33. This change in performance was not the result of damage to the eye or its extrinsic muscles caused by prolonged attachment of the scleral search coil. Henry's visual search pattern when he is not required to "fixate" has not changed since the coil was first inserted.
34. C. Rashbass, *J. Physiol.* **159**, 326 (1961).
35. D. Wyman, thesis, University of Maryland (1972); ——— and R. M. Steinman, paper presented at the Association for Research in Vision and Ophthalmology Meeting, Sarasota, 1971. There was also prior evidence that the "dead zone" is considerably smaller than suggested by Rashbass (*34*), for example, G. T. Timberlake, D. Wyman, A. A. Skavenski, R. M. Steinman, *Vision Res.* **12**, 1059 (1972). Also, J. Nachmias and M. Herman showed in an extensive series of experiments (unpublished) performed 8 years ago that subjects track target steps as small as those tracked in our more recent work. These authors also showed that the latency for responding to small target steps depended on the size of the target step. Also see D. Wyman and R. M. Steinman, *Vision Res.*, in press.
36. R. S. Woodworth and H. Schlosberg, *Experimental Psychology* (Holt, Rinehart and Winston, New York, revised ed., 1954).
37. G. M. Haddad and R. M. Steinman, *Vision Res.* **13**, 1075 (1973).
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40. W. James, *Principles of Psychology* [1890; Dover (reprint), New York, 1918], vol. 1.
41. D. A. Robinson, *J. Neurophysiol.* **33**, 393 (1970); A. F. Fuchs and E. S. Luschei, *ibid.*, p. 382; E. S. Luschei and A. F. Fuchs *ibid.* **35**, 445 (1972); D. A. Robinson, *Invest. Ophthalmol.* **11**, 497 (1972). These authors wrote classical papers on the machinery used by the primate to make large saccades. There is no known physiological data which forces us to suspect that miniature saccades would require a different physiological model than the model which was worked out and tested by Robinson and co-workers for large saccades. This belief must now be verified experimentally. The cat and kitten may also prove to be useful subjects in which to study the development of and occasion for miniature saccades. F. W. Hebbard and E. Marg [*J. Opt. Soc. Amer.* **50**, 151 (1960)] reported that the cat had fewer and somewhat smaller saccades than are usually found in man. R. Pritchard and W. Heron [*Can. J. Psychol.* **14**, 131 (1960)] reported similar results and suggested that the rare occurrence of miniature saccades (only seven were observed) results from the fact that the cat lacks the well-developed fovea packed with cones alone that primates have. This interpretation may explain why miniature saccades do not occur but is puzzling with respect to their average size (only 3.5 minutes of arc). Can the cat learn to make these miniature saccades as frequently as we do?
42. H. Collewijn and collaborators have worked out the occulomotor system characteristics of the rabbit in an elegant series of experiments; for example, H. Collewijn, *Vision Res.* **9**, 117 (1969); *Exp. Neurol.* **28**, 132 (1970); C. Oyster, E. Takahashi, H. Collewijn, *Vision Res.* **12**, 183 (1972). Recently, H. Collewijn and F. Van Der Mark [*Brain Res.* **36**, 47 (1972)] explicitly pointed out similarities between slow control in the human being and the rabbit, and suggested that the two species may have a similar primitive oculomotor system. This suggestion will now have to be examined by making a quantitative analysis of the human scotopic slow control system.
43. Large saccades have figured prominently in theories of form perception and also as explanations for a variety of visual illusions. See, for example, D. O. Hebb, *Organization of Behavior* (Wiley, New York, 1949). The possibility of large saccades causing or contributing to these phenomena has gained acceptance in some quarters recently, particularly since the intentions to make large saccades rather than the saccades themselves have been proposed as the causal perceptual mechanism. See L. Festinger, C. White, M. Allyn, *Percept. Psychophys.* **3**, 376 (1968); V. Virsu, *ibid.* **9**, 65 (1971). We cannot reject a similar purpose for miniature saccades, but prefer to believe that miniature saccades are not made for the purpose of perceiving form because the form of a target object that falls completely within the foveal floor (less than 90 minutes of arc) does not change when we suppress miniature saccades (B. Murphy, paper presented at the Association for Research in Vision and Ophthalmology Meeting, Sarasota, 1973). Of course, the intention not to make a miniature saccade of a certain size and direction may be functionally equivalent to the intention of making the same saccade.
44. We thank Profs. Nancy Anderson, Tom N. Cornsweet, Willard Larkin, John Z. Levinson, Jacob Nachmias, David A. Robinson, and Fredda Steinman for suggestions about and criticisms of various phases of the research described in this article. Also, we thank Joseph Kelly of Philcon Laboratories for making and fitting our contact lenses, Joseph Matthews for designing and constructing our electronic equipment, and Irma Nicholson for patient and skillful secretarial help with this and other manuscripts. Many present and former graduate and undergraduate students have also made valuable technical and conceptual contributions to our research. We particularly thank Robert Cunitz, Carol Jablonski, Elizabeth Kocher, Eileen Kowler, Patsy McGrath, Brian Murphy, Larke Nahme, Jane Puckett, Lucinda Romberg, Richard Sansbury, George Timberlake, Nina Weber, and Barbara Winterson for their help. The human research was supported by grant EY 325 from the National Eye Institute to R.M.S.; and the primate research was supported by PHS training grant GM 576 to the Department of Biomedical Engineering, Johns Hopkins University, and by grants EY 598 to David A. Robinson and EY 1049 to A.A.S. from the National Eye Institute.

Environmental Impact: Controlling the Overall Level

A rationing system may control environmental impact, while maximizing personal choice.

Walter E. Westman and Roger M. Gifford

Recent observations on the genesis of current environmental problems suggest that they stem from the interaction of three elements: the size and rate of growth of the human population (*1*), the growing per capita consumption of products (*2*), and the increasing use of products and technologies that are more pollution-generating and wasteful of resources (*3*). While people have disagreed on the relative contributions of each of these factors toward the overall impact of man's activities on his environment (*4*), there seems little doubt that the combined effect gives reason for concern. The Club of Rome report (*5*) is one of several (*6*, *7*) which puts the case vividly that unchecked growth of each of these elements of environmental impact is incompatible with the perpetuation of human civilization.

It seems to be true of all dynamic systems that negative feedbacks must come into play if a long-term steady-state is to be achieved. If natural environmental feedbacks in the system of the biosphere were to come to exert full force, resulting in some variant of the Malthusian crash, much hardship would no doubt occur. There is disagreement about the extent to which improvements in technology can mitigate the crises predicted by a Malthusian analysis of the limits to growth (*8*). Quite apart from the question of the degree to which technological improvements can postpone behavioral changes, however, there seems to be general agreement that negative environmental feedbacks in some form will be necessary. To minimize the social hardships that will otherwise occur, and to spread them as evenly as possible across the populace, while giving each person the maximum freedom of choice of activity

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possible, a mechanism is needed for purposefully instituting environmental feedbacks before the more inhumane natural ones come into play. Furthermore, it is important that these feedbacks operate sufficiently rapidly to avoid fluctuations around the steady-state level sought. In this article, we describe an equitable system of resource allocation that could be made to act as such a rapid, anticipatory feedback system, while placing an artificial cap on the overall impact that society is making on the environment. The proposal involves establishing trade-offs between alternative activities by means of a new pricing unit in such a way that governments could control environmental impact, and at the same time provide a large measure of choice for individuals and organizations.

Several points should be recognized from the outset. First, the system could be used to set the rate of environmental decay at any level within a wide range; that is, it is possible that governments may decide, using this natural resource policy, to set incentives that would lead to a rapid decline in environmental quality (*9*). It is our hope that, if implemented, the scheme would be used to prevent such a decline, but we wish to emphasize its fundamental independence from any particular set of sociopolitical priorities or ideologies.

Second, we recognize that, on theoretical grounds, no activity is without its environmental impact. If nothing else, our activities are increasing the entropy of the biosphere, or releasing heat. Numerous authors (*10*) have discussed the limited capacity of air, water, and land to absorb pollutants without degradation. Similarly, some resources are more readily renewed than others. Ultimately, life on earth will come to an end by one or another of the natural entropic processes, if not by some earlier catastrophe. What we seek is a method for prolonging the stay of human civilization on earth within these ultimate constraints, while sharing the stewardship of earth equitably.

The system we describe would, in practice, begin by limiting those resource uses and activities whose adverse effects on the environment are most severe and irreversible. The system could only be phased in gradually, starting with emphasis on the most destructive activities.

Third, some restriction of personal freedom is inherent in all regulations. It is likely that policies which lead to very low levels of environmental impact will require greater restrictions on personal freedom than we experience today. Thus, the policy we describe will almost certainly not receive immediate acceptance. On the other hand, the predictions of environmentalists, as summarized in the Club of Rome report, are too dire to ignore. As environmental impact increases, the changing conditions themselves may force upon governments an awareness of the need for comprehensive regulation, and upon the public a realization of the necessity to accept control.

We intend to initiate discussion of the implications and usefulness of the suggested scheme, to encourage tests of its properties with simulation models, and to help elucidate the kinds of data that need to be collected if such a scheme were to be implemented. It is our hope that such studies might lead to a series of detailed and pretested suggestions for regulating environmental impact when the public is willing to accept such controls. We suspect that a comprehensive national resource policy such as described here might be more protective of individual choice than the haphazard accumulation of governmental restrictions currently being imposed as particular environmental problems force themselves into the public arena. Although we are not prepared to propose the implementation of this system, we feel it deserves consideration.

The Natural Resource Unit: The Essence of the Scheme

The proposal is basically a rationing mechanism in which a single unit—the natural resource unit (NRU)—is expendable on a range of goods, services, and activities that have an impact on the environment. These NRU's would be allocated equally to all individuals and, by special means, to firms, nonprofit organizations, and governmental departments. The government would establish the overall level of environmental impact for the country by fixing both the total annual allocation of NRU's and the NRU price of each good, service, and activity. The NRU system would not replace, but would complement, the existing money-based system. The government policy of total NRU releases and prices would reflect existing data on levels and trends in environmental impact, as well as social priorities.

The kinds of environmental impact that might be rationed by this scheme can be grouped as follows: (i) pollution of air, water, and land; (ii) destruction or disturbance of valued species' habitats, ecosystems, and scenery; (iii) extraction and use of recyclable and nonrecyclable physical resources; (iv) contribution to human population pressure; and (v) transitory, immediately reversible disturbance to individuals' local environment (for example, noise).

The activities leading to these environmental impacts vary in their importance to different people. Impacts cannot be regulated fairly by levying a uniform tax, because some people and firms would feel the impact of particular taxes more acutely than others—depending (i) on the value they place on the particular resource and (ii) on their initial financial status (*11*). The first of these difficulties is normally circumvented by applying an excise tax on the product or activity. In this sense, NRU's act like excise taxes. The second difficulty, the inequality of wealth, is inevitable in a competitive system; yet, with regard to impact on the biosphere, we see no reason why the rich should be allowed to ruin the environment more than the poor.

The NRU and the Individual

In our system, all individuals would be allocated an equal number of NRU's. The rich could spend their excess money on activities that have low levels of environmental impact. The NRU's would not be transferable, nor could they be bought with money. Unspent NRU's could be saved from year to year, but would become invalid when the individual died.

In his pattern of spending NRU's, a citizen could express his own preferences in his life-style, while being held to a maximum overall level of environmental impact equal to the potential impact of any other citizen. A person's life-style—for example, where he goes on a vacation or how many cars he owns—is already severely constrained by many aspects of his physical, social, and economic environment. A main difference that NRU's would make would be that some of the constraints would be imposed by society with a view to benefiting future citizens. The individual's life-style would be fashioned in part by a series of environmental trade-offs of his own choosing.

Perhaps the most important and controversial example of an activity that is

costly in terms of environmental resources and that has a different value to different people is childbearing. For some, the right to have a large family may far outweigh the decrement in open space and resources that may result. For others, a self-imposed limit on family size might readily be undertaken in return for the use and conservation of wilderness and other resources. Unlike a financial tax on childbearing, an NRU system would not financially penalize citizens who wanted to have large families. Instead, they would have to weigh a large family against alternative uses of the environment. Through saving, parents could spread the NRU cost of bearing a child over a number of years. A child could be assigned NRU's annually from birth, perhaps starting at a low allocation and increasing to the adult number in the mid-teens.

Such a system for regulating population growth might help settle a particularly knotty conflict of interest between current supporters of zero population growth and some members of racial minorities who rightly point out that an across-the-board limit to population growth would freeze their relative numbers in the population at the level of a perpetual minority (*12*). The NRU system would permit such persons to raise large families without threatening the overall level of environmental impact, although not without some personal sacrifice in spending on other environmentally costly items.

It would be highly desirable for NRU's not to be borrowed from future allocations. Such a restriction would ensure that the rate of spending of NRU's could be controlled, that per capita allocation of NRU's would remain uniform, and that accounting processes would be relatively streamlined. As with money, the supply of NRU's would have to be regulated by the available resource base and could not be allowed to increase at will. However, as with money, it is inevitable that some persons would outspend their existing capital of NRU's—by having an unintended child, for example. The philosophy of the NRU system is based on control of such resource spending, but clearly society may decide, on humanitarian grounds, that it will suspend the rigidity of NRU control to avoid imposing involuntary abortion. In such a case, borrowing against the future could be allowed. Severe and persistent NRU indebtedness, however, would presumably not be honored with loans. Such a policy is harsh, but it has its direct parallels among the down-and-outs in our money-based society. In either case, society must reach some compromise between the rules of its resource control system and the "welfare" system.

The all-important complement to the distribution of NRU's among individuals would be a national "fiscal" policy to control the rate of consumption of resources and the rate of pollution generation. By setting NRU prices and determining annual rationing levels on the basis of existing data on environmental degradation and social priorities, the government would continuously control the overall level of environmental impact.

The NRU and the Organization

Industrial corporations and other organizations that play a role of their own in contributing to the welfare of society would have to be assigned NRU's on a separate basis. Of the several criteria that could be used (for example, size of work force, auction to least-polluting producer, and investment in R & D to reduce pollution), the following appears worthy of further consideration: an industry as a whole could be allowed to use up a set number of NRU's each year to offset the resources harvested by it and the total amount of pollutants released. The NRU allotment would be determined by the government on the basis of calculated allowable rates of resource consumption and pollution generation. Within a given industry, NRU's would be rationed to companies on the basis of existing plant capacity, using a standard production : NRU ratio set by the government. Obviously, a company that could devise ways during the year of increasing its production "efficiency" in relation to pollution generated and resources used (that is, increasing its production : NRU ratio) would be able to achieve higher production and possibly higher profits. The incentive is thus provided for improvement in pollution technology and resource conservation, while maintaining overall control of the pollutants generated and resources used each year.

In the following year, the company's NRU allocation would increase in proportion to its increased relative share of the industry's output. We recognize the tendency of this method to encourage amalgamation into larger companies to achieve efficiencies of scale. The proposed system would have to be used in conjunction with antitrust legislation, to the extent that amalgamation is considered undesirable.

Similar principles of resource allocation would apply to certain retail organizations, such as restaurants, with, perhaps, volume-of-trade : NRU ratios. Criteria closely related to the pollution-generating activity (for example, amount of grease burned as kitchen smoke) would be desirable, but in practice may be more difficult to measure. Most retail organizations generating simply sewage would be paying NRU's directly with their sewerage bills.

Nonprofit service organizations, such as public hospitals, churches, schools, and government departments themselves, engage in overhead activities that may warrant partial or total subsidization. In these cases, the administering agency of government would have to allocate an additional sum of NRU's to applying organizations, based on judgments of social priorities. The government's own NRU budget would have to be subjected to full public scrutiny, as is its money budget.

Certain goods and services accrue environmental impact costs at several stages between raw resource and finished product. These goods and services could be charged NRU's at each stage of the process. Thus a nonreturnable metal can would have accrued a certain NRU cost to the mining company in extracting the ore, another NRU cost in refining, another in manufacture, and another in sale. If the can were returnable and recyclable, the NRU cost at the retail level would be unnecessary (*13*). Note that in this system the "cost of pollution" is not wholly transferred to the consumer. The example of the metal can has, in fact, its precedent in the recent attempts in New York City to encourage recycling of containers through monetary incentives. Jerome Kretchmer, head of New York's Environmental Protection Agency, has said (*14*):

> The philosophy behind the tax [on nonrecyclable containers] is important. Its purpose is not to bring in revenues to the city but to establish economic incentives to manufacturers and wholesalers to recycle. It is a direct attempt on our part to reverse the economic realities in our society, to make recycled goods competitive in the marketplace.
>
> The tax [on nonrecyclable containers] imposes a one- to three-cent levy on rigid and semi-rigid paper, glass, metal and plastic containers for all nonfood items sold at retail. Any container made of a

prescribed percentage of recycled material is allowed a one cent credit against the tax. Wholesalers purchasing products from manufacturers reusing old containers would receive an additional one cent credit per container. As a result of the combinations of credits, all taxes are avoidable on paper, glass and single-metal cans. The per unit tax rate for each material is based on current estimates of the degree of difficulty of disposing and the feasibility of recycling for that material.

Administration and Politics of a National Resource Policy

The effective formulation of such a national resource "fiscal" policy would require a large data base and constant input from the private sector concerning spending patterns. We envision a separate department (or departments) within the government, to be charged with the tasks of assembling the data on existing NRU and resource reserves, population size, and state-of-the-art of pollution technology, and of monitoring rates of change in these parameters. This would require, of course, extensive computer facilities and more extensive and frequent surveys than are now undertaken. These data would be used by the administering agency to adjust NRU rations annually and NRU prices annually or semiannually.

A primary function of such a department would be to determine whether the environmental impact of the community needs to be lessened, held the same, or could afford to be increased. Part of this decision would be based on direct polling of public opinion, and part would be based on the philosophy of environmental conservation of the political party in office. Another important decision would concern the distribution of units among government departments and agencies, profit-making organizations, nonprofit organizations, and individuals. Again, the allocation of total environment impact would be a matter of party political philosophy to some extent. The constant monitoring of NRU spending patterns, however, should improve the precision with which the government can assay priorities on environmental issues at any time.

We envision NRU currency as held and used in the form of personal credit cards. Retailers could record spending on the account, and daily or weekly intake would be transferred through regional to central computer banks. As with money, customer credit could be checked through local bank records. It is principally through this regular inflow of data to the central data bank that current social priorities would be gauged. Only through constant data input could sensitive adjustments in NRU prices and levels be made.

The number of NRU's rationed and the number spent each year would be recorded on a computer; the exact number saved each year would therefore be known. Since NRU's are nontransferable, but capable of being saved from year to year, the number saved after the system had been running for some time would be, in part, a function of the age distribution of the population.

Initially, the social value of those amenities that do not have a money price but that do have an environmental impact would have to be estimated by relatively qualitative means. But the NRU accounting system would generate quantitative data on cost and benefit of many more intangible items than are now priced. Once the system was in operation, this feedback mechanism should enable fairly workable NRU prices to be obtained by successive approximation; like any iterative method, however, the first estimate would only be a best guess based on anticipated spending patterns and supplies of resources. Although we recognize the difficulty in such a task, we think this proposal provides one publicly responsive way of allocating such costs. In fact, experience persuades us that, until many environmental costs and benefits—the so-called externalities —are assigned a quantitative value, their importance will be consistently underestimated in the cost-benefit analyses upon which so many social decisions are currently based.

Although spending patterns in NRU's would serve to monitor community attitudes toward a wider range of social goods than financial records now do, the system of judging social priorities would still require much direct administrative and public discussion. We would still envision an annual NRU budget to be submitted by the administering agency to full public scrutiny and discussion and subjected to the equivalent of congressional or parliamentary checks. We would envision the persistence of lobby groups to argue the case for differential assignments of NRU's to various sectors of the resource economy. We acknowledge that the bookkeeping involved in processing two budgets instead of one is a bureaucratic bugaboo, but we would question whether the existing single economic budgeting accounts adequately for many of the important transactions and changes to which the natural resources of a country are currently subjected. A planned economy requires more data as a base for decisions; but the present alternative to such planning is a system in which the time lag between initial recognition of a problem with respect to a resource and the implementation of effective controls may be so long as to risk catastrophes (*15*).

The kinds of estimates of predicted environmental impact we will need will require computer simulation skills that are only now being developed. Computer modeling of the resources of wilderness areas, for example, has permitted estimation of the capacity of a park to sustain varying levels of human trampling (*16*). A number of workers (*17*) have developed the use of systems analysis in resource management, and recently a study group (*18*) has attempted to apply the technique to the State of California. Town and regional planners, resource economists, ecologists, and others (*19*) have developed skills in computer modeling, resource survey, and environmental impact assessment that are obvious tools in a resource policy system such as that presented. The National Environmental Center Bill (S. 1113) that passed the U.S. Senate last year already outlines as tasks the monitoring of environmental impact, the assessment of the effects of new technology, the study of current impacts on the environment, and the development of new methods for controlling environmental impact (*20*).

We emphasize again that the NRU system would apply at first to a limited number of the most environmentally costly activities and resources and would be gradually expanded as the data base, and public acceptance, increased. Lest phasing-in be slow, however, it should be borne in mind that the more items of environmental impact to be included in the NRU pricing system, the more equitable will become the distribution of true environmental impact throughout the population. Personal freedom (freedom from NRU pricing) is often inversely proportional to social freedom (freedom from environmental exploitation by others), as the "tragedy of the commons" (*21*) so compellingly illustrates.

Some Historical and Philosophical Roots

The system described above, of course, has its roots in the history of resource allocation theory. Economic systems are the obvious parallel to the system proposed here. In financial systems, all goods, services, and resources are given values in terms of a common monetary unit. Monetary transfer and resource allocation may occur freely, through supply and demand, or with partial or total government regulation of the means of production, distribution, and acquisition of resources and supply of monetary units. The NRU differs from money in that it is nontransferable; its system differs from Adam Smith's laissez-faire capitalism in its strong reliance on governmental adjustment of NRU prices and regulation of supply of the value units; it differs from a mixed economy (Western capitalism, for example) in its annual planning and governmental regulation of resource utilization; and it differs from a command economy (for example, that in the U.S.S.R.) in its stronger emphasis on consumer choice in the allocation of resources among the population. The reliance of this system on a strong fiscal policy is intended to dampen oscillations between resource spending (environmental impact) and resource saving (environmental conservation), although mild oscillations will probably occur. Note, too, that the NRU system differs from all economic systems in the very fact that it *coexists* with the economic system in a dual resource allocation scheme. The proper testing of the feasibility, stability, and effectiveness of a socioeconomic-NRU system requires, of course, considerable work.

The present proposal resembles that suggested by Edward Bellamy, in the 19th-century utopian novel *Looking Backward* (*22*), in its equal distribution of units to each individual each year. Bellamy's units were essentially nontransferable in that it was assumed that there would be an excess and no need to hoard; they differ from NRU's, however, in that the unspent excess dollars in Bellamy's utopia would be resumed at the end of the year, whereas we are proposing that NRU's remain usable and capable of being saved throughout the individual's lifetime. This capacity for saving should help increase the options open to an individual in choosing his life-style within an overall constraint.

The proposal is also related to various systems of rationing used in many countries during wartime and other stressful periods. In fact, the U.S. government has exercised fiscal control over a variety of resource uses, such as the rate of domestic oil consumption and the amount of farm land cultivated. The 1972 Federal Water Pollution Control Act Amendments impose a proportional charge on factories for wastes they send to a sewage treatment plant (*23*). Bills pending in Congress would permit government control of absolute amounts of toxic substances entering the environment and would establish national guidelines for land use (*24*). Still closer to the NRU idea is a passage in President Nixon's 1971 economic report (*25*):

> Another alternative would be an environmental usage certificate system. It would limit the amount of pollutants directly, but allow the price for pollution to be set indirectly. Under this system, as under a system of pollution standards, a Government agency would set a specific limit on the total amount of pollutants that could be emitted. It would then issue certificates which would give the holder the right to emit some part of the total amount. Such certificates could be sold by the Government agency at auction and could be resold by owners. The Government auction and private resale market would thus establish a price on use of the environment. The more pollution a user engaged in, the more certificates he would have to buy. Groups especially concerned about the environment, such as conservation groups, would have a direct method of affecting the environment. They could themselves buy and hold some of the certificates, thus directly reducing the amount of emissions permitted and increasing the cost of pollution.

The Nixon scheme differs from ours in that it is within the monetary framework and, as such, retains the existing financial inequalities. Not only would small industries be less able to compete for pollution certificates because of failure to achieve economies of scale, but poor citizens would have less control over the sale and use of pollution certificates than rich ones. Most conservation groups have no real means of competing with industry in the purchase of pollution certificates and, moreover, are acting at a level above pure self-interest. It is an important part of the NRU scheme to eradicate these initial inequalities.

Senator William Proxmire (D–Wis.) is one who has for several years suggested the application of effluent charges on the volume of water pollutants discharged by industry (*26*, *27*). The charges for dumping pollutants would be set higher than the cost of employing pollution control technology, so that the industry would have an economic incentive to minimize the amount of pollutants discharged. Other proposals for effluent taxation have also been much discussed (*28*). We have pointed out above how, in a competitive monetary system, a uniform pollution tax allows those individuals and firms who are initially rich to purchase "licenses" to pollute the common environment to a degree that may be out of proportion to the value of their service to society. The NRU system would avoid this problem by establishing an upper limit on the NRU's distributed to individuals and corporations. However, both tax and NRU systems suffer from the difficulties of estimating the appropriate initial price or tax level needed to achieve the desired degree of control.

Some International Implications

One of the major problems of our time is the gap in resource use between industrialized nations and the Third World. Writers on the global environmental crisis (*29*) anticipated the bitter differences in attitude toward resource allocation and environmental pollution between developed and developing nations some time before they were highlighted by the 1972 U.N. Conference on the Human Environment at Stockholm. The complaints by the developing countries are analogous to those of minorities in more developed countries: if environmental impact (or population growth) is frozen uniformly at the present level, we (the Third World) will retain our underprivileged position in terms of ability to purchase resources. Since the industrialized nations attained their control over resources without controlling pollution, the developing countries, it is argued, should be allowed to do the same. The difficulty is that, under existing conditions of international competition, there is little reason to be confident that the differential cost of pollution control will be sufficient hindrance to industrialized nations to close the economic (and resource) gap between nations. Indeed, we suspect that the only likely way in which developing countries could obtain their proportionate share of the world's critical resources would be to allocate them on the basis of population size, independent of money, in an internationally administered nat-

ural resource rationing scheme (*30*). By analogy with a national NRU system, in order to establish equality of access to resources, one must divorce it from existing financial inequalities. Along with the global redistribution of resource wealth to individuals would be the ability of an internationally administered body to set overall limits on the rate of environmental impact on the biosphere—the rate of world population growth, resource utilization, and pollution. We will readily admit, however, that global acceptance of such regulation is extremely unlikely at present. We will, therefore, briefly consider the implications of only one nation's adopting an NRU rationing policy.

Since resources would continue to be purchased from abroad, the more highly industrialized countries would continue to absorb a disproportionate share of the world's resources. Existing means of redistribution (that is, foreign aid) would continue the attempt to close the gap with the Third World. The difficulties with the foreign aid approach would remain virutally unchanged (*31*).

On the other hand, the NRU limit placed on production by a developed country at home would provide an incentive for companies to increase investment abroad. To the extent that the countries receiving those foreign investments regarded them as undesirable, they would impose on the investor increasing export tariffs on products and profit taxes on investments. To the extent that the country with the NRU policy felt threatened by decreased investment at home, it would be likely to impose import quotas and tariffs (including tariffs in NRU's) and offer tax concessions for domestic investment. It seems inevitable that the overall effect of an isolated policy of environmental impact control would be a self-imposed cramp in the rate of growth of the country's material wealth. It is partly for this reason, of course, that international cooperation in coping with problems of pollution of the biosphere is being sought by industrialized nations (*32*).

Feasibility and Acceptability of the NRU Scheme

We do not believe that public attitudes in the industrialized nations are at a stage where the NRU scheme would be acceptable. Nor do we regard increased regulation as desirable in the absence of demonstrated need. We do believe, however, that, as public awareness of environmental and resource problems increases, pressure will mount for steps to be taken to regulate population growth, levels of pollution, and rates of resource use. In phase with environmental education, it will be important to point out that regulations of resource supply and pollution imply consequent restrictions in personal freedom. As the inevitability of this becomes more widely acknowledged, and if public concern continues to increase with increasing environmental impact, public attitudes toward comprehensive resource pricing may well change. We could hope that the overall level of environmental impact will gracefully stabilize at a desirable level entirely because of laissez-faire adjustments in social behavior. But, as current trends in the growth of environmental impact do not offer much reassurance in this regard, we feel that discussions of possible future regulatory systems should begin now.

It is of prime importance that the feasibility of the NRU scheme, and others like it, be tested extensively. It seems to us a logical development from Jay Forrester's (*15*) computer modeling of world dynamics that attempts be made to simulate the problems and potentials of comprehensive resource-control systems. To do so, and as a first step in implementation, it is necessary to continue to collect data on existing environmental impacts and their effects, and on existing and predicted sizes of populations and resource pools. At the present stage of our knowledge, we regard the current proposal simply as a useful conceptual model to be discussed and tested, and then refined or discarded.

Summary

It is suggested that, by assigning to every resource use and activity (including childbirth) that causes environmental impact a price in money-independent units (NRU's), a new system of environmental trade-offs can be established—one which maintains maximum personal choice within overall environmental constraint. The social equality of the system in relation to resource exploitation would be enhanced by distributing NRU rations equally among the population each year. Special means of controlling industrial and organizational use of resources through NRU's are also discussed. The system is believed to offer a more sensitive means of gauging social priorities in relation to resource use than that achieved by an exclusively monetary system. Although involving more planning and more governmental regulation than is currently deemed feasible or acceptable, we believe the mechanism would lead to less restriction of personal freedom in a steady-state society than would the current trend toward unsystematic imposition of governmental regulations.

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28. See, for example, H. C. Wallich, *Fortune* (October 1972), p. 114. For an illuminating debate on the subject of effluent charges for water pollution, see *Congr. Rec.* (2 November 1971), p. S17425; also (*27*, pp. 187–200; 346–365).
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32. See L. K. Caldwell, *In Defense of Earth—International Protection of the Biosphere* (Indiana Univ. Press, Bloomington, 1972) and the resolutions of the United Nations Conference on the Human Environment, Stockholm, 1972.
33. We acknowledge the inspiration for ideas in this article provided by discussions with the late Joseph F. Hodgson, and with D. Ritchey and D. Kass of Cornell University. We are grateful to A. Costin, P. Ellyard, J. T. O. Kirk, M. M. Scurrah, M. R. Scurrah, G. Smith, and J. Zwar for their comments on drafts of this article.

NEWS AND COMMENT

Deepwater Ports: Issue Mixes Supertankers, Land Policy

Sometime between now and 1980 two or more deepwater terminals for the delivery of foreign crude oil by supertanker probably will be established in the offshore waters of the United States. No such terminal now exists, and, given the present shortage of refinery capacity in the United States, a huge increase in the importation of foreign crude could not presently be accommodated. Thus, the federal government and the coastal states have time to develop a policy for the siting of deepwater terminals which takes account of how such terminals and massive oil deliveries may effect environmental quality in the coastal zone, offshore and onshore, and influence the growth and location of refineries and petrochemical complexes nationally. The environmental as well as economic implications of deepwater terminals may be surprisingly favorable—or, in the absence of proper policies, disastrously unfavorable.

That it should now be widely accepted as virtually inevitable that deepwater terminals for oil deliveries will be built is attributable to four things:

- First, there is the fact that, by 1980, U.S. consumption of petroleum products is expected to have increased from the total of 16.4 million barrels a day consumed in 1972 to about 22.8 million barrels a day, with the proportion imported increasing from 29 percent (the 1972 figure) to as much as 48 percent. No matter how vigorously the development of such domestic sources of energy as coal (with gasification) and shale oil is pursued, the United States will be relying heavily on foreign oil at least through the 1980's. This undoubtedly will be true even if the nation adopts significant energy conservation policies, such as discouraging the use of heavy, high-gas consumption automobiles.
- Second, most of the 11 million barrels a day to be imported (some in refined products but the great bulk in crude oil) will come from the Persian Gulf, with each tanker delivery involving a round trip of about 24,000 miles. Given the great distance, enormous savings in transport costs are possible from the use of supertankers. Oil is shipped to East and Gulf Coast ports from the Persian Gulf at about $13 a ton in a conventional tanker of 47,000 DWT (deadweight tons). By contrast, the freight cost per ton drops to $5.70 when a 250,000-DWT tanker is used.
- Third, supertankers already comprise an important part of the world's tanker fleet. The conventional tanker of World War II was the "T-2," a 16,700-DWT ship with a draft of 30 feet and a length of about 500 feet. Even today, most of the several thousand tankers still in service around the world are ships of between 10,000 and 60,000 DWT, with the great majority at the lower end of this scale. But such ships are yielding rapidly to the supertanker in the long-haul transport of crude. The supertanker is most commonly a vessel of between 200,000 and 300,000 DWT, with a draft of 55 to 80 feet and a length of more than 1100 feet. There are now at least 228 tankers of 200,000 DWT or larger; by the mid-1970's, the number of ships of this size will exceed 800. For the United States, the only real choice is whether the supertankers will bring the crude directly to U.S. terminals or whether they will deliver it to terminals in the Bahamas, the Caribbean, and Canada, for subsequent shipment by smaller tanker to U.S. ports in the form of crude and refinery products.
- Fourth, it is neither economically feasible nor environmentally acceptable to dredge out existing ports and approach channels to the depths necessary to accommodate deep-draft supertankers. U.S. ports now generally have channel and berthing depths of between 35 and 45 feet. Even a medium-sized tanker (100,000 DWT) will draw almost 50 feet fully loaded. If the Delaware River ship channel were to be deepened by only another 10 feet from its present 40-foot depth, the cost would exceed three quarters of a billion dollars, and some 330 million cubic yards of material would have to be excavated and somehow disposed of.

In view of the cost of the alternatives, the building of terminals offshore in naturally deep water can be very much a bargain, even though these facilities do not come cheap. There are widely varying concepts of deepwater terminals, ranging from the elaborate (and probably economically infeasible) notion of building an artificial island and breakwater to the relatively simple concept of the single point mooring (SPM) system. The SPM is the kind of terminal receiving most of the at-