Resources

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Energy choices

The Overview chapter of RFF's three-year study, Energy in America's Future: The Choices Before Us, *was published in June as a separate report. A foreword to the Overview, by Charles J. Hitch, president of RFF, is reprinted below. The complete study, written by Sam H. Schurr, project director, Joel Darmstadter, Harry Perry, William Ramsay and Milton Russell, will be published in late summer by the Johns Hopkins University Press.*

In 1976 Resources for the Future began a comprehensive study of the technical, economic, institutional, environmental, and health and safety aspects of alternative energy futures. There was no dearth of energy studies at that time, but most of them dealt only with selective aspects of the energy problem. Some focused on oil, others on coal, nuclear, solar or other energy sources. Some were concerned with technological questions, or environmental issues, or other selected aspects of the problem. What was needed, in our opinion, was a systematic view of different energy supply possibilities, of demand projections, of the probable implications and consequences of different courses of action —all treated in a comprehensive framework that would facilitate the comparison of various strategies. By drawing on the wealth of special studies already completed and by supplementing them with additional studies that it commissioned, RFF sought to provide a comprehensive synthesis.

The report of the National Energy Strategies Project has now been completed for publication early in September, 1979. It begins with an Overview and Interpretation that we think is sufficiently self-contained to warrant separate publication in advance. It presents the major findings and central conclusions of the study. Specialists in the field will want to examine the full report which contains the supporting

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Reactor accidents and afterthoughts

Earlier this year, RFF published Unpaid Costs of Electrical Energy: Health and Environmental Impacts from Coal and Nuclear Power, *by William Ramsay. Chapter 4 of that book is titled, "Nuclear Reactor Accidents." Because of the recent Three Mile Island nuclear accident, we thought it might be interesting to reproduce most of that chapter here, with comments by Ramsay (in italics) on what effect the accident has had on his thinking about reactor safety.*

Nuclear energy in general is controversial, but one of the most passionately felt controversies of all has revolved around the question of accidents in nuclear reactors. Are reactors safe? The central issue stems from the awkward technical fact that the heating process generating power in nuclear plants is difficult to turn off. In case of operating problems, the main nuclear reaction in the uranium fuel can be stopped quickly, but the heat from waste products remains at a high level for long periods of time. This means that the nuclear fuel must be kept cooled, or else the metal-encased fuel rod will melt (a meltdown), releasing radioactive gases and clouds of particulates.

Naturally, precautions are taken against such an event. These are backup water supply systems to supply cooling in case of failure in the regular cooling systems that transport the heat used to generate steam. Nuclear power stations also have a large variety of other safety systems, designed to prevent a meltdown or to keep the radioactive gases from escaping into the atmosphere should a meltdown occur. Nevertheless, should the gases and particulates escape, the amount of radioactivity that would be spread about could be quite large, depending on how well the safety systems work.

Fortunately, such an accident has never happened. Unfortunately, this makes it difficult to analyze whether nuclear power plants are sufficiently safe. We must estimate the likelihood that such an accident would happen, guess at its consequences, and decide whether the risk is too great for the advantages of using nuclear power in the first place. Naturally, no such theoretical answer to the problem will ever satisfy the most demanding critics of nuclear energy. And one cannot pretend that theory is preferable to experiment. But even so, theory may be better than nothing.

It may be true, strictly speaking, that no meltdown occurred at Three Mile Island. However, the fuel rods did break, and some radioactivity was released.

Accidents and Predictions of Accidents. Nuclear power is unusual among modern technologies in that such a theoretical analysis does exist. Trying to clear up the doubts about safety that have clouded the future of nuclear electricity, the U.S. Atomic Energy Commission (AEC) and its successor, the Nuclear Regulatory Commission (NRC), issued in 1975 a complex mathematical study of the probabilities of nuclear reactor accidents. Since no large accidents, and relatively few minor ones, have ever occurred, the study relied on estimates of the probability that each of the different pieces of equipment and various safety procedures in the plant might fail. All these individual probabilities were combined, as they might enter into the chances of nuclear meltdowns and other serious accidents, and numerical predictions of reactor safety were made.

It seems strange to realize that any one single accident such as the one at Three Mile Island still tells us almost nothing about probabilities *of these events. We would need hundreds of accidents, which is probably not a result that anyone is anxious to achieve.*

The Reactor Safety Study, often called the Rasmussen report for Norman C. Rasmussen, the director of the study, predicted that *on the average* the damages to health and property by radioactive contamination, as a result of nuclear reactor accidents on a year-in–year-out basis, would be small. Here, the word *small* means as compared with effects from naturally occurring radiation or with risks from coal-fired power plants. The predicted fatalities (ranging from 1 to 20) and illnesses (ranging from 20 to 200) are significantly larger than those predicted for normal operations (at least for short-lived isotopes). Still, the incidence of fatalities from nuclear reactor accidents is less than that for many other coal- and nuclear-related ones, such as the fatal occupational diseases and accidents to coal workers. The predicted incidence of nonfatal illnesses is also small as compared with coal-related illnesses.

Here I used the error bounds more or less suggested in the Rasmussen report itself. In view of the Lewis report, which also came out after my book was published, and the Three Mile Island incident, I would feel happier with much wider error limits—both ways—or from, say, 0.00002 to 2 predicted fatalities. Such a change would mean that the statement about fatalities from nuclear reactor accidents being less than those for any other coal-related accidents or nuclear-related events would no longer* necessarily *hold.*

What the average numbers fail to show is that most of the predicted effects do not stem from a series of small accidents happening all the time, but are a result

* H. W. Lewis, chairman, Ad Hoc Risk Assessment Review Group, *Risk Assessment Review Group Report to the U.S. Nuclear Regulatory Commission,* NUREG/CR-0400 (Springfield, Va., National Technical Information Service, September 1978).

A Note on the Rasmussen Report— A Theory of Nuclear Accidents

The Reactor Safety Study calculated the probability that (1) a nuclear reactor accident would occur with a significant release of radioactivity, and (2) the radioactivity would be carried to locations where it could expose a population to possible health risks.

All possible components in the plant that might break down so as to eventually lead to such an accident were examined. For example, one possible way for an accident to occur would be for a large pipe to break, then for both the emergency core cooling system and the containment spray system to fail, and then for the containment itself to be breached, releasing radioactivity into the atmosphere. One must calculate the probability for this total sequence of events, and for all the different possible events—including human errors—that could lead to a core meltdown or other serious accident, such as the bursting of the reactor vessel.

The most worrying aspect of Three Mile Island is that aspects of the accident appear not to have been considered in the Rasmussen study at all. That goes especially for the hydrogen bubble.

This type of probability calculation was carried out for two typical existing reactors. Normal uncertainties in the design and the failure rates of components were also taken into account in order to reflect differing conditions in one hundred typical reactors.

If the radioactive material gets outside the reactor, then its destructiveness depends on whether the wind is blowing in the direction where people live, whether there is rain, and how many people live in the affected area. The chance of ninety different kinds of weather conditions occurring at each of six representative sites was then calculated, taking into account local populations.

For example, the probabilities for a worst-case accident could be calculated as follows: (1) The probability of an accident occurring in each reactor in which a substantial amount of radioactivity would be released was 5 in 1 million; (2) the probability of the weather being unfavorable and exposing a large population to the radioactivity was 1 in 1,000; (3) the chance of a worst-case accident happening was then 5 out of 1 billion for each reactor-year; and (4) the number of latent cancers inflicted on such a large population from such an amount of radiation would be 48,000; (5) this can be interpreted to mean that we "expect" only 0.0002 fatalities per reactor-year from this worst-case accident.

of a number of medium-sized accidents that have a chance of happening with relative frequency, and a very few serious accidents that should happen very rarely indeed. The worst-case accident, for example, was predicted to kill some 3,000 people by acute radiation sickness and some 45,000 others by radiation-induced cancers over a period of years. The yearly probability of such an accident occurring in any one reactor was predicted, at the outside, as being only five chances in one billion. This turns out to be a very small risk when compared with each citizen's chances of being struck by lightning, for example. But some people might think that the risks of a catastrophic accident happening only rarely are a somewhat different proposition—maybe worse, maybe better—than, for example, the few random deaths yearly caused by constant small leaks of radioactive material into the air near a power reactor. After all, normal radiation from reactors is uncertain in its effects because there is no answer to the question, *Who* will be affected? Radiation from reactor accidents is doubly uncertain, because the answers are unknown to the questions, *When* might an accident happen? *How much* radiation might be emitted?

Other unknowns are troublesome as well. The effect of an accident would depend on the nature of the winds and rains that would carry the radioactive material from the plant and deposit it where it could do damage to the surrounding population. The Rasmussen report averaged out weather and population over a great number of sites. It is perfectly proper to average these factors out. But our future projections of accident hazards might be slightly more pessimistic if additional nuclear plants tended to be located closer to densely populated centers or, more likely, if rural areas around existing plants become more urbanized.

Critics and Catastrophes. Does the Rasmussen report solve all our questions regarding safety? Hardly. In the first place, even though the report has received approval in some quarters, it has not gone without criticism elsewhere. Various critics, who have maintained that the risks are underestimated, have disagreed as to whether they are underestimated by a factor of 10 or 100, or more. Obviously, as we shall see in comparing these risks with the total risks for coal, the degree of understatement could be important. Perhaps these disagreements will be resolved by a comprehensive review of the whole report that is presently planned.

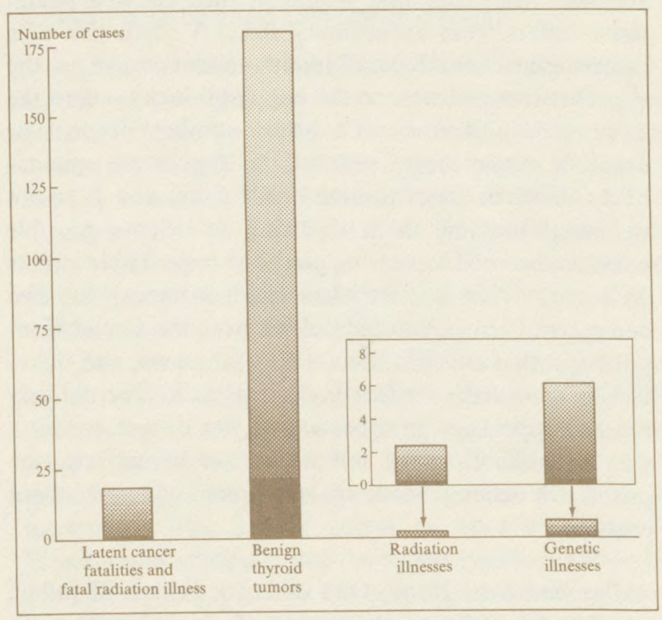
The Lewis report said the group was unable to draw up error limits on the accident probabilities but that it was evident that the error limits had been underestimated. If important accident sequences were omitted, such as appears to have happened at Three Mile Island, this criticism becomes indeed trenchant.

In the meantime, it should be noted that a recent review of the subject, while exceedingly critical of many parts of the Rasmussen report, has calculated on actuarial grounds that the dangers of a nuclear reactor accident were, at most, equal to 500 times Rasmussen's value. Five hundred times a minor impact turns out to be a larger but not overwhelming effect.

The effect may not be "overwhelming" as I stated, but it does mean that nuclear risks are up there with the coal risks.

Naturally, any study is only as good as its data. And data problems exist. Critics have pointed out the great difficulty of estimating the probability that an event initiating an accident will occur. Some possibilities are especially difficult to treat, such as a string of accident-causing events that occur together, and it could be that the study makes mistakes in this area. The behavior of the Emergency Core Cooling Systems (ECCS) cannot really be tested until there is an actual accident.

It is unclear whether the shutdown state of the cooling pumps on the secondary loop at Three Mile Island because of an oversight was an example of an area that is not treated correctly by the report, and the entire role of human error in the "common mode" failures may have been underestimated. As far as the ECCS systems are concerned, we have to find out whether they worked correctly; however, the irony is that the mysterious hydrogen bubble, rather than the pressure problems that have been of particular concern in theoretical analyses, seems to have gotten in the way of the correct operation of the system.



Estimates of fatalities and some illnesses that can be expected to occur as a result of nuclear power plant accidents, prorated per U.S. wattage.

Some have thought the cooling water would not actually penetrate into the overheated reactor core at the time of the accident; however, recent tests on this issue are encouraging if not conclusive. We have also been witnesses to the drama of former employees of nuclear plant manufacturers or of the NRC publicly questioning the accepted reliability figures for components of subsystems. And what about the effects that might have been omitted altogether, such as fires, similar to the serious one that occurred at a nuclear plant in 1975? True, the final Rasmussen report calculated that the inclusion of fires would not have changed the results very much. But where there is one omission, could there not be more?

This is probably the real worrying point: Are the Brown's Ferry fire and the Three Mile Island bubble representatives of an entire set of other phenomena that have not been thought of?

In view of such difficulties there is no reason to place overwhelming confidence in the Rasmussen report. On the other hand, no other detailed calculation exists, and critics have not convincingly established that Rasmussen has seriously underestimated the risks. Therefore we accept here the Rasmussen estimates, as modified by modest error limits.

As above, after the Lewis report and Three Mile Island, there is no such easy acceptance.

But if we should decide to give the Reactor Safety Study tentative credence, we should again emphasize that "the risk of a risk"—that is, a small risk that an accident will occur that would in turn cause a health risk—differs from an ordinary risk. A small risk of a catastrophe could look different—either worse to the apprehensive or better to the happy-go-lucky—than the more certain deaths of a given number of coal or uranium miners every year. Catastrophes are qualitatively different from routine small risks, and it is not irrational to view them as being so. Some possible catastrophes will never happen, but improbable events do occur. What was the chance, for instance, that two commercial aircraft would collide over the Grand Canyon? But that crash is now a part of the past, and therefore is recorded as a fact instead of as a very unlikely future happening. In other words, we do not *expect* a very improbable event, but we cannot be entirely surprised if it occurs: hence special human concerns about disasters.

A Psychological Note. One odd risk is that of public reaction to nuclear catastrophes. It is widely thought that if there were a large accident, resulting in deaths and injuries, public reaction would force a shutdown of all reactors. If so, the resulting waste of resources would be an expensive unpaid cost of nuclear power.

This is a curious point. Even though there were no deaths—except for possible latent cancer fatalities of which we will be hearing a good deal more in the months and years ahead—I would have expected there to have been more outcry from the public about the Three Mile Island incident. While everyone took the accident seriously enough, and people were indeed frightened, I have yet to see a groundswell for closing down nuclear power plants.

The most interesting aspect of such a shutdown is that a nationwide reaction of this kind would be more surprising if the catastrophe were to involve hydroelectric power (a dam break) or an air pollution catastrophe related to coal-fired power. Naturally, there are generally differences in the nature of the health risks concerned for catastrophes involving the different technologies. Nevertheless, there may well be special aspects to the way the public perceives nuclear risks, even when those risks appear to be equivalent to other nonnuclear risks in type and magnitude. The reasons for such a special status are not clear, but anxieties related to nuclear war and to fears of radiation and radiation-related death have been suggested as possible motivations.

On the other hand, the unfamiliarity and newness of the nuclear power industry may play an important role, in that the public must learn to judge a whole array of potential consequences of a new technology.

Ironically, it may be that Three Mile Island is making nuclear less "unfamiliar."

Fragmentary evidence that unfamiliarity may be important has been observed in studies showing that people have more anxiety about a local nuclear plant if they live moderately close to the reactor site (several kilometers away) than in the immediate neighborhood (less than a kilometer away).

It would be interesting to know whether this phenomenon took place in the communities near Harrisburg.

But one cannot tell whether such phenomena are indeed psychological, that is, irrational, or whether they represent a strong distaste for catastrophic risks, or whether they merely reflect a public skepticism as to the opinions (or capabilities) of nuclear experts. Furthermore, is such an attitude consistent with recent polls showing strong public support for developing nuclear technology? If such special attitudes toward nuclear risks are important, they are fully as legitimate—though perhaps not as immutable—an unpaid cost of nuclear power as any other. And such costs would become tangible in monetary terms if the occurrence of a catastrophic accident led to a lengthy or even permanent shutdown of all reactors in the United States.

I would guess the purely psychological part of the anti-nuclear reaction mentioned here was not prominent and that a healthy skepticism about experts and a distaste for catastrophic risks showed up as one might have expected from a rational public.

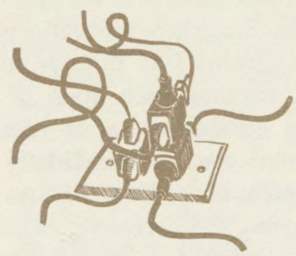
Safer Reactors? What could be done to improve reactor safety? A significant amount of money already goes into research and regulation to improve safety by preventing and mitigating the results of accidents in nuclear power plants. Expenses for extra standby safety systems are already large. For example, the ECCS required within the last few years for all plants have inevitably added to the cost of nuclear electricity. Every new problem that arises, from cracking of the stainless steel pipes that carry the essential cooling water, to fires in so-called flame-resistant materials that can paralyze control circuits, leads to new and improved safety regulations and therefore to new costs. But there is a question of how much safety can be improved in any pressurized system in a cost-effective manner. Not to mention the problem of the "reliability" of the human beings that run the system; automation can help to alleviate this latter problem but cannot do away with it entirely.

It might be that pressurized systems, at least the light water reactor, are just too unsafe. Maybe nuclear policy should examine gas reactors or low-pressure systems such as liquid metal coolants to develop inherently safer systems.

It would help if we were sure that the safety level of new reactors was the same or better than that of the Rasmussen calculation. The Rasmussen results depend on the actual finished engineering of the two reactors studied in detail. Almost every individual reactor—at least up to now—has been a new and different engineering creation, even if the differences have sometimes been minor. Each reactor receives an exceedingly thorough safety review, but even so, the lack of homogeneity means that the Rasmussen results do not necessarily apply to all reactors at all sites. If each plant were to be analyzed separately in the Rasmussen style, the expense would be enormous, since it is unlikely that the detailed calculation can be carried out from blueprints alone.

If a point of sharply diminishing marginal returns has been reached in safety systems, it still should be possible to increase safety levels by siting nuclear power plants farther away from population centers. It has been suggested that plants be sited underground. Unfortunately, there are drawbacks to these solutions. If a small cloud of radioactivity were released just west of Fort Worth and blown eastward by the wind, the individual dose would fall off with distance, but the widening cloud would include more people; therefore, the impacts in both Fort Worth *and* Dallas would be important, even though the site would be relatively "remote" from Dallas. Underground siting promises to be costly and is good only to the extent that the radioactivity released cannot penetrate to the surface—a question of some uncertainty. But it would be difficult to achieve levels of safety high enough to satisfy some conceivable standards without moving nuclear power plants to the North Pole, or at least to isolated islands in the Pacific—as indeed has been proposed in recent futuristic studies.

Siting power plants farther away from population centers, while it might help the emergency evacuation problem, is probably a no-win policy and appears even less promising after the Three Mile Island incident. The AEC was right not to get into urban siting of power plants, but it is difficult to place a site far enough away that it will not cause trouble to somebody somewhere.



All this legitimately raises the question of how safe is safe enough. It is notoriously difficult to pursue any human activity without risks. Usually we have to balance risks against benefits, and on this basis the Rasmussen results seem reassuring. But the catastrophic possibilities involved suggest that improving the estimates of nuclear accident risks be given high research priority.

Subsidies and Risks. Is the electricity-using public paying for the possible costs of nuclear catastrophes? This question comes up because if an electric utility has a serious accident in one of its nuclear power plants, its liability is restricted by law—currently to $560 million—under the Price-Anderson Act. Comparing this liability restriction to the probable losses from an accident could give an indirect indication of the value of the unpaid costs of nuclear accidents.

There is also the related implied question that has excited public interest in this law: that is, if nuclear reactors are so safe, why does the nuclear industry need a special dispensation against liability? This is a good question, and the Rasmussen study was designed to answer it. The answer seems to have an Alice in Wonderland quality in that the report concluded that the limitation was justifiable because the accidents were so unlikely that no limitation was needed! Therefore, if we accept the Rasmussen results as reliable for an estimate of reactor accident dangers, clearly we have to accept the implication that Price-Anderson liability limitation is not a serious problem. Prorated costs would be less than $40,000 per reactor every year, or about 1 cent on the "monthly electric bill." We would infer higher estimates of risk from the premiums now actually being charged to utilities (for the $125 million for which they *are* liable). But even on the basis of such risk estimates, the effective subsidy for higher liabilities would still be small, representing an unpaid cost of, say, 6 cents on the "monthly electric bill." But again, the billed cost of an *actual* catastrophic accident in any given year would be more like $28, or $25 billion for 1 USW.

The insurance problem obviously has to be rethought. Even Three Mile Island liability claims may be substantial. Claims after a real meltdown could be astronomical.

The Breeder and Plutonium. Is there a breeder reactor economy in the U.S. for the future? It is difficult to tell. But it may be mildly reassuring to realize that safety problems are likely no worse for the breeder than for ordinary LWRs. Some new instability problems do arise that could conceivably lead to large releases of energy and radiation, because each gram of fuel contains a relatively large number of active (fissionable) atoms. The liquid metal breeder (LMFBR) that has been under development in the United States would also have problems involving the corrosive, extremely chemically active metal sodium that is used to transfer heat from the reactor to the steam generator. On the other hand, the sodium is not under pressure, so that it is easier to avoid the sudden losses of the cooling liquid that can occur in ordinary pressurized LWRs. Safety concerns for the LMFBR could turn out to be similar in degree, if not in kind, to those for LWRs.

Other new types of accidents might occur within the other parts of the plutonium economy, however. The reprocessing plants that separate the plutonium from the spent uranium fuel could be hazardous. Sudden, large accidental releases of the radioactive wastes in the fuel are not likely to occur during reprocessing; in fact, official predictions of possible accidents show that the probability is small that even one death in such an accident would occur—which would have little impact if the occurrence of the accident is improbable also. There has been some public concern about the handling and shipment of plutonium in general, because—judging from large doses given in animal experiments—even small quantities of plutonium are carcinogenic if inhaled into the lungs. But it has been estimated that only a small amount of plutonium and related elements would be released during normal operations from a large breeder reactor fuel cycle. And it has been argued that in practice much more plutonium than the microgram quantities sometimes quoted would have to be initially dispersed in order to be ultimately inhaled by human

lungs and cause cancer. Even if such estimates were correct, some claim that plutonium is still a critical safety hazard when it is deposited nonuniformly in the lung. Such a *hot particle* theory is possible, but there is little convincing evidence to back it up. This is not to say that all these plutonium problems might not turn out to be more severe than we think. We would be dealing with a new kind of technology, one we do not fully understand. But based on what we know at present, and assuming prudent design, only the level of concern appropriate for any technology having certain obvious risks seems called for. And it is fair to also take into account that the use of a breeder would reduce the expected number of yearly fatalities from uranium mining and milling operations.

Conclusion. Even though no catastrophic accidents have taken place, there is an inherent danger of serious, accidental radioactive emissions from nuclear power plants. A large theoretical study has calculated that risks from this problem are small—*on the average*—as compared with other electricity-related risks. Although the Rasmussen study is not above criticism, pending further investigation the results constitute a reassuring best estimate of the risk of nuclear accidents. We must also recognize that there is always the chance that a fairly large catastrophe will occur; it is a legitimate value choice to view such a risk as worse than a noncatastrophic risk.

There is no compelling reason to expect dramatic improvements in the safety of reactors. Breeders and plutonium economies introduce some new safety problems—such as dangers of cancer from inhalation of plutonium and of a more dangerous type of reactor accident—but they may eliminate or reduce other problems, such as other specific types of reactor accidents and part of the impacts connected with the uranium mining and milling industry.

See Resources *No. 61 for a brief description of the book from which this chapter is taken.*

data and analyses on which the Overview rests, but we hope that they will find this brief treatment stimulating. For others interested in energy policy, however, a treatment of the length offered in the Overview may be more helpful than the detailed analysis. We have endeavored to make it readable as well as responsible and authoritative.

No contemporary analysis of energy proceeds very far before its intimate connection with other issues becomes evident. Indeed, much of the frustration over lack of progress and consensus in energy policy arises from such interrelated concerns about, or conflicts with, economic growth, social equity, foreign policy, technology, and environmental impacts. The capability for dealing with this range of subject matter requires a diversity of disciplines—economics and public policy analysis, physics and engineering, and public health and medical sciences. RFF was fortunate in being able to assemble—as authors and consultants for this study—persons who are specialists in each of these fields. The study was directed by Sam Schurr, then RFF Senior Fellow and Co-Director of the RFF Center for Energy Policy Research.

We are grateful to the Andrew W. Mellon Foundation for its generous financial support of this project.

An Overview and Interpretation of Energy in America's Future is available for $2 from the publications department of Resources for the Future, 1755 Massachusetts Avenue, N.W., Washington, D.C. 20036

New RFF Books

The Benefits of Environmental Improvement: Theory and Practice. A. Myrick Freeman III. 286 pp. 1979. LC 78-20532. $18.50. ISBN 0-8018-2163-0. Paper, $6.95, ISBN 0-8018-2195-9.

Until now there has been a substantial gap between the definition of welfare change and benefit derived from theoretical welfare economics and the *ad hoc* empirical techniques used by some researchers to estimate the benefits of environmental improvements stemming from air and water pollution control. In this book Freeman bridges the gap with a unified theoretical treatment of the concepts of benefits and the empirical techniques appropriate for their measurement.

He describes the techniques for estimating various forms of benefits, shows how they are related to underlying economic welfare theory, and discusses some of the pitfalls and problems in applying the techniques. In this book, individual preference theory is used as a yardstick against which the theoretical adequacy of empirical estimating techniques can be measured. The author includes a systematic analysis of how interactions between demands for public goods and private goods can be used to derive conceptually sound estimates of benefits from market behavior. He also discusses nonmarket approaches, such as surveys and bidding games. With the objective of helping practitioners select the appropriate technique for a particular purpose, Freeman examines those techniques that have a sound theoretical foundation. The book is intended for professional economists and students with a background in microeconomic theory.

The Leasing of Federal Lands for Fossil Fuels Production. Stephen L. McDonald. 1979. $15.95. LC 78-23437. ISBN 0-8018-2194-0.

Ownership of offshore and onshore lands bearing coal, oil, and gas gives the federal government a dominant role in future domestic energy production. Some may welcome this and others deplore it, but neither attitude will alter the importance to the economy of the terms and pace at which the federal government leases its fossil fuel resources.

Formation of the Public Land Law Review Commission in 1965 fostered an interest in assuring "that the public lands of the United States shall be (a) retained and managed or (b) disposed of, all in a manner to provide the maximum benefit for the general public."

Today, in search of this goal, the nation is in the midst of a vast federal effort to answer such questions as whether to retain or dispose of federal lands, to lease now or later, to favor royalties or bonuses, to control or not to control production rates, or how to choose among the various standards of engineering and economic efficiency.

The Leasing of Federal Lands for Fossil Fuels Production offers the reader a basic understanding of the goals and practices that are involved in answering these questions.

The Law and Policy of Toxic Substances Control: A Case Study of Vinyl Chloride. David D. Doniger. 192 pp. 1978. LC 78-24624. $12.50. ISBN 0-8018-2234-3. Paper, $4.95, ISBN 0-8018-2235-1.

When three workers in a plant which converts vinyl chloride into polyvinyl chloride died of an extremely rare cancer, the disclosure set in motion an attempt to regulate this pervasive chemical. This effort involved five major federal agencies operating under fifteen separate health and environmental statutes. In clear and precise terms, David Doniger examines the federal regulation of vinyl chloride, and through that experience, the complex law and policy of toxic substances control in the United States.

The book is suitable for classroom use in the fields of law, economics, the environment, health, and government.

Simulation of Recreational Use for Park and Wilderness Management. Mordechai Shechter and Robert C. Lucas. 240 pp. 1978. $18.50. LC 78-17920. ISBN 0-8018-2160-6.

The authors detail the results of a large-scale testing of a wilderness travel simulator in one of the most densely used areas of the National Forest Wilderness System, the Desolation Wilderness of California. They include a description of the model, discuss input data, validation tests, experimentation with the simulator, and use of the model in formulating and testing use-management policies.

RFF Reprint Series

The following reprints of staff material have been added to the RFF Reprint Series. Single copies are available free on request to Resources for the Future.

161. *Development and Environment*, by Allen V. Kneese. 1979. Nontechnical discussion of the future growth of environmental problems in developing countries.

162. *Oil Shale: A New Set of Uncertainties*, by John J. Schanz, Jr. and Harry Perry. 1979.

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