"See a CER — M-074 ‘AN ECOSYSTEMS FRAMEWORK FOR ENERGY-RELATED ENVIRONMENTAL RESEARCH PLANNING IN PUERTO RICO by Michael A. Chertock May 1980, CENTER FOR ENERGY AND ENVIRONMENT RESEARCH.

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1.0 Introduction

1.1 Context

This report summarizes one systems ecology approach to develop a strategic energy-related environmental research planning capability for the Center for Energy and Environment Research, University of Puerto Rico. The Center is one of the principal energy and environment research arms of the Puerto Rico Commonwealth government and conducts research for the federal government. The near term and long term research plans and approaches for

The Center is important for an adequately informed government to respond to the serious energy challenges that Puerto Rico addresses. This report describes one conceptual basis for gathering critical information needed to examine energy-related environmental problems of the near future. It is a document that describes the challenges to the Puerto Rico Island System and outlines a framework for developing a general strategy for addressing society's environment-related information needs.

4.2 Organization and Objectives

This report first briefly provides an overview of selected characteristics of the man-nature island system. It then describes one basis for developing research priorities and an approach for predicting large-scale system changes. The last two sections summarize potential Puerto Rico environmental consequences. In the conclusion, the paper describes how shifts in potential pollutants provide an example to inform planning and research priorities.

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1.3 Approach and Limitations

Systems ecology emphasizes the behavior of indicators of total system function and stresses the interrelationships among component parts. This paper places emphasis on energy flows and materials cycles in the linked natural and man-dominated Puerto Rico ecosystem. In part, it assumes that understanding or predicting changes in the hierarchical structure of system components provides a basis for energy and environmental planning. By including both technological or hardware components and institutional or social components, research plans can provide the basis for gathering information that affects the future behavior of the Commonwealth and its natural environment. A systems approach has the capability to include a full range of natural and social components.

Processes. This paper summarizes several types of interrelationships as examples. While a systems approach can suffer from substituting an understandable model for the complexity of a poorly understood and unpredictable reality, it offers a rational framework to predict, plan, and evaluate policy. This paper also briefly describes selected major assumptions and a general framework for developing future planning and management to address the tangible problems that Puerto Rico will face.

2.0 The Coupled Man-Nature Island System

2.1 Hierarchical Structure for a Research Plan

Its purpose is limited, however, to demonstrating that systems have a hierarchical arrangement of parts that structure the flow of energy and channel the cycle of materials. This structure is maintained and developed by renewable and/or exhaustible sources of energy. The temporal "program" of these energy sources controls the size, distribution, and flows among component parts. For example, horses, oxen, and human labor energized Puerto Rico's dispersed agricultural economy, prior to the 20th Century. Wood, water power, and coal provided for a more industrial society during the early part of the 20th Century, contributing to fixed transportation paths and strong central cities. Liquid and gaseous fuels account for the mobile and energy-intensive Puerto Rican society of today, which is more dispersed along the coastal zone.

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These major periods of energy use are summarized in Table 1. Four general periods are indicated along with summary references to transportation, urbanization, and environmental change. These data provide a broad picture and are intended only to indicate the major transitions that occurred at the termination of the pre-Columbian era, about the dawn of the 20th Century, and during the post World War II periods when Puerto Rico experienced dramatic changes in the form and intensity of energy use. Figure 1 shows some of the patterns of human settlement during these periods of energy use (Department of Natural Resources, 1977).

With any large-scale energy flow moving in one direction, a counter flow of energy in the opposite direction exists that exerts a feedback control (Odum and Odum, 1976). Consumers control the flow of energy to their homes with overt decisions supplying in the opposite direction to energy, a controlling flow of money.

The Commonwealth and federal government control energy flow with purchases, taxation, regulation, and other policies. The form, distribution, and activity of flows upwards through the hierarchy of Puerto Rico and the countercurrent control flows are diagrammed in Figure 2. As indicated in the figure, all energy flow is ultimately dispersed as heat, although energy may be stored for varying periods of time.

Most energy incorporated in ecosystems moves along paths of material flows, and all material flows contain some energy. The paths of energy movement in a complex ecosystem intersect at structures where changes in the form of quality occur. As energy moves upwards, the power to control increases along with its quality or ability to influence other flows. Materials in turn are frequently concentrated in these process steps.

For example, on the social level, some wealth in most societies tends to concentrate among the few people in the controlling sectors of the economy. Recognizing this problem, the government of Puerto Rico instituted some economic

Redistribution policies are implemented to achieve socially desirable goals of enhanced equity among citizens. An analogous process occurs as cities become larger, pollutants also tend to concentrate in centers with high rates of energy input. Secondary industries develop in close conjunction with primary industries, contributing to socially desirable economic development. This is the case in cities such as San Juan, Ponce, and Pefvel.

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However, these developments can also lead to adverse environmental consequences, such as urbanization, air, and land pollution. Technologized consumer atmospheres can increase pollution. Factories contribute to the pollution, particularly in dense industrial areas. Modern power plants also contribute to pollution, but they are less apparent sources of thermal addition. As society grows, it further concentrates pollutants in clusters.

In land use, the more complex the source and method of flow, the more materials are concentrated or move faster. Although the flows are not necessarily experienced in a linear fashion, the increasing complexity creates vortex-like flow. The diversity of these vortex-like systems in developed countries is directly linked to their industrial and natural complexity.

As humans develop value systems and manipulate nature, they become a significant, if not dominant, component of the environment. An industrial ecosystem is one that is dominated by man. Humans tend to modify pathways of biogeochemical cycles. Although the effect varies depending on technologies used and the materials cycled, the sheer number of humans (4.0 million in Puerto Rico) now makes them the dominant force, irrespective of the technology.

Taken as a whole, humans affect a behavior pattern in the global ecosystem in various ways: they tend to maximize energy flow through their sector and do so by extending control over more complex energy paths. They do this through social controls such as industry.

Government of consumer behavior. Technologies are generally extended to increase the power (energy flow/unit time) and stability of the system or subsystem. For example, widespread use of automobile transportation in Puerto Rico generally increases the effectiveness and power of those riding in them and the corporations selling them. This mutualistic situation is how progress in ecosystem development to exponential increases in domestic animals following the pre-Colombian era. The U.S. Environmental Protection Agency (EPA) has controlled automobile emissions so that people can continue.

Improving professional and talent in an exponential growth of system vigor: Vehicle supplies, auditors, and new parts and instructions. The past will likely continue whereas environmental law and occasional sources persist by the courses of natural energy (Hunt, 1972), and by the continuation of radiation of materials in any one or more components in most deaths from two increased causes: (1) accumulation of materials to toxic concentrations that poison components (2) lack of components. Accumulation as a hazard may take many forms such as, all properties of the atmosphere or hydrosphere can subsequently trigger changes at larger geographic scales such as meteorological changes or physiological and genetic responses. However, overall systems characteristics may rotate changes or dramatically rise. Thermal pollution may eliminate some species, but total system respiration and production may increase, creating a more powerful developmental step (Hunt, 1974), for example.

2.4 Values and System Function

Scientists, managers, and laypersons establish values as a part of their activities to make operational judgments or to evaluate the quality of the environment and system function. These values take several general forms. Deviation or change from a steady state can be established as one value. Others may not agree that a steady state exists and feel that the composition of cities, forests, lakes, etc.

Streams and have been continually changing. Some believe that a steady state exists, around which a pattern or random fluctuation occurs. To a part, this apparent probabilistic behavior is due to the complexity at all levels of system's structure (Kowal, 1971). The relative advantage of this developmental step is dependent on a range of criteria, such as stability and value of species.

The basis of environmental policy and information seems frequently to arise out of the aggregate of current measures. The rate of significance of the action of systematic environmental components often comes into contention. System content is established in diversity, state of resonance, and thrust, among other examples. Second, and perhaps more importantly, the values that are developed and applied by government and industry change through time, and these shifts can be observed in systems context. As liquid and gaseous fuel became widespread, there followed a shift in values. For example, expanded transportation within dependent rural areas is a major effect of the events in the Puerto Rico ecosystem.

When disparities between the intensity of energy use and the assimilative capacity (recycle pathways) occurred, the changing values brought about new federal policy. An emerging set of values is also likely for the near as well as more distant future, in the sense of concentration is achievable by tracing the efforts of new energy sources.

2.0. Criteria for Developing Research Activities

Future energy-related research activities will be largely influenced by the industrial character and ecological opportunities available to Puerto Rico, the values and norms that influence the direction of policy, and the scientific basis for accurate and effective decisions. Each of these criteria is likely to change. Several approaches are possible in attempting to develop changes: (1) develop a responsive, process-oriented research framework that is flexible; (2) develop a system that identifies alternative likely futures; and (3) identify critical elements in the current situation and project their likely impacts.

Existing problems and issues, along with associated uncertainties and areas where new information would have an effective payoff. Some combination of the above or related approaches can be useful. The development of effective anticipatory or predictive systems for Puerto Rico can provide one rational approach. This approach would examine critical alters suiting factors or forcing functions.

Ensure that the potential ranges of new scenarios and predictions might be described and integrated with a transition, changes in the distribution of specific values approach, and a linkage among analytic responses through population and total impact. This also provides a significant link between the natural and social sciences and engineering disciplines. By examining alternative futures, the research agenda is not locked on a technical fix, but can provide information about a range of choices.

3.1 Alternative Futures

If an effective research plan is to be developed for the likely future, only limited research and development would need to be undertaken. The assumption that we now know enough is highly uncertain. The uncertainty of even historic accounts provides support for this. A systems approach informs us, however, that societies do collapse and perish, but that management and control result in a persistence of systems behavior patterns.

Because the future is also highly uncertain, an effective research plan must be informed on the basis of alternative futures and their implications on human health and environmental quality. A research planning strategy is used here to measure the deployment of limited research resources in a manner that increases understanding of the major risks to the environment from technological change and identifies courses of mitigating action. This strategy must take into account the magnitude of risks within alternative futures and prepare a contemporary research infrastructure to meet the challenges of the coming decades. While alternative futures are affected by a wide range of policies...

Within the Commonwealth, the netic and in other countries, this paper rests primarily on the concept that the form of society and natural systems is largely affected by energy policy and other resource limitations.

Factors such as trade, growth, energy, and environment are essential due to their singular yet interdependent nature. 2.2 Realising Systems Changes: Several critical factors influence and maintain the organization of natural systems. The most critical or driving forces are the Commonwealth of Puerto Rico, like any political or natural entities to such an economic sector, hardly makes sense of a completed system (the boundaries of a system are defined for convenience of analysis and for effective policy development) except that social and technical controls primarily are implemented as bounded by Commonwealth. Principal forcing functions in Puerto Rico are the available energy sources and the equipment and raw materials which act as a gate to use these energy sources. So many resources are now imported, that environmental controls must begin to reverse the relative position of the Puerto Rican ecosystem within the world. An obvious example, petroleum is extensively imported, and as petroleum supplies are diminished, they will act as a forcing function requiring policy and technological change in power generation. By systematically examining the future availability of energy sources and limiting factors, a general understanding of alternative futures can unfold.

3.3 Potential Fluctuations: A range of possible alternative futures exists, based on potential future "driving forces". As discussed in Figure 2, these future paths basically include continued exponential growth, sigmoid growth, fluctuating growth, and growth and decay. However, as indicated in section 2.4, it is difficult to distinguish small scale patterns of fluctuations to larger patterns of steady-state, growth or decay. In fact, frequently steady states are maintained through "pulses" (Osm, 2871).

The text is continually changing, either over the short or long term in response to evolving functions of long-term internal change. A totally comprehensive understanding of research strategies is not possible. It is difficult to evaluate the merits of policies within a system, since the system structure is modified when policies are in place. It should be noted, however, that often tendencies to stabilize a fluctuating system are one part of the controls that enhance long-term growth and output.

Factors and other forces are unpredictable over the short term. For example, without environmental controls, pollutants accumulate to make conditions undesirable. Environmental laws and controls influence the natural behavior of the system leading to disruptive situations. Energy can be the ultimate determinant for geographic, technical, and political equilibrium, but frequently it is not. In the arid states of the country, for example, populations are limited by water availability, not the availability of refined water forces the fuel-rich economy to ship the rest out of state. However, water limits the availability of natural energy development of large populations and urban growth. Thus, Puerto Rico and eastern parts of the U.S. accommodate high population densities through vegetation and high rainfall that protect both people and the terrestrial and aquatic habitats from intensive urban and industrial growth.

4.2. Pollution and waste

The effect of pollution and waste is to manipulate growth negatively. This can be used as a predictive tool because energy is frequently a key factor, growth tends to form in relation to the availability of energy. The pattern of population distribution comes close to that of energy availability, as modified by transportation technology and overt policy decisions. This combination of Federal and commonwealth policies for growth have developed incentives to attract businesses and people in Puerto Rico. An underlying factor is also the assimilative capacity of the natural environment.

Environment, and the changes in values of those deciding velocity. Information about density patterns that relate to the distribution of resources and assimilative capacity of the environment can provide a policy basis that recognizes the natural capacity of the environment to disperse pollutants at low resource cost or limited change in the hierarchy of system structure.

4.3. Pollution sources

The criteria for evaluating environmental policies rests on a range of values described in Section 2.4, since research is directed to the evaluation of cost-benefit analysis, with little concern to overall system power or function. The performance standards have been developed for separate plants for several industries with the understanding that the value contributes to the system of resources. As the emission of pollutants is reduced at the cost of net output, each rotated and chemically pure material is cycled with less waste.

Any plan for its part and the advancement of each technological development can be a model of stability and power, it is more likely to dominate over competing systems and those that divert energy to the heat sinks, producing more residuals into the environment.

4.4. Environmental Heterogeneity

As technology develops, environmental losses become more extensive. However, the controls can be supplemented using system performance as a principal criteria. System performance criteria recognize heterogeneity in environmental types and the adaptation of technology to meet the assimilative capacity of respective geographic areas. In some locations, residuals can be dispersed in air, in others in water, and still others concentrated in landfills.

System performance also recognizes the cyclic nature of environmental processes, and recognizes different time frames (gestation periods, seasons, geological time and evolutionary time, etc.). The performance of the system can be monitored, and a reaction of social or technical innovation can be undertaken.

5.0. Environmental Research Plans

5.1) Planning for Practices of China's Alternative Forcing Functions

The development of the Commonwealth's social and environmental system can be used to predict shifts in major economic sectors and sources of "residuals" (pollutants). Table 2 illustrates some of these shifts. It indicates, for example, that continued system development typically moves towards increased complexity and increased residuals accumulation and management. Changes in heavy metals associated with the electronics in action may develop as petroleum supplies become scarcer. Alternative sources of energy are likely to be discovered. The timing of reduced growth in energy supply would result in greater conservation and energy storage. This may be encouraged by the deployment of new battery or storage technologies for energy. Shifts in energy sources could result in a significant change in residuals. Continued decrease in energy supplies would likely result in shifts in the ratio of urban and rural populations, (Adams and Gums, 1975) and potential for letting the environment self-cleaning functions rather than rely on energy-intensive population control technologies may be an area of research importance.

5.2 Developing a Framework

The timing and magnitude of environmental changes can be estimated through quantitative modeling techniques. Accuracy is largely dependent on the certainty of underlying assumptions. Because these assumptions are frequently weak, a selected range of scenarios considering problems that affect alternative energy resource development policy may be a basis for maximizing environmental protection with limited research support. The examples discussed in this paper are exploratory and are intended to indicate the qualitative application of this approach to environmental research planning. Further quantitative development of this approach would permit an evaluation of some untested assumptions, and an elaboration of the research consequences for environmental protection in specific social sectors and natural environments.

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