Incorporating Emergy Synthesis into Environmental Law

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I. Introduction

Virtually all areas of environmental law are concerned in some way with both the ecological and the economic impacts of environmental decision-making. Unfortunately, existing environmental law statutes tend to incorporate ecological and economic considerations in a simplistic, piece-meal, and awkward fashion. Moreover, these laws have not kept pace with significant developments in ecological and economic research. Emergy synthesis, which incorporates both ecological and economic considerations through a sophisticated scientific methodology holds the potential to not only inform the law, but also perhaps to revolutionize environmental decision-making.

Emergy synthesis, first developed by Dr. Howard T. Odum in the 1970's, and further expanded and refined by scholars such as Dr. Mark Brown over the past 30 years, relies on the "intrinsic" value of a resource or service. Rather than relying on consumer preferences, emergy synthesis might be called a "donor" value system as it is based on the principle that the energy embodied in a resource or service determines its value, In recent years, the emergy accounting approach has reached a high level of sophistication with increasing acceptance by the scientific community and scholars world-wide. However, to date, this approach has not been embraced (or even considered) by the legal community.

This interdisciplinary paper explores the viability of incorporating the methods of emergy accounting into environmental law and policy decision-making. Specifically, this paper examines the viability of Emergy synthesis in decision-making by analyzing the advantages it offers and the mechanics of how to make it work, using a number of existing statutory frameworks (including the cost/benefit standard of FIFRA and the pure science standard of the ESA) as illustrations. We demonstrate that emergy synthesis has the potential to revolutionize environmental law by providing a well-developed scientific methodology that addresses both ecological and economic considerations in a comprehensive manner. Although emergy accounting procedure has not been used by environmental regulators in the United States, it is interesting to note that the U.S. Environmental Protection Agency (EPA) offers a two-week emergy short course and that in 2005 EPA published a report entitled "Environmental Accounting Using Emergy: Evaluation of the State of West Virginia." Moreover, University of Florida researchers currently are using emergy synthesis as part of a United Nations Environment Programme project to restore West African drylands and improving rural livelihoods. Perhaps these actions indicate that emergy's time has come.

II. The Need for a New Approach

The majority of existing environmental law statutes were adopted during the 1970s and early 1980s in a piecemeal fashion in response to specific environmental crises and public demand to address specific environmental concerns, such as water pollution, air pollution or hazardous waste disposal. Consequently, the existing suite of environmental statutes is primarily media-based and is rife with inconsistencies, gaps, and overlaps. These laws incorporate a variety of different approaches to considering the economic impacts of environmental regulation or decision-making and do not address ecological concerns in any comprehensive science-based manner. Moreover, Congress has not adopted any significant amendments to any major environmental statutes in many years. The interpretations of ecological realities on which existing statutes are based are outdated and in need of serious reexamination. Although many existing environmental laws pay lip-service to ecological science, they do not incorporate scientific understanding of the ecological world in any meaningful way. Emergy synthesis is one of the best studied new developments in ecology, and is one that holds significant promise for transforming environmental law and policy.

In the past thirty-plus years of environmental regulation, perhaps no topic has dominated the scholarly debate as much as the proper role of economic considerations in environmental decision-making. Economic considerations arise in the form of cost/benefit balancing or feasibility analysis required by environmental statutes and economic analyses are often used to choose between competing project sites, pollution control technology, and environmental restoration approaches. More recently, economics have been used in the valuation of ecosystem services for ecosystem services payment programs.

Despite the widespread use of economics in environmental law, many legal scholars, practitioners, and policy-makers have been uncomfortable with such analysis due to its numerous shortcomings. One of the primary concerns is whether economic valuation of ecological resources and services --typically through contingent valuation (a determination of consumers' willingness to pay) -- can truly capture the intrinsic value of such resource or service. The academic community of scientists has been researching alternative methods of valuation for many years. Unfortunately, to date, most of these approaches have not been vetted in the legal discourse and have not been incorporated into environmental laws, regulations, or policy-making. Emergy synthesis holds the potential of providing a valuation methodology that relies on science rather than consumer preferences.

Proponents of emergy argue that money is not a good way to measure environmental contributions to the public good because money is paid only to people for their services, not to the ecological system generating the resources or providing a service. In addition, they maintain that price tends to be inversely related to the contribution natural resources can make to an economy due to the fact that resources contribute most to society when they are easily available, require few services for delivery, and are therefore inexpensive. Emergy, on the other hand, takes into consideration all contributions to the public good, regardless of human preference and is therefore a better measure of intrinsic value.

One controversial issue in the cost/benefit debate is whether environmental values are significant only to the extent that consumers are willing to pay to preserve them. Many ecological goods and services are not assigned any value by neo-classical economic analysis despite the fact that they are integral for making economically valuable products and may even be essential for life on earth, leading to criticisms of economics as "pricing everything and valuing nothing." The value of many ecological goods and services is not readily quantified, and thus is rarely included in any meaningful way in traditional cost/benefit analysis. Consequently, human disruptions to ecological systems are rarely part of cost/benefit analyses. The values inherent in ecological integrity or biodiversity are particularly ill-suited to be reduced to a dollar value under neo-classical economics. Although, many ecological products and services have instrumental value as food, medication, fiber, etc., that can be valued in a market system, many goods and services provided by nature do not have direct instrumental value and are not traded in a market system. Moreover, most consumers do not have the information available to them, or the technical understanding of the value that many ecological goods and services have in sustaining life. For example, many species serve important roles as producers, consumers, decomposers, competitors, dispersers, or pollinators. Each of these roles provides value to other members of the ecosystem, including humans. However, due to a lack of information and technical understanding, a typical consumer's willingness to pay for these services probably has no relation to the true value that the good or service provides.

In contrast, emergy synthesis rejects willingness to pay, which emergy proponents characterize as a receiver system of value, in favor of a donor system of value. As Dr. Mark Brown has stated "[a] donor system of value based on solar emergy required to produce things is . . . the only means of reversing the logic trap inherent in economic valuation, which suggests that value stems only from utilization by humans."

In sum, as currently implemented, both cost-benefit based regulatory standards and science-based regulatory standards have significant limitations. New scientific understandings and methodologies, such as emergy synthesis, hold the potential to improve decision-making by incorporating ecological, economic and social concerns into a comprehensive scientifically sound methodology.

III. The Emergy Alternative

A. Overview of Emergy Synthesis

In the words of the father of emergy synthesis, Dr. H.T. Odum, "[e]mergy, spelled with an 'm,' is a universal measure of real wealth of the work of nature and society made on a common basis." The starting point for understanding the concept of emergy is an understanding of energy. Energy is the ability to cause work to be done. Energy exists in many forms, including sunlight, wind, geopotential energy of elevated water, fossil fuels, and information. However, not all forms of energy are equivalent. While all of forms of energy can be converted to heat, one cannot say that calories of one form of energy are equivalent to calories of another form of energy in their ability to cause work to be done. Energy quality is influenced by a number of factors including concentration, flexibility, ease of transportation and convertibility. The notion of energy quality requires a conception of energy that recognizes that not all forms of energy have the same qualities and that provides a quantitative means of measuring such quality. Emergy is the means of assigning a quantitative value to energy quality. Emergy, sometimes referred to as "energy memory" is the energy of one type that is embodied in any form of energy, good or service. In other words, emergy is defined as the energy required directly and indirectly to make something. Emergy is expressed in energy of the same form, usually solar energy in units of solar emergy Joules or solar emJoules (seJ). Emergy can easily be converted to a money equivalent, expressed as emdollars (em$), by using a standard conversion factor based on the total emergy use in the United States divided by the Gross Domestic Product of the U.S.

The emergy accounting method is termed “Emergy Synthesis” instead of emergy analysis. Analysis results in the breaking apart of wholes into component parts to gain understanding, while synthesis is the act of combining elements into coherent wholes. Emergy synthesis is a “top-down” approach to quantitative policy decision-making and evaluation. Rather than dissect and break apart systems and build understanding from the pieces upward, emergy synthesis strives for understanding by grasping the wholeness of systems. Emergy is the amount of energy of one form used directly and indirectly to make something. Emergy is context driven. It is a systems concept, and cannot be fully understood outside a systems context and is a quantitative concept that is based on energy, but different from energy. The theory of emergy is grounded in the understanding that not all forms of energy are the same and that heat, as a measure of energy, is inadequate to describe the ability to do work, especially complex work. Emergy recognizes that there are quality differences to energies of different form.

In determining the value of ecological processes or goods, there are two different ways to view “value.” The view of value used in neo-classical economics, and therefore in traditional environment law and policy is the “receiver” view of value, that is, a utility theory of value. Emergy synthesis, on the other hand relies on “donor” value. Receiver value is value in the eye of the beholder, whereas donor value is derived from what goes into something. The fundamental flaw in neo-classical economics and traditional environmental law is that due to lack of information and problems inherent in contingent valuation, receiver value is not a good surrogate for the intrinsic value of a natural good or service. As other scientific scholars have pointed out, the most attractive characteristics of emergy synthesis are:

• It provides a bridge that connects economic and ecological systems. Since emergy can be quantified for any system, their economic and ecological aspects can be compared on an objective basis that is independent of their monetary perception.

• It compensates for the inability of money to value non-market inputs in an objective manner. Therefore, emergy synthesis provides an ecocentric valuation method.

• It is scientifically sound and shares the rigor of thermodynamic methods.

• Its common unit allows all resources to be compared on a fair basis. Emergy synthesis recognizes the different qualities of energy or abilities to do work. For example, emergy reflects the fact that electricity is energy of higher quality than solar insolation.

•Emergy synthesis provides a more holistic alternative to many existing methods for environmentally conscious decision making.

Nevertheless, emergy synthesis is not without its critics. However, a recent detailed evaluation of criticisms that have been leveled at emergy synthesis demonstrates that most of the criticisms are based on a lack of understanding on the part of the critics, insufficient communication of emergy theory outside of the scientific world of emergy scholars, lack of clear links with related concepts in other disciplines, and the types of general criticisms that are often directed at new groundbreaking ideas.

It is important to note that while emergy synthesis may share similar characteristics with ”ecological economics” approaches such as willingness to pay, contingent valuation, and replacement costs in the field there are important distinctions. Most significantly, most ecological economic approaches to evaluating environment continue to rely on human centered values, whereas emergy synthesis is based on the principle that value is derived from what goes into something rather than on what a human gets out of it.. Thus, emergy synthesis is a completely different approach, as opposed to common ecological economics approaches, which are more of a tinkering with the neo-classical economic paradigm.

B. Potential Uses of Emergy in Environmental Law & Policy

1. Valuing Environmental Services & Products

Emergy scholars have developed a number of indices to evaluate services and products. The "emergy yield ratio" is a measure of how much a process will contribute to the economy. "Environmental Loading Ratio" is a ratio of nonrenewable and imported emergy use to renewable emergy use. This ratio serves as an indicator of the "load" (or stress) on the environment that results from a production system. "Emergy Sustainability Index" is the ratio of emergy yield ratio to emergy loading ratio. This index measures the contribution of a resource or process to the economy per unit of environmental loading. "Emergy Investment Ratio" is the ratio of emergy fed back from outside a system to the indigenous emergy inputs (both renewable and non-renewable). It evaluates if a process as a good user of emergy that is invested in comparison with alternatives.

These indices could be employed as tools assess the economic value of ecological goods or services as part of ecosystem services payment programs. Moreover, these indices could be used to determine the harm to ecological resources for purposes of determining natural resources damages under the Comprehensive Environmental Response and Compensation Act (CERLCA), or for determining the quantity and quality of mitigation required to offset impacts to wetlands under section 404 of the Clean Water Act (CWA). To date, emergy synthesis has not been used in such decision-making. However, researchers have conducted numerous analyses that demonstrate the utility of such an approach. For example, researchers at the University of Florida have determined the cost of the environmental damage caused by the Exxon Valdez Oil spill. A similar approach has been used to determine the ability of phosphate mining reclamation to offset the environmental impacts resulting from the mining activity.

2. *Comparing Options in Environmental Decision-making*

Emergy synthesis can be used in a number of ways to evaluate alternative proposals. For example, emergy synthesis can be used to determine the ecological and economic fitness of a development proposal. It can also be used to compare particular alternatives to determine the best alternative. Moreover, emergy synthesis can be employed to determine the best use of resources to maximize economic viability.

Although environmental decision-makers have relied on emergy synthesis to choose between alternative proposals in only a limited number of cases, researchers have conducted such syntheses in a wide variety of case studies. For example, researchers at the University of Florida have evaluated water supply alternatives for Windhoek, Namibia. Emergy synthesis was conducted on three alternative sources of water supply: aquifer water; Kavango River water; and desalination. Each alternative was evaluated including a variety of factors: renewable resources, purchased inputs, and environmental and socioeconomic impacts. The emergy synthesis demonstrated that the use of aquifer water was the preferable alternative primarily due to the environmental and economic costs of desalination and the downstream environmental impacts to the Okavango Delta wetlands and wildlife should water from the Kavango River be diverted.

In another study, University of Florida researchers evaluated effluent treatment alternatives for wastewater discharged from an existing pup and paper mill in Florida. In this case, emergy synthesis was used to evaluate three options: constructing a pipeline to pipe wastewater from the mill to the Gulf of Mexico; piping water to the headwaters of an existing wetland for treatment by the existing wetland system; and constructing a new wetland strand between the mill and the Gulf, through which wastewater would be discharged. The analysis concluded the best option, from an emergy standpoint, was the treating wastewater in the constructed wetland strand.

A final example of the use of emergy synthesis to evaluate environmental options is an analysis conducted by H.T. Odum that evaluated alternatives for cooling water disposal from a nuclear power plant in Crystal River, Florida. In this case, two alternatives were evaluated: 1) the construction and operation of cooling towers and 2) discharging the hot waters to the adjacent estuarine ecosystem. The emergy synthesis took into consideration a number of factors including the ecological costs of impacts to zooplankton, juvenile fish, and reduction in ecological metabolism and compared these to the emergy costs of construction, maintenance and operation of the cooling towers. The analysis concluded that that a direct discharge of cooling water to the bay was the better alternative.

A significant benefit of using emergy synthesis over other alternative methodologies to compare alternative proposal is that emergy evaluation of environmental alternatives has been found to be much less expensive and time-consuming than other evaluation methodologies. As an example, Dr. Odum has cited the analysis done to evaluate restoration alternatives for the Cross Florida Barge Canal where $500,000 was spent on questions to find population's preferences and only $5000 would be necessary to prepare a more rigorous emergy evaluation.

The use of emergy synthesis to evaluate project alternatives not only can provide a useful tool to inform decision-making, but also could be incorporated into existing statutory schemes requiring consideration of alternatives. For example, emergy synthesis could provide a ready tool that could be consistently applied in the analysis of alternatives component of Environmental Impact Statements (EIS's) required under the National Environmental Policy Act (NEPA). Currently, the Council on Environmental Quality (CEQ) regulations implementing NEPA state that the weighing of the merits and drawbacks of alternatives does not have to be done via classical cost/benefit analysis, in particular where they are important qualitative considerations. Thus, it appears that emergy synthesis could be utilized in EIS alternatives analysis even under existing regulations. In fact, emergy synthesis can provide a means to consider the "qualitative' factors that the CEQ regulations recognize as an important component of alternatives analysis. Although to date emergy synthesis has not been used in the United States to conduct an alternatives analysis under NEPA, it is interesting to note that it is currently being used in some environmental assessments being conducted under a NEPA-like law applicable to countries in the European Union.

3. *A. Methodology for Existing Regulatory Standards*

A final way in which emergy synthesis could be incorporated into existing environmental law is as a methodology for decision-making under existing regulatory standards. Current environmental regulatory standards span the range from pure science or risk-based through a variety of feasibility or technology-based approaches to strict cost/benefit balancing. While the legal scholarly literature if rife with discussions of the advantages and disadvantages of existing approaches, there appears to be general agreement that for the most part, environmental decision-making must be based on science, with consideration of economic and social factors. Emergy synthesis could serve as a clear well-developed methodology employable under a number of regulatory standards.

At the cost-benefit end of the environmental regulatory standard spectrum, lies the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). Regulation of pesticides in the United States is conducted primarily under the authority of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). FIFRA requires that all pesticides sold or distributed in the United States be registered by EPA. Generally, a pesticide may be registered only if it will not cause an "unreasonable adverse effect on the environment." As defined by FIFRA, unreasonable adverse affects on the environment are any unreasonable risks to humans or the environment, taking into account the economic, social, and environmental costs and benefits of the use of any pesticide. Accordingly, when determining whether to register a pesticide, EPA must consider not only any risks the pesticide poses to humans or the environment, but also the economic and social implications of using the pesticide. Significantly, however, while Congress did direct EPA to take into account economic factors in defining unreasonable adverse effect on the environment, it did not explicitly mandate that EPA conduct a strict cost/benefit analysis. In fact, the legislative history of FIFRA suggests that adverse affects were not intended to be tolerated in absence of "overriding benefits" from the use of the pesticide. Nevertheless, for more than thirty years EPA's approach under FIFRA has been what is in essence a cost/benefit balancing to support pesticide registration.

Although Emergy Synthesis has not been employed to conduct the cost/benefit balancing required by statutes such as FIFRA, researchers have demonstrated how it can be used to analyze environmental harm from toxicity and other hazards. In analyzing the toxicity of a substance from an emergy perspective, a critical concept is the emergy intensity of a substance usually measured in solar emergy per gram of the substance. Studies have shown that as emergy intensities, increase, their potential effect on ecosystems increase. The effect may be either positive or negative, depending on the concentration of the toxin. When the emergy of a substance released to the environment is expressed in units of areal intensity, emergy density results (much like population density) The ultimate effect of a pollutant or toxic substances is not only related to its emergy intensity, but more importantly, to its concentration or emergy density. If the emergy density of a stressor is significantly higher than the average emergy density of the ecosystem it is released into, one can expect significant changes in the ecosystem. For example, emergy density of an average Florida lake ecosystem is approximately 1 E9 sej/m^2, whereas mercury at a lethal concentration in the lake has an emergy density of 3.7 E12 sej/m^2, or about three orders of magnitude greater than the ecosystem itself. Consequently, the release of mercury into a Florida ecosystem at these concentrations would be expected to result in significant environmental impacts. Accordingly, emergy synthesis could be used as a methodology to carry out the "unreasonable adverse effects on the environment" determination mandated by FIFRA.

At the other end of the regulatory spectrum lies certain aspects of the Endangered Species Act (ESA). As opposed to the cost/benefit balancing required by FIFRA, the ESA mandates certain decisions be made without the consideration of economic or social concerns. For example, section 4 of the ESA requires the Fish and Wildlife Service (or National Marine Fisheries Service in the case of marine species) to promulgate regulations determining whether a species is an endangered species or a threatened species, based on a list of enumerated factors. Subsection 4(b) directs the agency making such a determination to base its determination "solely on the basis of the best scientific and commercial data available." A strict reading of this provision suggests that the agency is not authorized to consider economic or social impacts as part of the listing determination. In contrast, in listing critical habitat, the agency is authorized to consider other factors, including economic impact. The significance of the science mandate in listing decisions is that only listed species are subject to the protections afforded by the section 7 consultation process and the section 9 prohibition on taking listed species. Accordingly, the listing of a species may result in significant economic impacts. Moreover, as part of the section 7 consultation process, Congress has mandated the use of the scientific data available in determining whether a federal action is likely to jeopardize the continued existence of a listed species. The strong scientific mandate of the ESA has led to considerable debate over whether, or how, to make such determinations in the absence of economic or social considerations.

Many legal scholars have argued that this "pure science" approach is fundamentally flawed in that it ignore considerations such as the value a particular species has to society or what level of risk of extinction society should tolerate. The seeming inability to consider such considerations had led to what one scholar has described as a "charade" in which agencies pretend to make what are in reality non-scientific decisions, on the basis of science alone. Leading to more confusion and debate, the ESA does not define or otherwise provide guidance on what is meant by the term "science," not to mention the phrase "best available science."

Because emergy synthesis is a scientific analytical approach that can be subjected to scientific scrutiny and that includes economic and social considerations, perhaps this scientific approach would provide a useful tool for ESA listing decisions. The major contribution of emergy synthesis to the process may be that while it takes into consideration economic and social factors, it does so not based on consumer preferences or social values, but instead based on a scientific evaluation of the embodied energy of the resources and services in questions. Dr. H.T. Odum recognized the importance of endangered species protection and described how emergy synthesis relates to endangered species when he stated that "[a]n important part of 'natural systems' is genetic information and biodiversity. Endangered species have a very high . . . emergy values, which are estimated from the environmental processes required for their replacement."

III. Conclusion

Current application of regulatory standards under existing environmental statutes is severely limited by outdated approaches to incorporating both ecological and economic considerations into environmental decision-making. Emergy synthesis is a comprehensive sophisticated scientific methodology that holds the potential to inform environmental decision making. By employing emergy synthesis, environmental decision makers can incorporate ecological, economic and social concerns into their decision-making without relying on subjective standards of consumer willingness to pay or other nonscientific indicators of receiver value. Because emergy synthesis is a science that values human and nonhuman inputs based on measurable quantity and quality of energy, it has the potential for use under a variety of regulatory standards including those requiring consideration of economic and social concerns a, as well as those mandating reliance on science alone. Moreover, emergy synthesis holds the potential as a significant methodological tool to be used in valuation of ecological goods and services in ecosystem payment programs, or in determining natural resource damages under CERLCA, ESA or as part of a common law remedy. Finally, emergy synthesis could be a useful methodology to employ in the evaluation of alternative proposals, such as that required under NEPA.

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