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?AN ECOSYSTEMS FRAMEWORK FOR ENERGY-RELATED.
ENVIRONMENTAL RESEARCH PLANNING IN PUERTO RICO
by
?Michael A. Chertock
May 1980
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Center for Enercy and Environmental Fé Marine Ecology Division
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1.0. Introduction

1.1 context

?This report sumarizes one systems ecology approach to develop a strategic energy-related environmental rescarch planning capability for tho Center for Energy and Environnent Research, University of Puerto Rico. The Center is one of the principal energy and environment research ams of the Puerto Rico Commonwealth goverment and conducts research for the federal governsent. The near term and long term research plans and approaches for the Center are 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 informa tion needed to examine energy related environmental probless 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 societies environent-related information needs.

This report firet briefly provides an overview of selected char~ acteristics of the man-nature island system. Tt then describes one basis for developing research priorities, and an approach for predicting large scale system changes. The last two sections sunmarize 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.

"pormanent address:

Department of Zoology and Science and Public Policy Program
University of oklahoma

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Oak Ridge Associated Universities, Oak Ridge, Tennessee

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1.3 Approach and Limitations

systems ecology onphasizes the behavior of indicators of total system function and stresses the interrelationships among component parts. ?This paper places enghasis on energy flows and materials cycles in the inked natural and man-dominated Puerto Rico ecosysten. In part it asounss that understanding or predicting changes in the hierarchical structure of systems components provides a basis for energy and envizon~

ental re

woh planning. sy incluaing both technological or harduare components and institutional or social components, research plans can provide the basis for gathering information that affects the future behavior of the CommonvesIth and its natural environment.

[A systems approach has the capability to include 6 ful) range of natural and social components and processes. This paper only sumarizes 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 franework to predict, plan, and evaluate policy. ?This paper is also briefs it describes selected major assumptions and a general framework for developing eh

planning and management to the future tangible problems that Puerto Rico will face.

- 2.0 The Coupled Man-Nature Island system
- 2.1 Bierarchical structure

fa research plan. Its purpose is Limited, however, to tying re

systems have a hierarchical arrangement of parts that structure the flow of energy and channel the cycle of materials. This sturcture is maintained and developed by renewable and/or exhaustable sources of energy. ?the temporal ?progran" of these energy sources control the size, distribution and flows among component parts. For example, vided for the Sispersed, pre-Columbian economy. The use of horses, oxen land human labor energized Puerto Rico's dispersed agricultural economy, peior to the 20th Century. Wood, water power and coal provided a more industrial society during the early part of the 20th Century contributing to fixed transportation paths ané strong central cities. Liguid and

?gaseous fuels account for the mobile and energy intensive Puerto Rican

solar energy pro-

society of today, nore 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 reference to transportation, urbanization and environnental 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 davn of the 20th Century and during the post world war 12 periods when Puerto Rico experienced dramatic changes in the form and intensity of energy use. Figure 1 chows some of the patterns of hunan settlement during these periods of enersy use. (Department of Natural Resources, 1977).

With any large scale energy flow soving in one Airection, a counter flow of energy in the opposite direction exists that exerts a feedback control (Odun and Odua, 1976). Consumers control the flow of enersy to their hones with overt decisions supplying in the opposite Girection 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 upeards through the hierarchy of Puerto Rico and the countercurrent control flows are diagraned in Figure 2. As indicated in the figure, all energy flow is ultimately dispersed as heat, although enersy may be stored for varying periods of time.

Most energy incorporated in ecosystems, moves along paths of materials flows, and ali materials flows contain some energy. The paths of

energy movement in a complex ecosysten intersect at structures where changes in form of quality occur. AS energy noves upwards, the pover to control increases along with its quality or ability to influence other Flows. Materials in turn are frequently concentrated in these process

steps. For exampl

fon the social level some wealth in most societies
tends to concentrate anong the fev people in the controlling sectors of

the economy. Recognizing this problem, the government of Puerto Rico Anstitot

sone economic redistribution policies to achieve its socially

Qesirable goals of enhanced equity anong citizens. In an analogous process as cities becone larger, pollutants also tend to concentrate in centers

With high rates of

energy input secondary industries develop in close conjunction with pri-

of activity, such as, San Juan, Ponce and Pefvel:

nary industry contributing to socially desirable economic development,
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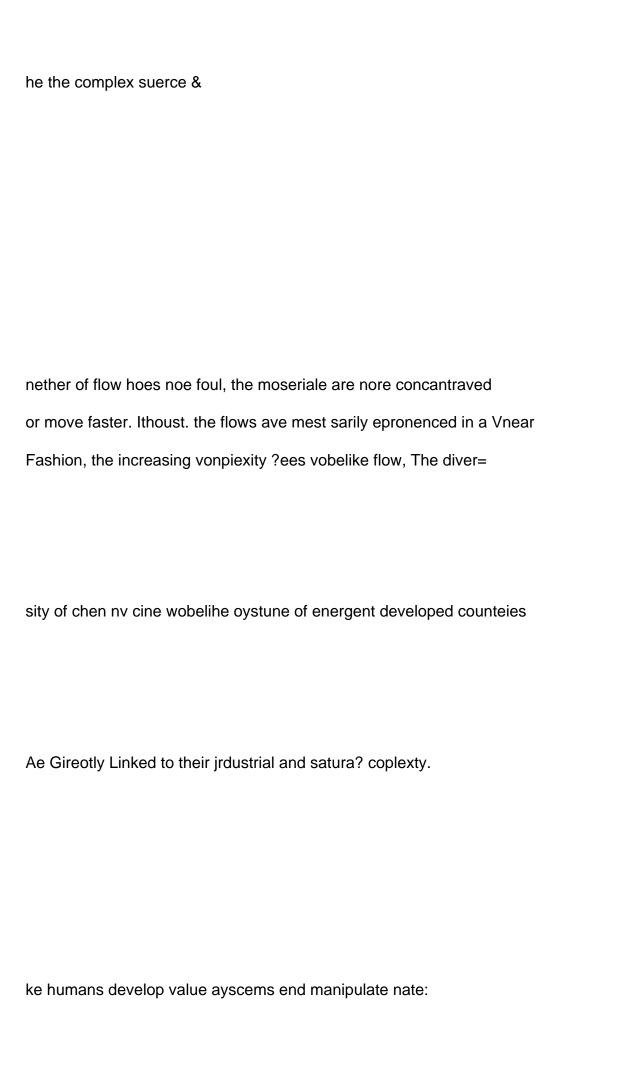
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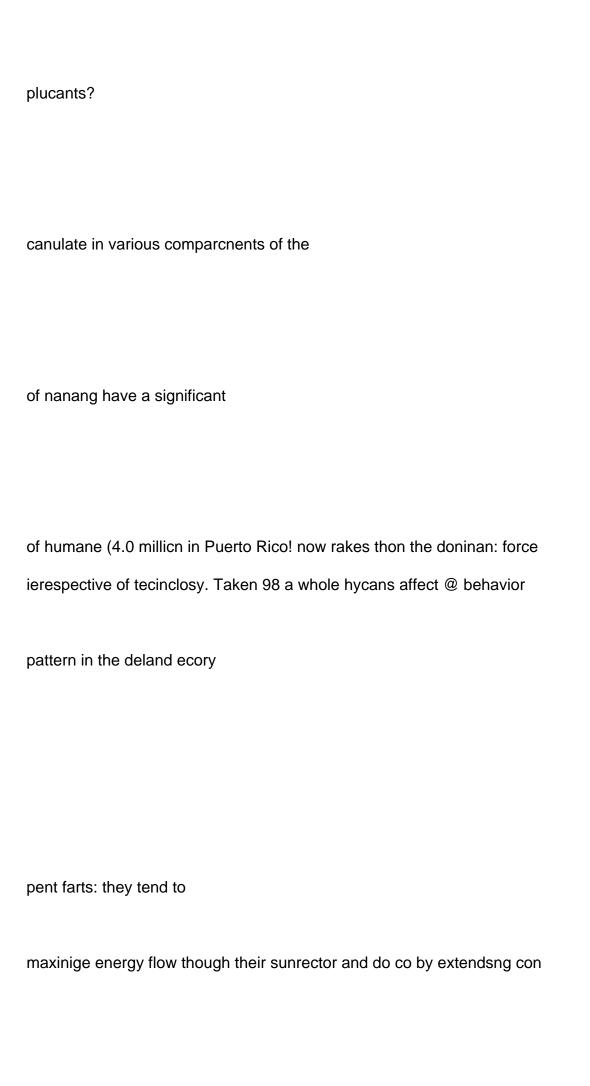
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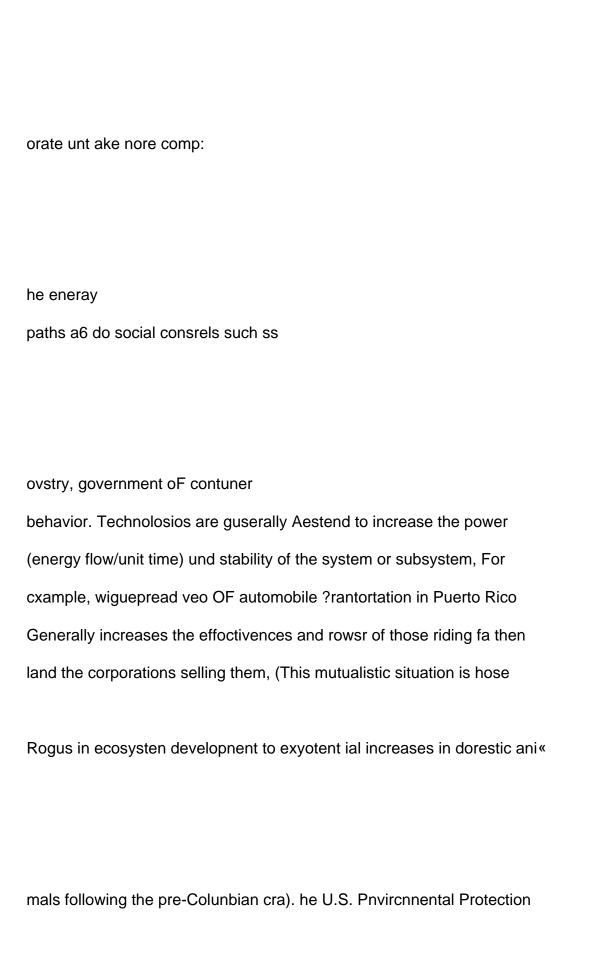
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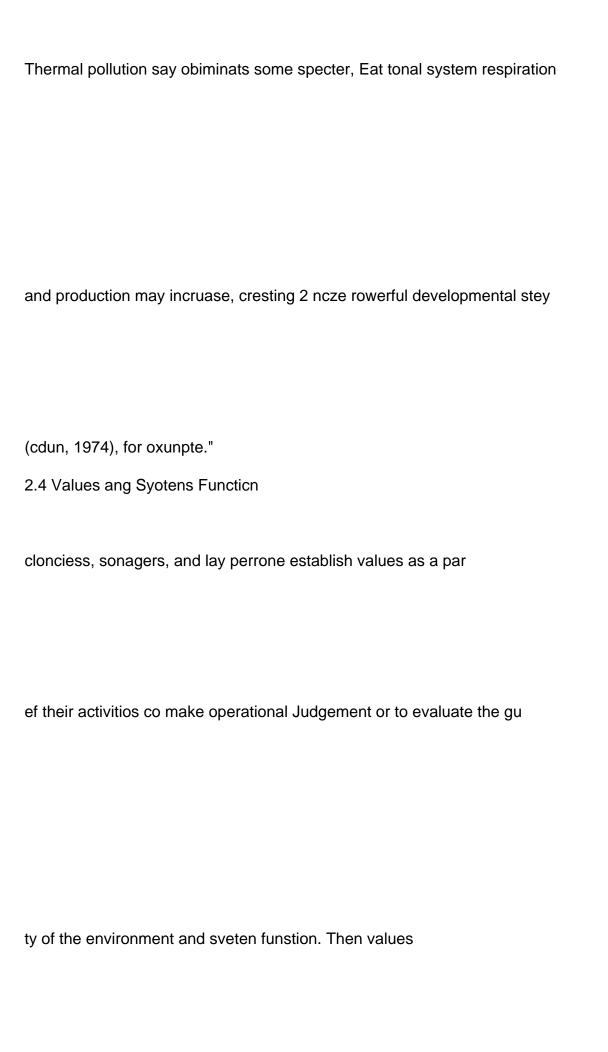




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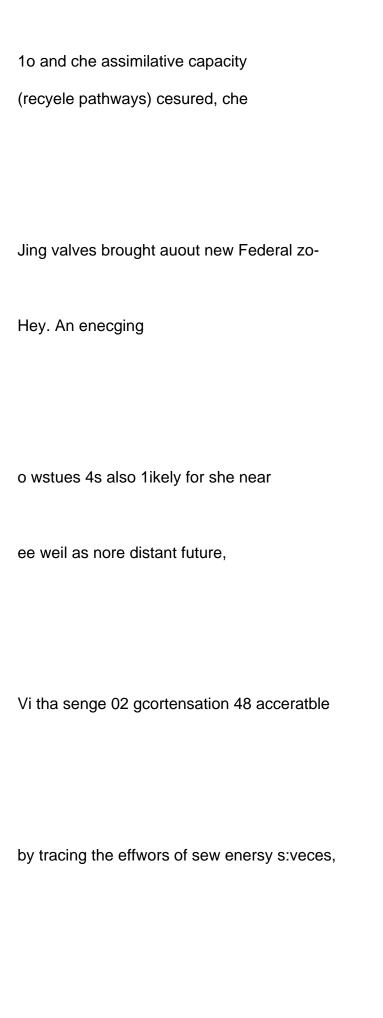


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ands has beer continually changing. Some heliove that # steady state	

exists, = ound which @ pattern or
random fluctuation occure. Ta part this apparent probabilistic behavior
As due to the couplexity at all levele ef eystens structure (Kowal, 1971).
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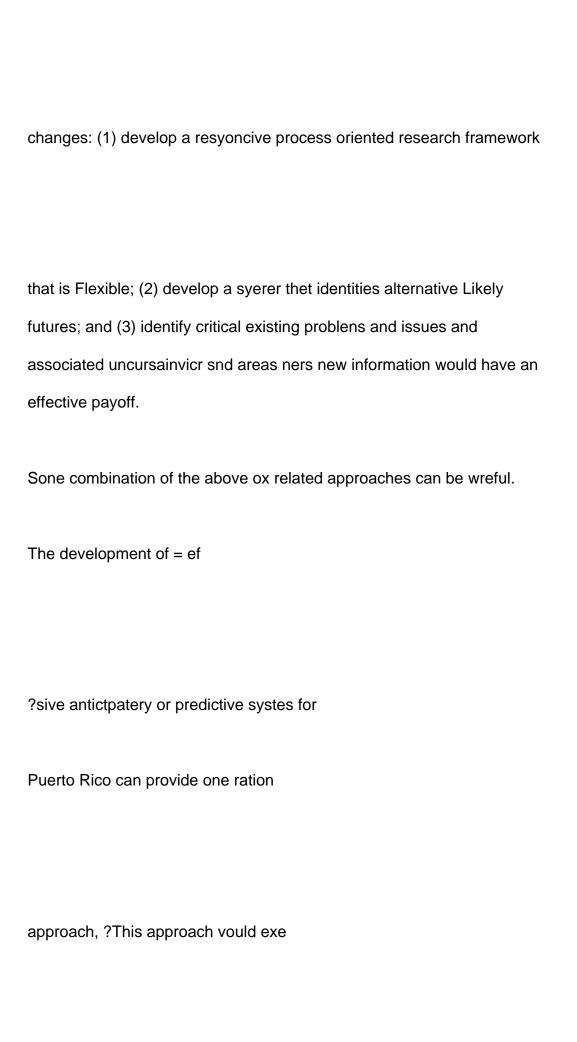
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attempting to develop an «

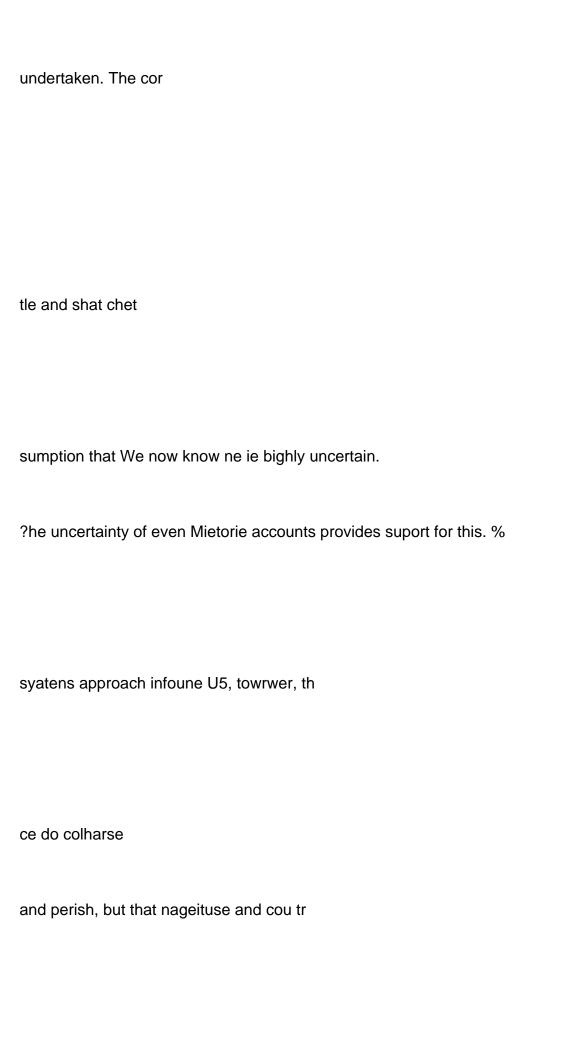
2.0. Criteria fer Developing Research Frisrivies

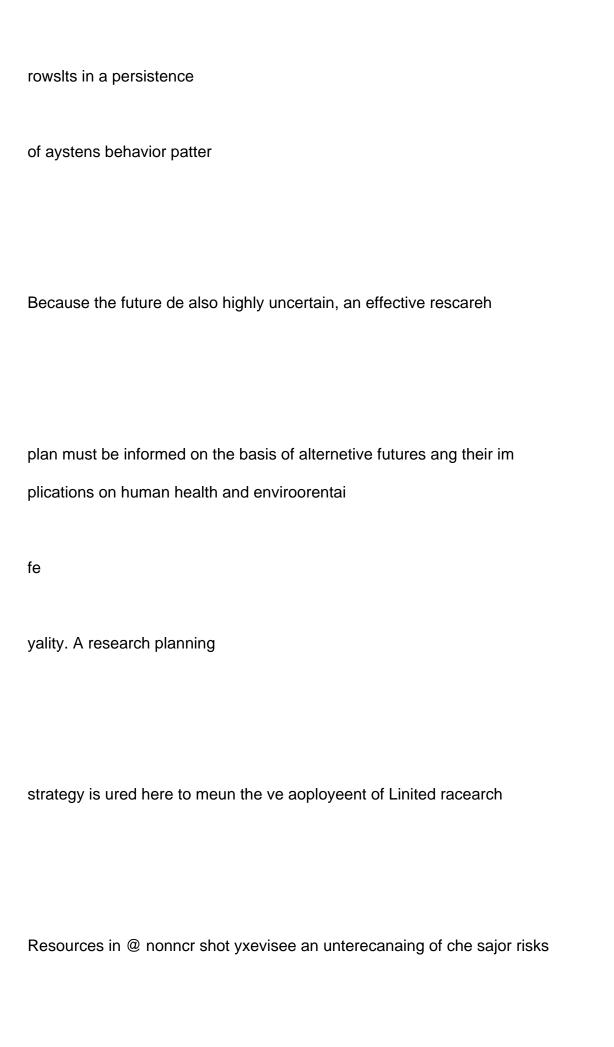




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ko link the natural und aocéal sciences anf cnginesring disciplines, ay
cxarining alternative farure-, the ressarch agenda is nog Tetked on a
echnical fix, wut can provide information about & range of ciotoes oF
3.1 Alsernacive Fu
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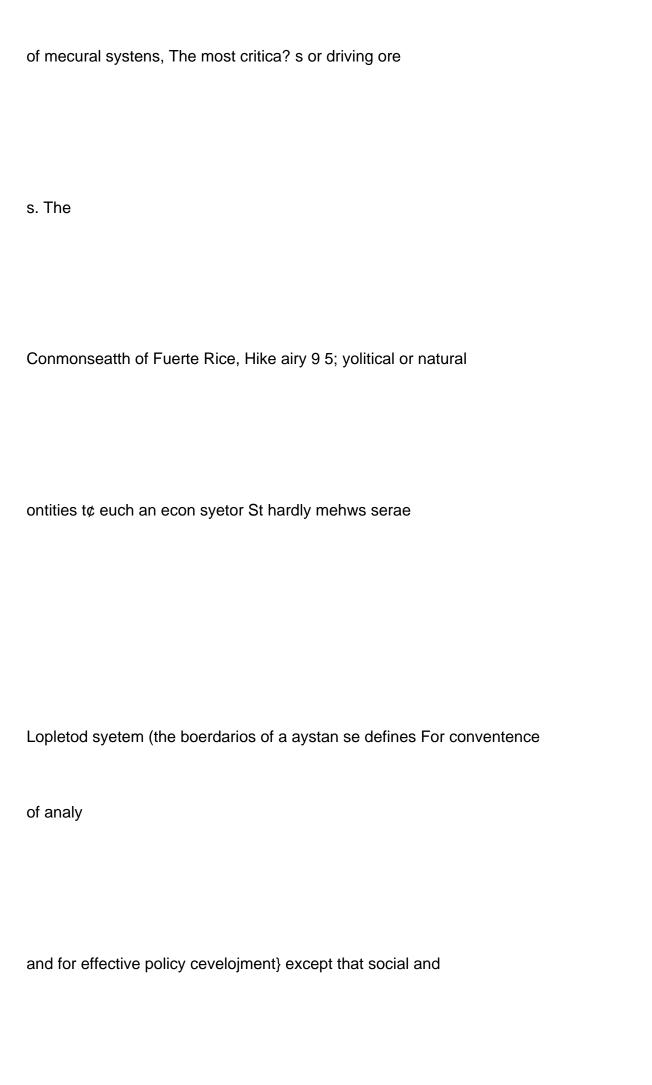


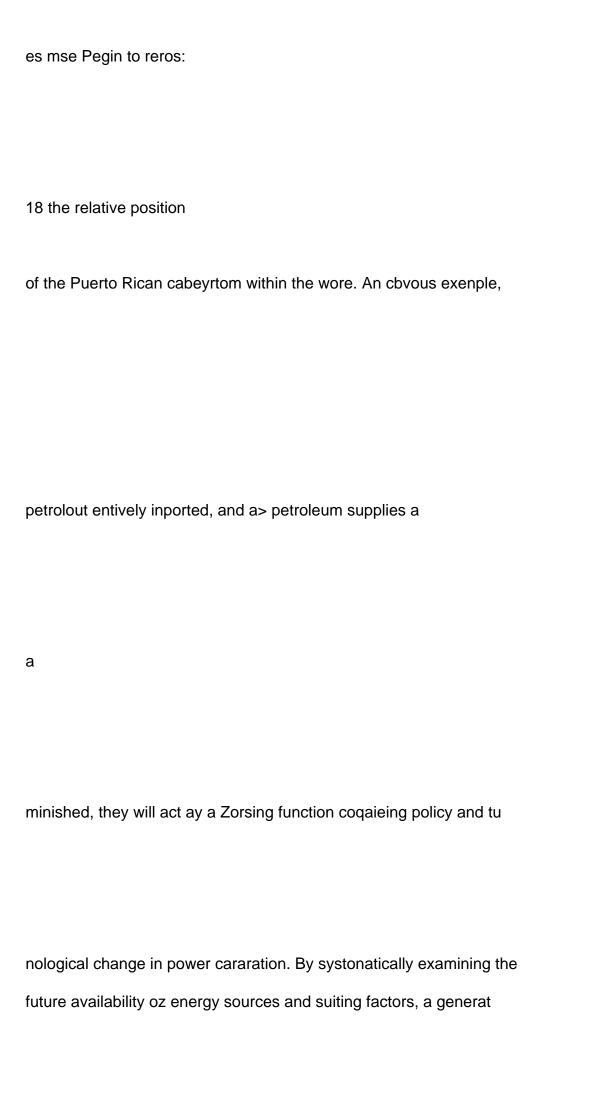


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change and identifies courses of niticating action. This stratesy must
?take into account the magnitude of risks within alcernative futures, and
prepares a consempora Jeercs infre.cruciure te mest the challenges
of the cosine decades.
WhSie alternative futures are affected by a wide range of policies
oth within the Conmonmesith, tho netic and in other countries, this
poper rests primarily on the concept that the form of society and nacural
systems is largely affected ty enersy pottey and othor resource Linteing

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factors. ficwever, for Puurio Kino, the Vinkage ?etween trade, Growth,
?energy and environment ace veitival because of Jue ingular yet interde-
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2.2 rodiesing systems Changes

Several critical factors inflcence and maintain the organizacion

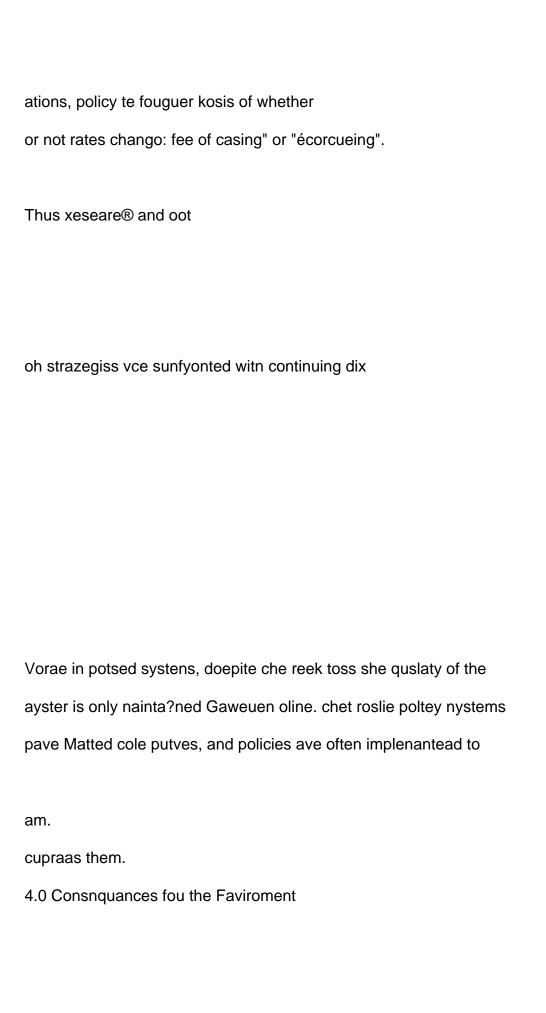




3.3. Potential Flyctsazions
A range of possible alternative futnees existe, based on potentiat
Future "ériving forsee". Ae diasroned &
cgure 2, these future pat
basically include -ontinued oxpenontiat seowen, sigmesd growth, fluctusting
growth, and qrosth ang ascey, Homsver, ar indicated Sn section 2.4, it is
Sifesoult to distinguish mali scale cacterns of Fluctuations to leryer
patterns of steady-state, growth or decay
Tn fact, frequently steady

understanding of alternative futures can snfold

states are maintained through *puisss". (osm, 2871). TH
88 pulsos
apply short texm bursts of rower, ané may be ruquired for systems function,
?Thus a system may not bo able to apply continuing high cates of eneray use
to maintain conplenity without periods of decay as wastes accumslate, par
wear ovt or congestion occurs. Svssequent periods of reduced power output
functionaMy represent timas in which the ?katteries" are recha-ged (ca~
pital accumilates) or wastes are disposed, so to speak. For Puerto Rico
pital accumilates) of wastes are disposed, so to speak. For Fuerto Nico
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An snveneary of savera) conutaavione of future (nergy sourose for
Puerts Rica and the rasulesnt systom attributus ave described in Table 2,
?Thess selected cparucturistice are size, noxee, hunan values, and onntrol.
ovhere parimevers could be incluted, These caransters were chosen te
emphasize the underlying velationshins totween foreine fmevions and is
portant charaoterictice ist vay affece cuviscnvental research and do~
cision making. The actus? eining as to when seo of tes
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say predominate to part is Copantect on the use and flow of information

about the sycten. Ruv{scusentsl rersazen tues ea anticipate chee problens, and the widespread antictystion of those <turacteriaties ean result in earlier policy afjuetionts oF envivoarentsl controls, Environmental atti tudes and values are 1ikely to cone into adjustment with the foreing fune~

?ions at cone time, however.

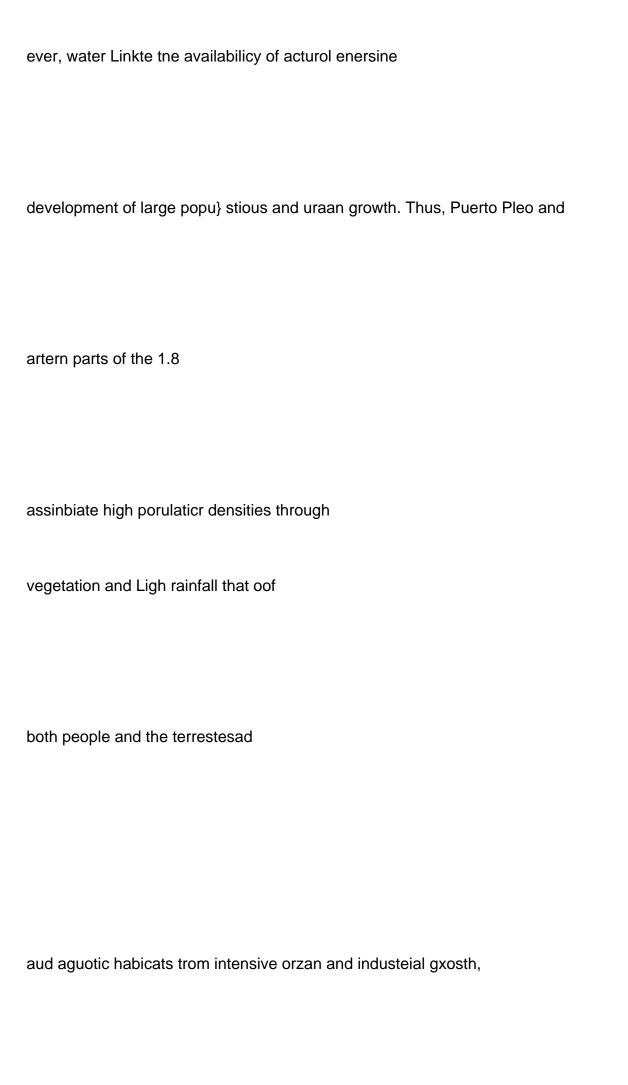
None suppression or sulsos 1 partly aye 0 ure oF near Ferm Antormation rather than data relating to long tern strrslity or erowth of the total system.

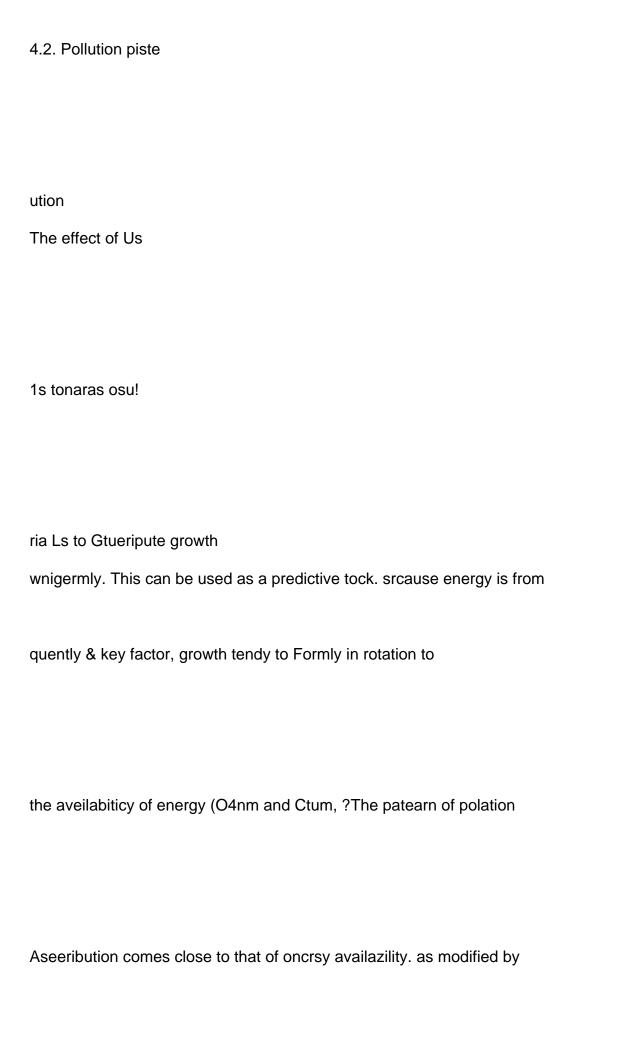
This points to the Limizutions of any comprononsively rational straregy: or plan. Facause the system structure is continually changing, either over the ehort of lang term in respons te fossing functions of long tem internal change, # cotelly conprchensive ungezstanding of research stra~ tegies Le not poessble. Jt se difrieule co evaluate merits of policies within systen, since che aysten structure le wedi fied when policies

aro in place. it shoulé 29 noted, houever, that often tundencier to sta
balize a fluctuating systom are one part of the controls that enhance
Yong term growth and output.
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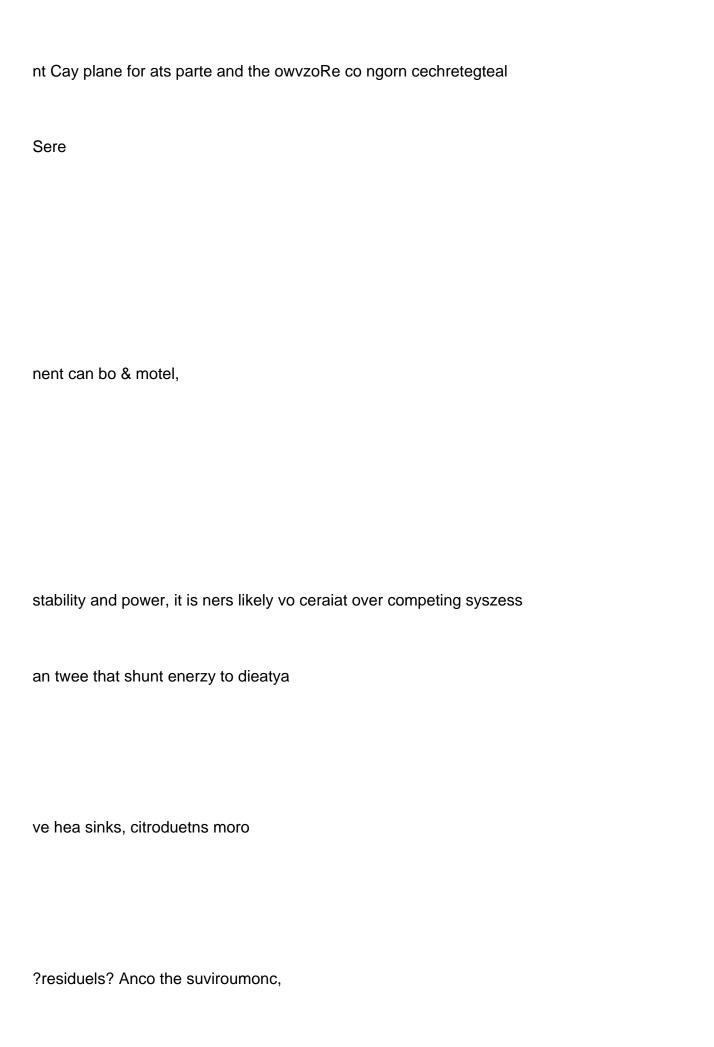


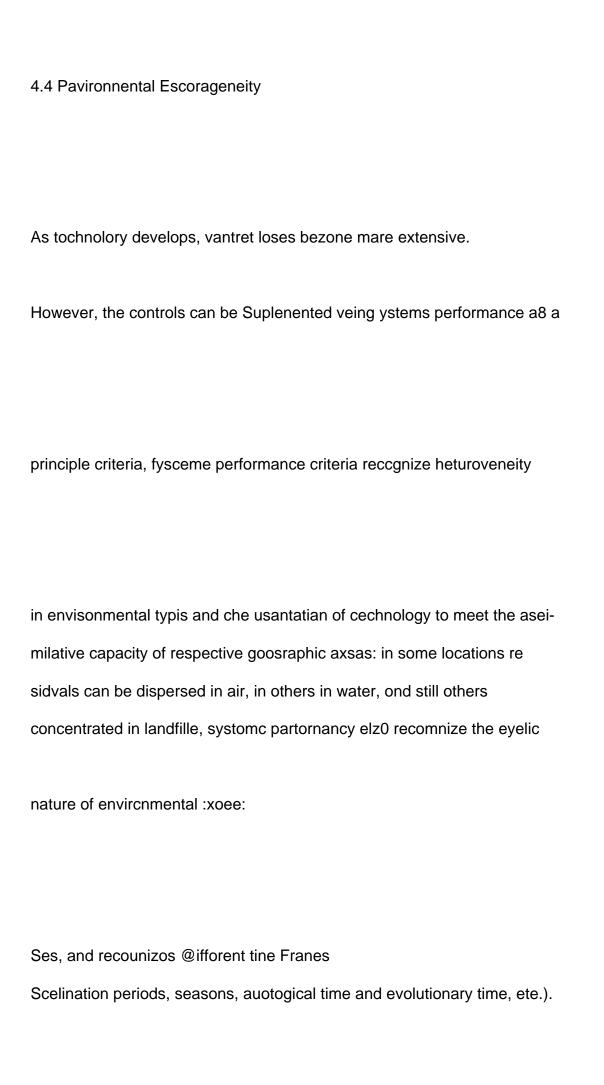
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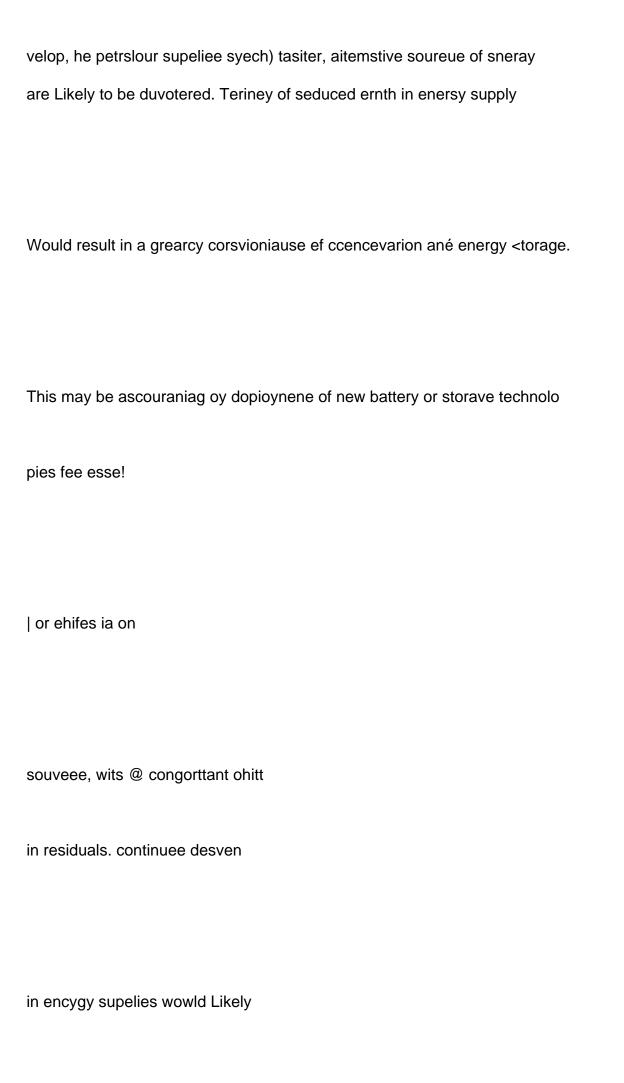
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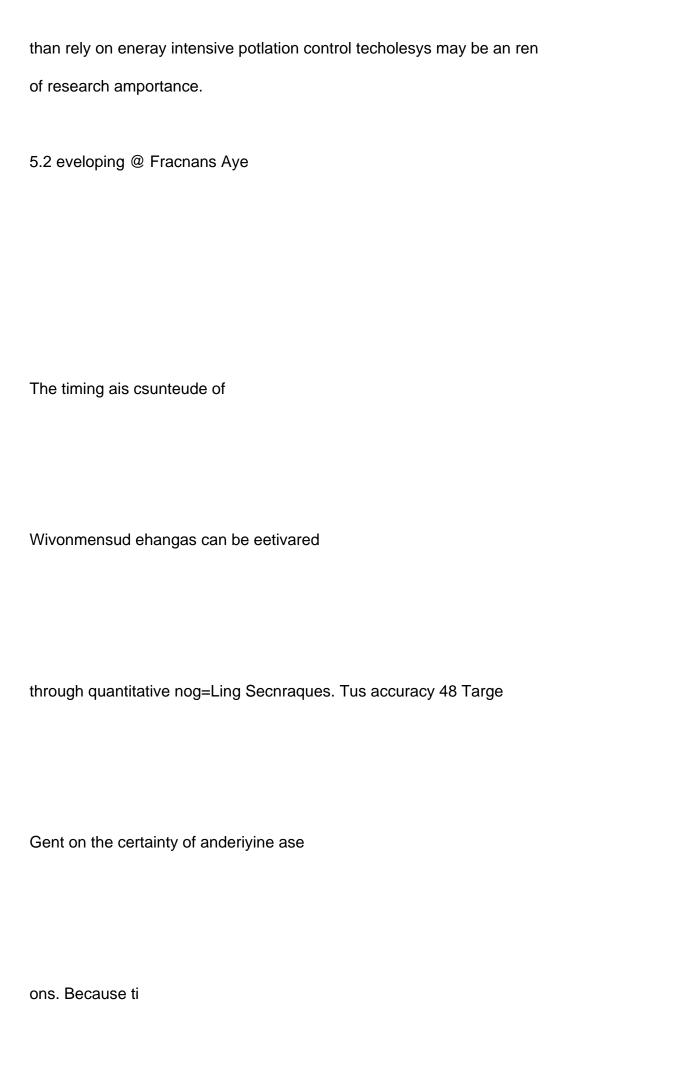


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5.0 Environvental kesvareh tians
5.1) Planning for Pactuzas of Chinas
Alternative forcing functions and the development of the Common
wealth social and envirvowntal eyetom can be used to predict shifts in
major economic sectors and sources of ?soniduale? (pollutants). Table 2
illustrates sone of these shifts. It Indies!

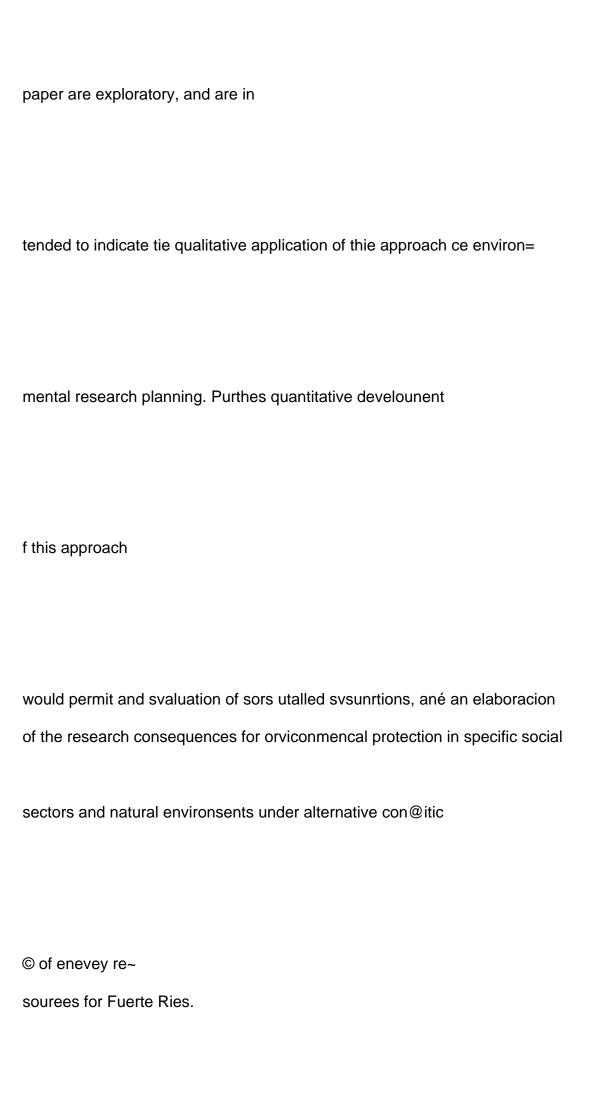
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associated vith the clectruries in action may 4e-







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