Government regulations? Changes in labor relations? They, too, are agents of transformation. Even when such developments do not amount to what might be considered innovations, however, they can have an impact on productivity change. Sometimes they drive innovation more than depletion does. Competition is one example.

ically improved trees are paying off. Selective breeding for commercial attributes like superior growth and quality is becoming more common. The adverse consequences of selection for such attributes can be offset by the use of pesticides and fertilizers, as well as irrigation and preharvest thinning.

In the coal industry, the advantage of "longwall" mining to more effectively exploit thinner and deeper seams increased in lockstep with improvements in the power and positioning technologies for deploying it. In fact, the advent of ever larger and more powerful machinery—including trucks the size of small buildings—has enhanced coal productivity overall. These developments depended on a host of mechanical improvements.

Of course, sometimes an industry's technology does advance piecemeal. Although the history of oil and gas exploration is an incremental one built on adaptation of outside technologies, it is also episodic: That is, first one technology was developed that could identify one type of deposit; deposits of that type were discovered and exploited. Then a second technology was developed to identify a second type of deposit; deposits of the second type were discovered and exploited; and so on.

But close inspection of industry histories suggests that episodic evolution is the exception that proves the rule. The clear evidence of all the case studies is that even major innovations are accompanied by ancillary developments that enhance their efficiency and broaden their applicability.

A Culture of Innovation

The pressure of circumstances and the spillover benefits from complementary technologies do not provide a complete explanation of how and why innovation occurs. As seen in the case studies as well as in general data on world economic development, those nations and firms that pioneered new technologies in one period are likely to do so in the next. To some extent, this tendency might be seen as a consequence of the factors already cited. If depletion induces innovation, further depletion may induce further innovation. And if the existence of one generation of technology creates conditions for the birth of another, the firms and countries that produce the first generation may be better positioned to produce the second. Innovations do get diffused throughout the world, but technological leadership tends to persist.

Why do some countries that enjoy an advantage with respect to their endowments of natural resources fail to press that advantage by investment? And why, on the other hand, do some nations with relatively few resources invest in extraction and grow rich? Simple theory predicts that the return to capital investment ought to be higher in areas in which capital stock is low compared with plentiful labor, resource reserves, and other factors of production. The

Competition

By and large, the case studies support the view that competition begets innovation. The study of coal provides ample evidence that a period in which regulatory considerations generated greater competition between producers was also one in which tremendous technological strides were made.

Being denied protection from foreign competition in the 1970s appears to have strengthened the U.S. copper industry. Those firms that survived were forced to innovate. As a result, the U.S. industry is arguably more competitive now than many of its foreign rivals, who, despite their advantage of richer reserves, have not made the same investments in modernization.

In the 1980s, the U.S. petroleum industry faced a squeeze between competition from foreign producers and the upward pressure exerted on costs by the depletion of easily accessible domestic reserves. This double bind forced development of techniques to exploit known reserves at competitive costs.

Public Funding

Government ownership of resource stocks might be expected to reduce incentives for innovation. Nonetheless, public support for research and development has proven important. The solvent extraction-electrowinning process now used in copper mining was first employed in mining uranium for military purposes. Byproducts of publicly funded research related to outer space include global positioning systems used in the coal industry to make extraction and movement of coal more efficient, and satellite communications used to transfer seismological data from petroleum exploration. Public funding has also helped advance diffusion. Research at the U.S. Bureau of Mines helped foster the introduction into this country of longwall mining technologies pioneered in Britain and Germany.

basis for this theory is that investment would flow from the wealthier to the poorer nations of the world. In fact, it appears that the opposite is often true. Japan, for example, has relatively few natural resources but receives a great deal of capital investment, while many richly endowed African nations receive very little.

A great many explanations for this apparent paradox have been proposed. One common notion is that capital investment—and, in particular, investment in high-technology equipment—either creates or attests to conditions where further investment in high-technology equipment is profitable.

We can only point out that improving technologies incrementally, borrowing related technologies, and recombining existing ones to generate innovations are facilitated by corporate ties and physical proximity. Even in the absence of these factors, relative openness with respect to information sharing, as may occur among firms within and among advanced industrial countries, seems conducive to innovation.

A more basic consideration yet is that innovators, if they are to have an incentive to innovate, must have some confidence that they are going to enjoy the rewards of success. Many regions blessed with abundant resources lack what may be termed the political, social, and cultural prerequisites for world-class production. It would be a good thing for both humanitarian and pragmatic reasons if developing nations could quickly acquire these prerequisites.

To the extent that they do not, however, we can anticipate that U.S. natural resource industries will remain competitive in world resource markets despite the fact that geology and a longer history of depletion would seem to place them at a cost disadvantage. It is true that the scale of U.S. production has, in some instances, declined in absolute terms or relative to world production. The fact remains, however, that U.S. firms are able to produce at costs that make them competitive with foreign rivals. This fact must be ascribed to an ability to develop and adopt new technologies more readily than many of its competitors.

Like the United States, those firms and nations that demonstrate a persistent commitment to innovation and the development and use of new technologies are likely to remain profitable even if their new technologies can be copied in a matter of years or even months. The reason is that successful research and development have as much to do with continuing experimentation as they do with specific breakthroughs. Those who are willing to experiment—and who are blessed by experience, temperament, and, perhaps, cultural support—may remain industry leaders for longer periods than their resource endowments suggest.

A New Era of Scarcity?

With gasoline prices near historical lows one might not expect it, but some researchers are suggesting that a new era of oil shortages is just around the corner. As Richard Kerr has reported (*Science*, 21 August 1998, pp. 1128–1131) these researchers predict that the end of cheap oil is coming soon. They argue that since the most easily accessible petroleum reserves are near exhaustion, costs of production will begin to rise.

RFF researchers Joel Darmstadter and Michael Toman challenge this assertion, however, as indicated in their letter of response (*Science*, 2 October 1998, pp. 47–48). The innovations documented in *Productivity Change in Natural Resource Industries* provide examples of how the petroleum industry might again deal with difficult circumstances. Moreover, the issue is not so much the physical depletion of petroleum reserves as society's demand for them. Just as more fuel-efficient cars were built in response to the energy crisis of the 1970s, we might again successfully substitute efficiency for quantity of energy use and weather future shortages.

R. David Simpson is a fellow in RFF's Energy and Natural Resources Division. This article was adapted from his introduction to the new RFF book *Productivity Change in Natural Resource Industries*, which he edited. To order a copy, see page 22.

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

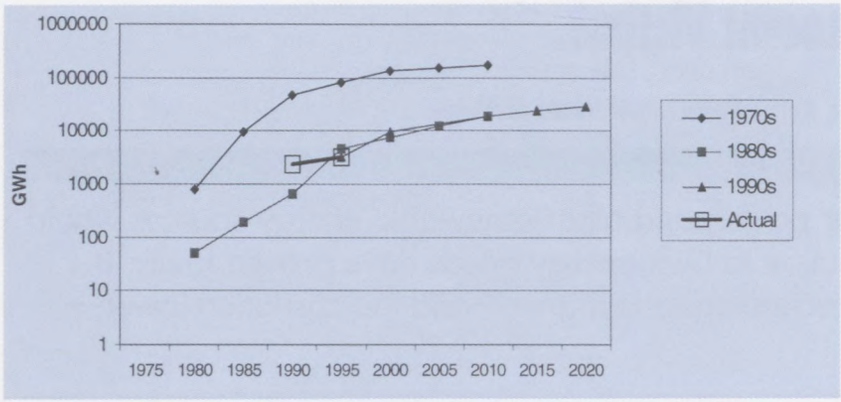


Figure 1. Wind Generation by Date of Forecast

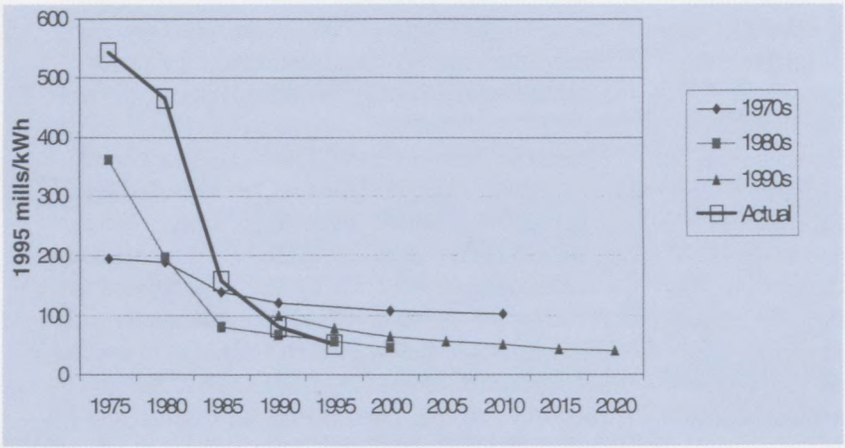


Figure 2. Wind Cost of Electricity by Date of Forecast

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 reoccurs in a similar way for solar photovoltaic produc-

tion. 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.

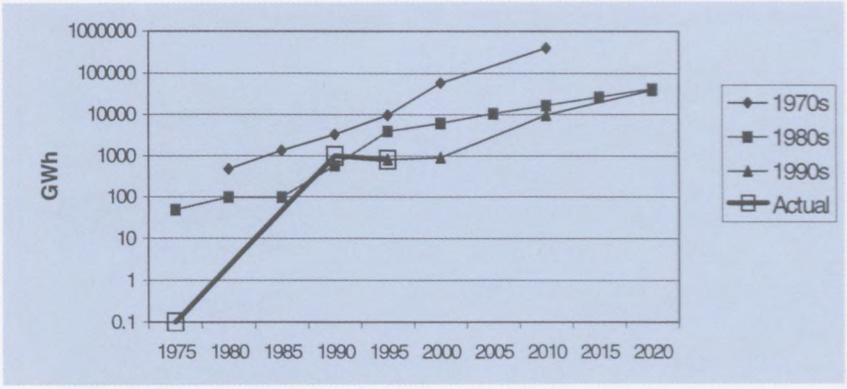


Figure 3. Solar Thermal Generation by Date of Forecast

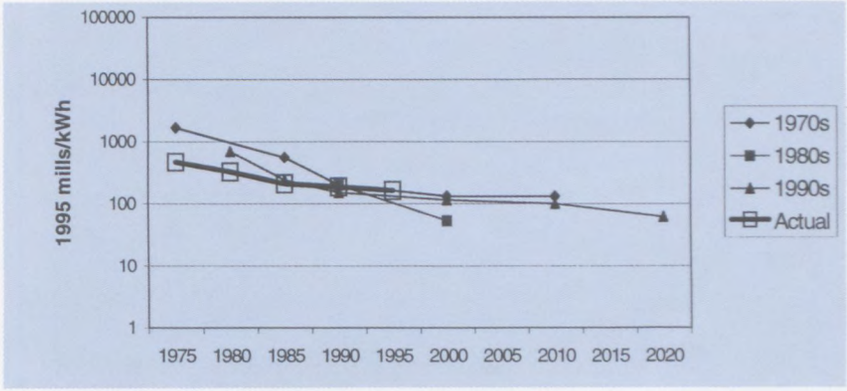


Figure 4. Solar Thermal Cost of Electricity by Date of Forecast

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.

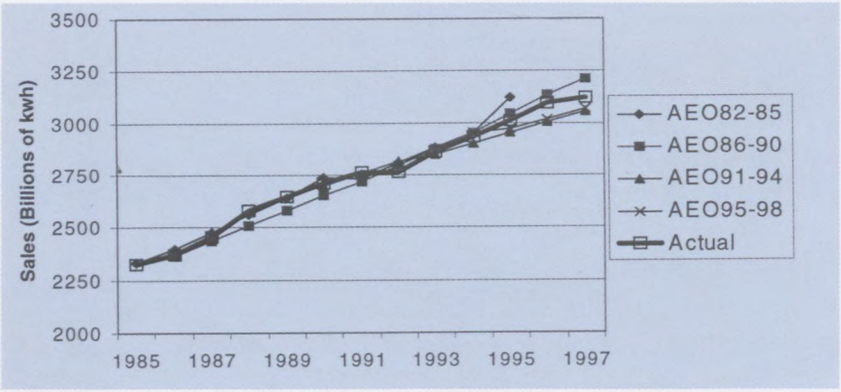


Figure 5. Conventional Generation (Retail Sales) by Date of Forecast

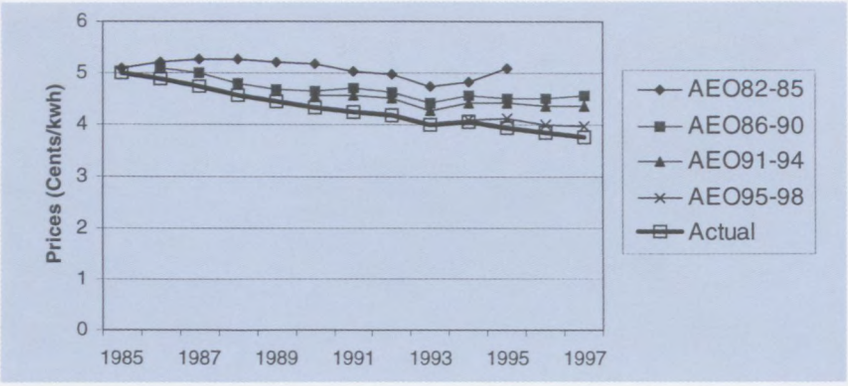


Figure 6. Conventional Generation Cost of Electricity (Retail Prices) by Date of Forecast

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.

The **Renewable Energy Policy Project** supported the research reported in this article. *http://www.repp.org*. The authors are also grateful to **Martin Heintzelman** and individuals too numerous to list for their help in the study.

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Environmental Accounting

Where We Are Now, Where We Are Heading

by Joy E. Hecht

Interest is growing in modifying national income accounting systems to promote understanding of the links between economy and environment.

The field of environmental accounting has made great strides in the past two decades, moving from a rather arcane endeavor to one tested in dozens of countries and well established in a few. But the idea that nations might integrate the economic role of the environment into their income accounts is neither a quick sell nor a quick process; it has been under discussion since the 1960s. Despite the difficulties and controversies described in this article, however, interest is growing in modifying national income accounting systems to promote understanding of the links between economy and environment.

Why Change?

Governments around the world develop economic data systems known as national income accounts to calculate macroeconomic indicators such as gross domestic product. Building a nation's economic use of the environment into such accounts is a response to several perceived flaws in the System of National Accounts (SNA), as defined by the United Nations and used internationally. One flaw in the SNA often cited is that the cost of environmental protection cannot be identified. Consequently, money spent, say, to put pollution control devices on smokestacks increases GDP, even though the expenditure is not economically productive, some argue. These critics call for differentiating "defensive" expenditures from others within the accounts.

Also misleading is the fact that some environmental goods are not marketed though they provide economic value. Fuelwood gathered in forests, meat and fish gathered for consumption, and medicinal plants are examples. So are drinking and irrigation water, whose sale prices reflect the cost of distribution and treatment infrastructure, but not the water itself. While some countries do include such goods in their national income accounts, no standard practices exist for doing so. When nonmarketed goods are included in the accounts, they still cannot be distinguished from those that are marketed.

Valuing environmental services such as the watershed protection that forests afford and the crop fertilization that insects provide is difficult. Though some experts call for their inclusion in environmentally adjusted accounts, typically neither the economic value nor the degradation of these services is included. On the other hand, however, the alternate goods and services needed to replace them—water treatment plants, for example—do contribute to GDP, which can be rather misleading.

Still another problem is that national income accounts treat the depreciation of manufactured capital and natural capital differently. Physical capital—a building or a machine, for instance—is depreciated in accordance with conventional business accounting principles, while all consumption of natural capital is accounted for as income. Thus the accounts of a country that harvests its forests unsustainably will show high income for a few years, but will not reflect the destruction of the productive forest asset. While opinions vary on how to depreciate natural capital, they converge on the need to do so.

Which Indicators Are Useful?

Some proponents advocate simple "flag" indicators to alert policymakers to the broad role of the environment in the economy, for example, comparing conventional GDP with environmentally adjusted GDP, or conventional savings with so-called "genuine" savings that account for environmental factors. Both of these indicators can provide valuable warnings of the impacts of environmental degradation on an economy.

However, such flags are less useful in determining

the source of environmental harm or identifying a policy response. For this reason, many economists place primary importance not on the bottom line, but on the underlying data used to build environmental accounts. These data can help answer such questions as how natural catastrophes like the fires that raged in Indonesia in the summer of 1998 may affect economic growth, or how environmental protection policies such as green taxes may affect the economy.

Who Is Doing This?

Environmental accounting is underway in several dozen countries, where bureaucrats, statisticians, and other proponents both foreign and domestic have initiated activities over the past few decades. Several countries have made continuous investments in building routine data systems, which are integrated into existing statistical systems and economic planning activities. Others have made more limited efforts to calculate a few indicators, or analyze a single sector. Some of the earliest research on environmental accounting was done at RFF by Henry Peskin, working on the design of accounts for the United States.

One of the first countries to build environmental accounts is Norway, which began collecting data on energy sources, fisheries, forests, and minerals in the 1970s to address resource scarcity. Over time, the Norwegians have expanded their accounts to include data on air pollutant emissions. Their accounts feed into a model of the national economy, which policymakers use to assess the energy implications of alternate growth strategies. Inclusion of these data also allows them to anticipate the impacts of different growth patterns on compliance with international conventions on pollutant emissions.

More recently, a number of resource-dependent countries have become interested in measuring depreciation of their natural assets and adjusting their GDPs environmentally. One impetus for their interest was the 1989 study "Wasting Assets: Natural Resources in the National Income Accounts," in which Robert Repetto and his colleagues at the World Resources Institute estimated the depreciation of Indonesia's forests, petroleum reserves, and soil assets. Once adjusted to account for that depreciation, Indonesia's GDP and growth rates both sank significantly below conventional figures. While "Wasting Assets" called many to action, it also operated as a brake, leading many economists and statisticians to warn against a focus on green GDP, because it tells decisionmakers nothing about the causes or solutions for environmental problems.

Since that time, several developing countries have made long-term commitments to broad-based environmental accounting. Namibia began work on resource accounts in 1994, addressing such questions as whether the government has been able to capture rents from the minerals and fisheries sectors, how to allocate scarce water supplies, and how rangeland degradation affects the value of livestock.

The Philippines began work on environmental accounts in 1990. The approach used there is to build all economic inputs and outputs into the accounts, including nonmarketed goods and services of the environment. Thus Filipinos estimate monetary values for such items as gathered fuelwood and the waste disposal services provided by air, water, and land; they then add in direct consumption of such services as recreation and aesthetic appreciation of the natural world. While their methodology is controversial, these accounts have provided Philippine government agencies and researchers with a rich array of data for policymaking and analysis.

The United States has not been a leader in the environmental accounting arena. At the start of the Clinton administration, the Bureau of Economic Analysis (BEA) made a foray into environmental accounting in the minerals sector, but this preliminary attempt became embroiled in political controversy and faced opposition from the minerals industry. Congress then asked the National Research Council (NRC) to form a blue ribbon panel to consider what the nation should do in the way of environmental accounting. Since then, Congressional appropriations to BEA have been accompanied by an explicit prohibition on environmental accounting work. The ban may be lifted, however, once the recommendations of the NRC study are made public.

How to Account?

How environmental accounting is being done varies in a number of respects, notably the magnitude of the investment required, the objectivity of the data, the ability to compare different kinds of environmental impacts, and the kinds of policy purposes to which

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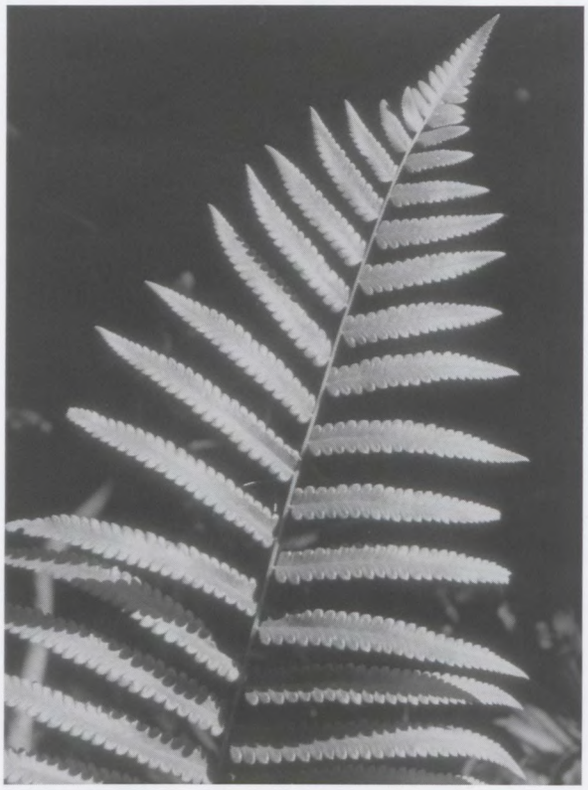

they may be applied. Here are some of the methods currently in use.

Natural Resource Accounts. These include data on stocks of natural resources and changes in them caused by either natural processes or human use. Such accounts typically cover agricultural land, fisheries, forests, minerals and petroleum, and water. In some countries, the accounts also include monetary data on the value of such resources. But attempts at valuation raise significant technical difficulties. It is fairly easy to track the value of resource *flows* when the goods are sold in markets, as in the case of timber and fish. Valuing *changes in the stocks*, however, is more difficult because they could be the result either of a physical change in the resource or of a fluctuation in market price.

For environmental goods and services that are not sold, it is that much harder to establish the value either of the flow or of a change in stock. However, even physical data can be linked to the economy for policy purposes. For example, changes in income can sometimes be traced to changes in the resource base or to the impact of environmental catastrophes on the economy.

Emissions accounting. Developed by the Dutch, the National Accounting Matrix including Environmental Accounts (NAMEA) structures the accounts in a matrix, which identifies pollutant emissions by economic sector. Eurostat, the statistical arm of the European Union, is helping EU members apply this approach as part of its environmental accounting program. The physical data in the NAMEA system are used to assess the impact of different growth strategies on environmental quality. Data can also be separated by type of pollutant emission to understand the impact on domestic, transborder, or global environments. If emissions are valued in monetary terms, these values can be used to determine the economic cost of avoiding environmental degradation in the first place, as well as to compare costs and benefits of environmental protection.

Disaggregation of conventional national accounts. Sometimes data in the conventional accounts are taken apart to identify expenditures specifically related to the environment, such as those incurred to prevent or mitigate harm, to buy and install protection equipment, or to pay for charges and subsidies. Over time, revelation of these data makes it possible to observe links between changes in environmental policy and costs of environmental protection, as well as to track the evolution of the environmental protection industry.

While these data are of obvious interest, some people argue that looking at them in isolation can be misleading. For example, while end-of-pipe pollution control equipment is easily observed, new factories and vehicles increasingly are lowering their pollutant emissions through product redesign or process change rather than relying on special equipment. In such cases, no pollution control expenditures would show up in the accounts, yet environmental performance might be better than in a case where expenditures do show up.

Value of nonmarketed environmental goods and services. Considerable controversy exists over whether to include the imputed value of nonmarketed environmental goods and services in environmental accounts, such as the benefits of an unpolluted lake or a scenic vista. On the one hand, the value of these items is crucial if the accounts are to be used to assess tradeoffs between economic and environmental goals. Otherwise, the accounts can end up reflecting the costs of protecting the environment without in any

way reflecting the benefits. On the other hand, some people feel that valuation is a modeling activity that goes beyond conventional accounting and should not be directly linked to the SNA. The concern underlying their view is that it is difficult to standardize valuation methods, so the resulting accounts may not be comparable across countries or economic sectors within a country.

Green GDP. Developing a gross domestic product that includes the environment is also a matter of controversy. Most people actively involved in building environmental accounts minimize its importance. Because environmental accounting methods are not standardized, a green GDP can have a different meaning in each project that calculates it, so values are not comparable across countries. Moreover, while a green GDP can draw attention to policy problems, it is not useful for figuring out how to resolve them. Nevertheless, most accounting projects that include monetary values do calculate this indicator. Great interest in it exists despite its limitations.

Toward Consensus on Method

Environmental accounting would receive a substantial boost if an international consensus could be reached on methodology. The UN Statistics Department has coordinated some of the ongoing efforts toward this end since the 1980s. In 1993, the UN published the System for Integrated Economic and Environmental Accounting (SEEA) as an annex to the 1993 revisions of the SNA. SEEA is structured as a series of methodological options, which include most of the different accounting activities described above; users choose the options most appropriate to their needs.

No consensus exists on the various methods that the UN recommended. In fact, SEEA is now undergoing revision by the so-called "London Group," comprised primarily of national income accountants and statisticians from OECD countries. The group's work will be an important step toward consensus on accounting methods, but the process will be lengthy: Development of the conventional SNA took some forty years.

Toward Widespread Use

A number of steps can be taken now toward the goal of ensuring that environmental accounting is as well established as the SNA. First, information must circulate freely about existing environmental accounts and how they are contributing to economic and environmental policy. Ongoing work needs to be identified and systematically reviewed and analyzed to learn lessons, which may inform the design and implementation of future accounting activities. The Green Accounting Initiative of the World Conservation Union has embarked on this effort, and a number of other organizations are calling for similar activities. Use of the World Wide Web may facilitate access to unpublished work, although it will require a concerted effort to obtain accounting reports and seek permission to load them on the Internet.

Second, development of a core of internationally standardized methods will contribute to willingness to adopt environmental accounting. Experts in the field—including economists, environmentalists, academics, and others outside of the national statistical offices—should take a proactive role in tracking the work of the London Group and insist that the standard-setting process involve participants representing a spectrum of viewpoints, countries, and interested stakeholders. An opportunity exists for research institutes to take a lead in identifying the financial resources needed to facilitate a broader standard-setting process, and to elicit a full range of voices to build a consensus on methodology.

Finally, and perhaps most importantly, the more countries institutionalize construction of environmental accounts, the greater the momentum for more of the same.

Still, building accounts—like developing any time-series statistics—will not happen overnight. Their construction will require sustained institutional and financial commitment to ensure that the investment lasts long enough to yield results. But the experiences of Norway, Namibia, and the Philippines show that such a commitment can pay off; it is a commitment that more countries around the world need to make.

Joy E. Hecht coordinates the Green Accounting Initiative at the International Union for the Conservation of Nature. *http://www.iucnus.org/greenacct.html* . While on the RFF staff in 1980–81, she began working on environmental accounting. This article is based on a talk she gave last fall as part of RFF's Wednesday Seminar Series.

INTERVIEW

AS THE WORLD SHRINKS

Think Globally, Act Globally

Under Secretary of State for Global Affairs Frank E. Loy has had a long career in business, government, and law, including much international engagement. Among other things, he helped found the Regional Environmental Center for Central and Eastern Europe, Budapest, and was president of the German Marshall Fund of the United States. He once directed the State department's Bureau of Refugee Programs and was a deputy assistant secretary of state for economic affairs.
Loy is also a former RFF board member. He spoke recently with J.W. Anderson, RFF's journalist in residence.

RFF: Let me ask you to talk about the shift of environmental policy and politics from domestic to international affairs.

Loy: The shift in emphasis is, I think, profound, and the changes that are required of people and governments are equally profound. Years ago you didn't have, or at least you weren't aware of, depletion of the ozone layer or concentration of greenhouse gases or the junk left in space from orbiting satellites. And one more thing I should mention is the globalization of world trade. If a large fraction of your goods come from or go to foreign countries then all of a sudden, not only what comes in but how it is manufactured and the environmental impact becomes a matter of concern. Formerly we were able to deal meaningfully with the environment—with our environment—by focusing on the neighborhood, or the state, or the United States. Today we realize what we do as a neighborhood and state and the United States isn't enough.

RFF: How is this going to affect the way Americans think about environmental protection? Are we going to have to think in terms of slower progress now that it's a matter of dealing with one hundred and eighty other governments?

Loy: I think so, although we have had some examples—the Montreal Protocol is an excellent one—where we were able in a rather short period of time to deal with a big problem quickly. But mostly environmental progress internationally takes a long time. You start off with the stark proposition that there is no legislature,

and so you can't adopt a law. Therefore you have got to find ways you can get people who are not subject to "law" to go along. The most common technique we have for that perhaps is a treaty, although we can have less formal measures—common consent or mutual action— not mandated by law or by treaty. But still all of those actions take a lot longer and are very frustrating.

On top of that we have a phenomenon that many people in America are quite concerned about and may be even suspicious of and that is international agreements.

RFF: Or international regulations.

Loy: Or international regulations or international bureaucracy. Some see that as another layer of government, a foreign layer, and in some ways a bit of intrusion on our sovereignty. So we need to bring along the techniques of making international agreements and we need to bring along concurrently a broader understanding by the American people of the necessity of doing that.

RFF: What's the government going to have to do to maintain that public support?

Loy: We have to do a big educational job. I think we need help to make progress. We need the help of those parts of American society that understand the need for progress, and hopefully agree with it. What help we do get is frequently from nongovernmental organizations some of whom are dedicated to similar ends. But also we need to have the business community or at least significant parts of it. There one can be somewhat encouraged.

If you look at the biggest of the international environmental issues facing us today—like climate change—you have to say that the attitude of the business community today is much different than it was two or three years ago. I don't mean to say it's uniform. But there are now international business entities being quite progressive for a variety of reasons having to do with a sense of profit, a sense of social responsibility, or a sense of being on the right side of history, if you will. They are saying: look, we've got to accept the notion that science tells us there's a huge problem, that man is part of that problem, that we the business community are part of man's contribution, and thus we've got to do something about it. Those are words you did not hear a few years ago. You do hear them now. So that's encouraging.

We also need to try to remove some of these issues from partisan argument, and be able to treat them more on their merits. In today's climate that's not easy, but there is almost no reason really why some of these issues ought to be the subject of partisan dispute.

I think one of the reasons the standing of the environmental community as a whole has over the years suffered in the minds of certain conservative elements in the United States, both in Congress and among the general population, is that environmental progress has been equated with federal regulation. We know that form of regulation is distrusted by many, and is a concern to many. On the other hand, we now have enough examples where federal action has actually helped solve problems that we are beginning to break down some of those hostile attitudes.

When you go from federal action to international action, then of course some people see intrusive bureaucracies, high costs, investigators snooping on your land. It takes a long time to make clear that's not what we are talking about. I do think the inevitability of the internationalization of the problem and therefore the solution is going to mean that we are going to have some success—but it takes a lot of education.

RFF: How difficult is it going to be to bring along other countries who have no tradition of environmental protection? Is that going to be a fifty-year process?

Loy: Gosh, I hope not because I'll probably no longer be in office at the end of that period. I think the problem is less and less that the countries to which you're referring are handicapped by the absence of an environmentalist tradition. That's beginning to change; they do recognize they have a huge stake. On the other hand, the climate negotiations have certainly shown that the division between North thinking and South thinking is not dead.

There are two strong feelings that make it hard to get international agreements. One of them is that, in the particular case of global climate change but also in a lot of other environmental issues—the cause of the environmental problem is the developed world. Of course, there's much to that. We've put out most of the fossil fuel emissions. And therefore the equities require us to do most of the work. And second, there is a great feeling that what we propose to them in some way or another would thwart their development strategies. Or that in some way or another we ask of them something that is too complicated, and for which they have neither the human nor the dollar resources to respond. And frequently that latter part is true. We don't have a big capability of helping them, although we do help. The Department of Energy has had a program of country studies, along with EPA. AID has done work on capacity building. But nevertheless it is true that many of the developing countries feel they can't effectively participate, and others feel that they'll just wait until we've done all the heavy lifting.

RFF: What can an organization like RFF do usefully? If you were still on the board, what would you be telling them to do?

Loy: My sense is that think tanks or collections of scholarly investigators such as RFF ought in large part to seek to occupy a hole in the selection of information and analysis that is available to policymakers. Policymakers like myself get very good help on stuff that will arise tomorrow or next week. You get very good briefings. If we want, on the other hand, to push out the frontiers of knowledge, we have a contracting capability to go to universities. If you went to a university, about four years later the project might be done and it would be very good. But for the time period in between, it's hard to get help.

The second thing I would say is I think it's important for the organization to establish something of a research agenda and that agenda, in turn, be related to the needs of the policy community.

The third thing has to do with timing. There are times where analyses and research that is provided by think tanks like RFF is relevant and there are times when it is not relevant, wasted. When one sets research agendas one frequently ought to think about when the product ought to be done. I do think timing these products is important. Those are the three things I would say to RFF.

How to Manage Hazardous Waste

Developing A Successful Program

by Katherine N. Probst and Thomas C. Beierle

In most countries, the development of environmental programs follows a similar pattern. Early efforts concentrate on direct threats to public health, such as contaminated drinking water and air pollution. Only after these problems are addressed does management of wastes deemed "hazardous" rise to the top of the environmental agenda. Many countries in North America and Europe enacted legislation instituting hazardous waste requirements during the 1970s. By the late 1980s, hazardous waste management programs could be considered "fully operational" in many of these developed countries. In most, attention has now turned to minimizing waste production in the first place.

Few developing countries have effective hazardous waste management programs, but many are seeking to institute them. Looking back at the experience of countries with mature programs, it is possible to identify some key components of success.

- A definition of what constitutes "hazardous waste";
- Requirements for how wastes are to be treated, stored, and disposed;
- Information on the origin, type, and quantities of waste generation;
- A designated agency (or agencies) to set regulatory requirements and see that they are enforced;
- Adequate capacity in modern waste management facilities so that wastes can be treated, stored, and disposed of in an environmentally sound fashion;
- A "culture of compliance" where meeting requirements is the norm, and waste generators and those operating waste management facilities—as well as the general public—believe government requirements will be systematically monitored and fairly enforced.

Some of these elements are easier to achieve than others, and all of them take time. Even in developed countries with well-established and credible environmental programs, such as the United States and Germany, creating an effective program took ten to fifteen years. Some developing countries, such as Thailand, Malaysia, and Indonesia, have been actively involved in regulating hazardous waste for the past five to ten years, but still have a long way to go. In many ways, the central challenge is creating incentives for proper hazardous waste treatment and disposal, the demand for which is driven largely by regulatory requirements.

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Absent such requirements, it is unlikely that hazardous waste generators will pay the price for proper waste management. One of the concerns about instituting more stringent—and costly—requirements is that it makes proper waste treatment and disposal *more* expensive, thus creating a powerful incentive for *improper* waste disposal. One answer may be for government to subsidize the cost of proper waste disposal, at least in the early years of new hazardous waste requirements.

In fact, in many countries, government plays an important role in ensuring that modern treatment and disposal facilities are built. One of the difficulties for countries seeking to encourage better waste management is that few, if any, high quality waste treatment and disposal facilities usually exist, absent requirements for proper waste management. Yet without these facilities, waste generators often cannot comply with new requirements for proper treatment and disposal (unless they build their own facilities on site, as some large generators do).

What lessons can we offer countries embarking on this challenge? First, the time it takes to see a marked improvement in hazardous waste management is measured in decades, not years. Second, there is no "correct" approach to creating a program that will work in every country, or every situation. Each country has a unique economy, legal and cultural institutions, and governmental system to consider. Third—and perhaps most important for success—is the existence of credible and effective regulatory and enforcement institutions. Absent these, sound requirements may be on the books, but are unlikely to be met. Finally, in those countries lacking effective regulatory and enforcement systems, direct public financing of hazardous waste infrastructure may be the best policy for ensuring that modern waste treatment and disposal facilities are built, and equally important, for encouraging (through subsidized disposal fees) that these facilities are in fact in demand.

Katherine N. Probst is a senior fellow and Thomas C. Beierle is a research associate in RFF's Center for Risk Management. This article is based on their report *The Evolution of Hazardous Waste Programs: Lessons from Eight Countries,* to be issued in June. To order the report, see page 22; to download it electronically, go to *http://www.rff.org.*

Environmental Advocacy

Prospects for the Twenty-First Century

by J. W. Anderson

PALM SPRINGS, California, April 22–23—Alliances between greens and business will be central to environmental progress in the next century, a succession of invited speakers told the RFF Council at its annual meeting. (This is the group of individuals, foundations, and corporations that provide significant support to RFF.) But those alliances will be uneasy, several environmental leaders emphasized, and the subject of continuing controversy among their organizations.

"We have a low comfort level" with broad agreements with business corporations, observed Mike McCloskey, about to step down as chairman of the Sierra Club. Case-by-case cooperation, he said, is preferable.

Paul Portney, president of RFF, asked whether corporations are not more likely than national governments to carry the developed economies' environmental standards abroad. Joshua S. Reichert, director of the environment program of the Pew Charitable Trusts, briskly replied that he hoped not. There are opportunities to work productively with business, he said, but the goals of corporations and of environmentalists are fundamentally different.

McCloskey agreed that multinational corporations are likely to build to U.S. environmental standards abroad, but doubted that they could make much difference in countries like China, India, or Russia.

The Council session was devoted to the direction that environmental advocacy is likely to take in the years ahead. Pressure for alliances between green organizations and their sometime adversaries in the business world is rising for two reasons, the increasing importance of international environmental issues and the deadlock in Washington over national policy.

Marcia Aronoff, deputy director for programs of the Environmental Defense Fund, said that, because of the deadlock, her organization saw little hope of persuading federal regulators to tighten their rules for paper-making. Instead it went directly to McDonald's restaurants and persuaded it to use less, and different kinds of, paper for its containers and wrappers. When the dominant corporation in the field changed its practices, other companies in the fast-food business rapidly followed.

Privatization is good for the environment, John E. Bryson told the Council. Bryson, a co-founder of the Natural Resources Defense Council, is now chairman and chief executive officer of Edison

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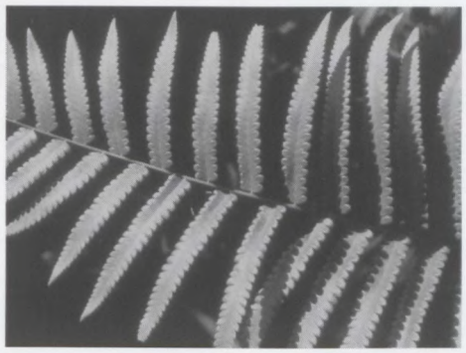

International and its subsidiary, Southern California Edison. Drawing on his experience as a former chairman of California's Water Resources Control board, he said that it was relatively easy to enforce the law on private corporations, and almost impossible to enforce it on the state's two biggest violators of the water pollution rules—the cities of Los Angeles and San Francisco. Environmental advocates who keep a close relationship to business, he argued, tend to have greater effect, at lower cost, than those who are adversarial.

Adversarial tactics have vigorous defenders. Luke Cole, of the California Rural Legal Assistance Foundation's Center on Race, Poverty and the Environment, foresaw more attacks on corporate charters and criminal actions against businesses in environmental cases. He chided what he termed the traditional environmental movement for "fusing" with business.

But environmentalism itself "is a social change movement," retorted Mark Van Putten, president of the National Wildlife Federation. "One of its great assets is the passion the believers bring to the cause."

Victoria Tschinkel, a member of RFF's board of directors (many of whom participated in this meeting), raised a question about indicators, from the size of new houses to the number of miles that people drive daily, that are moving rapidly in the wrong direction. The environmental movement is very middle class, she observed, and its organizations do not challenge middle class values. Aronoff replied that while few environmentalists were willing to dispense with, for example, air conditioning, they are receptive to producing it with the least damage to the ecology. But it's also true, she wryly added, that everybody in China wants a car.

Some of the environmentalists at the conference acknowledged that they had not yet worked out effective techniques to deal with international issues.

"Tensions will continue to grow between the clean and the dirty parts of the planet," McCloskey warned. These issues will become more salient as pollutants are better understood. International agreements are extremely difficult to negotiate, he said, but action solely at the national level is inadequate.

And yet, as Aronoff observed, with the arrival of the Internet, technology has given the environmental movement a powerful new tool. A worldwide communications system offering instantaneous speed at almost no cost, it promises to be a significant force, she forecast, in shaping green politics.

J.W. Anderson is RFF's journalist in residence. For many years, he was a staff writer for the *Washington Post's* editorial page.

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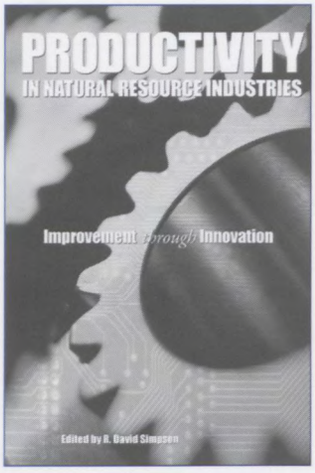

Productivity in Natural Resource Industries
Improvement Through Innovation

Edited by R. David Simpson

Through individual case studies, distinguished scholars chronicle the development and diffusion of recent innovations in coal mining, petroleum exploration and development, copper mining, and forestry. Where do such innovations originate, and how do they come to fruition? What net effect have they had on productivity? What lessons can we draw from the experience of these industries over the past quarter century?

The primary focus of this book is on extraction and production technologies, but important changes are also considered in other areas, such as government regulation, management techniques, and macroeconomic conditions. The introduction presents an overview of the major issues, especially the connection between resource depletion and economic activity; the concluding chapter presents a statistical analysis of productivity changes in the four industries.

R. David Simpson is a fellow in RFF's Energy and Natural Resources Division.

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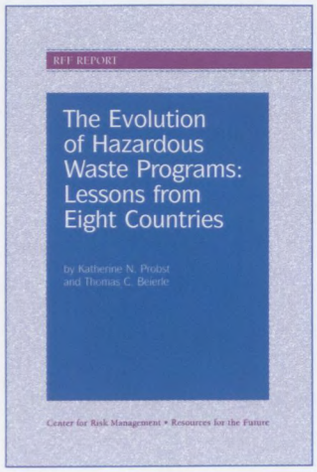
The Evolution of Hazardous Waste Programs: Lessons from Eight Countries

Katherine N. Probst and Thomas C. Beierle

In this new report, the authors compare the development of hazardous waste management programs in eight countries—the United States, Canada, Germany, Denmark, Indonesia, Hong Kong, Malaysia, and Thailand—and focus on two questions: What were the major steps in the evolution of a successful hazardous waste program? What role, if any, did the public sector play in financing modern treatment and disposal facilities?

An effective hazardous waste management program must change the behavior of organizations that generate and manage hazardous wastes. To achieve this change, an effective regulatory program and adequate facilities must exist for treatment, storage, and disposal. The authors conclude that a successful program takes 10-15 years to develop, even in countries with strong government institutions. They also conclude that public sector financing and subsidies are important policy tools for bringing facilities on-line and for creating incentives for waste generators to manage their wastes responsibly.

Katherine N. Probst is a senior fellow and Thomas C. Beierle is a research associate in RFF's Center for Risk Management.



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Like most organizations, RFF cannot afford to rely on the kindness of strangers. How fortunate for us, then, to be blessed with friends and benefactors willing to support for nearly fifty years our mission of providing the best possible research and policy analysis on natural resources and the environment.

RFF has gratefully received many different types of gifts over the years, most typically annual contributions of cash. Some of our friends, meanwhile, have discovered an excellent alternative way to show their support, and that is through a *planned gift*: On the one hand, such a gift permits a handsome contribution to support RFF. On the other, it allows our contributors to accrue to themselves attractive tax benefits and/or income for life.

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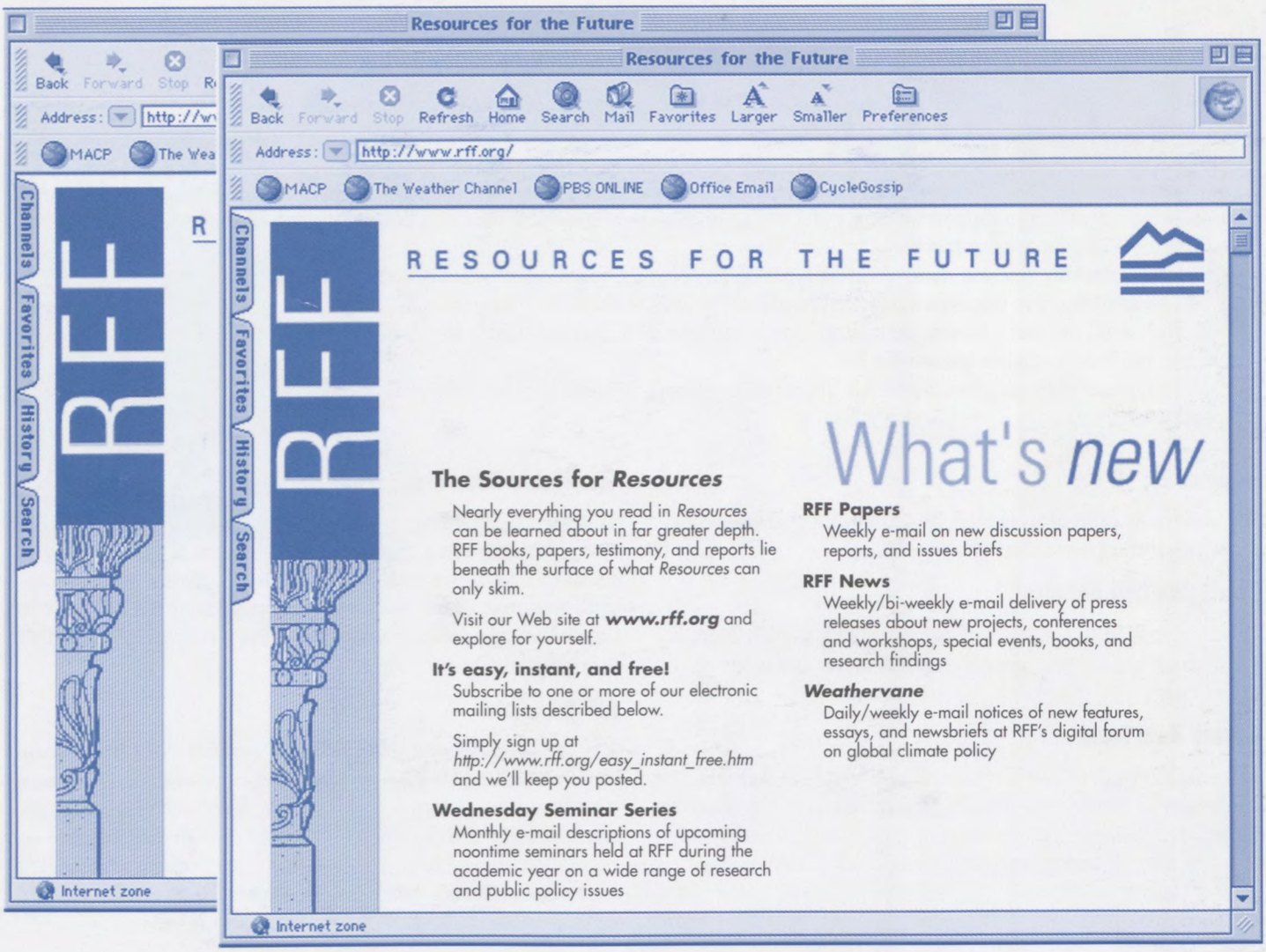

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