~ ABSTRACTS ~

12th Biennial Conference

Emergy & Environmental Accounting

Theories, Applications, and Methodologies

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1. Emergy Evaluations of Ecosystem Services in an Indonesian Coral Reef

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Abstract:

This Article includes the results of assessment from a coral reef impacted by a ship grounding in Raja Ampat, Indonesia in May 2017. The survey centred on 0°32'53"S 130°40'42"E showed the total impact area of 11,978 m^2 (the Study Area). The total area of live coral impacted is 2038 m^2 from coral mortality of 91.3 % (SeaGround Report 2022).

The Study Area lies at the north-eastern entrance to the Indonesian Flow Through (ITF) and has a high convergence of environmental energies from Sunlight, Rainfall, Tide and Currents Flows and Waves. The climate is tropical and experiences considerable seasonality in many of the physico-chemical flows mainly related to the annual movement of the Inter-tropical Convergence Zone (ITCZ).

The largest Exergy and Emergy inputs are: Tide/Current physical energy 5.723 E+10 J ha yr^{-1} (5.36 E+17 Sej ha^{-1} yr^{-1}); Organic material in water flow 8.25 E+11 J ha^{-1} yr^{-1} (2.08 E+17 Sej ha^{-1} yr^{-1}); Phosphate in water flow (8.7 E+6 J ha^{-1} yr^{-1} (6 E+16 Sej ha^{-1} yr^{-1}) and Waves 1 E+12 J ha^{-1} yr^{-1} (5.2 E+16 Sej ha^{-1} yr^{-1}).

In this Article, Em$ is used as a measure of value for the Ecosystem Services (ES) from the Study Area's main storages using the global Emergy to $ ratio of 1 E+12 Sej/$ for 2014 (Campbell and Tilly, 2014).

The reef landform value of Em$ 144,910 ha^{-1} yr^{-1} is based on the reef's consolidated structure with an accretion rate of about 0.8 mm yr^{-1} (McClanahan, 2007). The landform ES value reflects the combined ES values for Climate regulation, disturbance mitigation and erosion control in the Gov't of Indonesia's damage claim of US$ 231, 555 ($ 2007) based on published data in a database (Costanza *et al.*, 2014).

Fish Biomass Production ES value is Em$ 54,250 ha^{-1} yr^{-1}. It is based on the standing biomass of fish species estimated 1000 kg ha^{-1} based on observations on equatorial Indian Ocean reefs (McClanahan, 2007). The reef's Primary Production was valued at Em$ 49,666 ha^{-1} yr^{-1}. The Benthic Invertebrate Production ES value of Em$ 5,832 ha^{-1} yr^{-1} is based on an estimated standing crop of 130 g wwt m^{-2} and an annual turnover (Odum 1955).

An overview systems model is used to help reconcile the significant ES for Recreation and Cultural Heritage totalling $US 1.367 E+6 ha^{-1} yr^{-1} ($ 2007) claim by the Ministry of Environment and

Forestry (MoEF), Indonesia.

In this Article, Loss to Society ES values are based on the Study Area's 'Image'. The 'Image' is a storage on the right of the systems model and supported by emergy flows from in and outside of the Study Area. The Image information storage includes the reef's genetic biodiversity, landform and the locally shared cultural knowledge of the reef built up over considerable periods of time and on differing scales.

The shared cultural knowledge of the reef is demonstrated by the functioning 'Sasi', a knowledge-based reef management system considered to have been generated by the local Ma'ya communities over an estimated 500 years (McLeod *et al*., 2009). The Image valuation of Em$ 120,000 ha^{-1} yr^{-1} is based on an estimated 300 people on Kri Island (area ~250 ha) and each persons' average energy expenditure of 10% for cultural activities (Doherty 1990).

The results in this Article allows a comparison of methods to calculate ES values. The Emergy approach shows clearly the relationship between ES and ecosystem function and reduces the potential for double counting ES values by referring to data bases alone.

On the other hand, the 'Image' storage is subject to increasingly complex levels of reef management based on a framework of regulations and conservation efforts in Indonesia. This is driven increasingly by the globally shared values for these environmental support systems as information is shared via media channels outside of Indonesia. Over such a large territory, the 'Image' transformity would be greater so this result may be an underestimation.

The systems model approach was used to calculate estimates of the reef recovery without restoration (60-80 years) and with restoration (15-20 years).

Key Words: Ecosystem services valuations, coral reef restoration, Indonesia

2. An emergy approach for assessing the co-benefits of preserving farmland as a strategy for climate change adaptation

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Abstract

The term "co-benefits" was introduced in the IPCC's Third Assessment Report (AR3) to emphasize the positive spillover effects resulting from the implementation of climate change policies. For example, urban forests can contribute to climate change mitigation through carbon sequestration and improve air quality, benefiting the health of urban residents. In this study, we present a case study using an emergy approach to evaluate different land use alternatives on the Guandu Plain, the last remaining flat and large-scale open space in Taipei, to assess the co-benefits of preserving urban farmland for alleviating flood hazards. Expert workshops identified several co-benefits of preserving the Guandu Plain for flood management, including runoff regulation, recreational opportunities, economic benefits for local farmers, and environmental education. We developed several emergy indices to estimate the inflows of energy and materials, performance, costs, and environmental sustainability associated with different land use activities on the Guandu Plain. Results indicated that citizen farming yielded the highest return in co-benefits, and all proposed alternative land use practices provided greater co-benefits than traditional practices. This is the first study to employ emergy synthesis to assess the co-benefits of different land use alternatives for preserving farmland as a strategy for adapting to climate change. Our findings demonstrates that the analysis of the co-benefits provided by farmland to adapt to climate change is feasible with the use of emergy synthesis.

3. Emergy evaluation of multi-cropping: Afterthoughts and prospects

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Abstract

Agricultural land loss is occurring rapidly in fast growing urbanizing regions in Asia; the agricultural activities have also shifted to multi-cropping practices to cope with the changes in social and economic demands. More research is needed to assess the impact of different cropping practices on the role of regional agriculture systems. This study focuses on Changhua County, which is a highly intensive agricultural region in Taiwan. Due to Changhua County's proximity to the Taichung metropolitan area, agricultural land has been under significant development pressure from urban expansion and industrial development in recent years. We consolidated by integrating the study area's socioeconomic and environmental components into a socio-ecological system and formulated a hierarchical emergy synthesis framework to explore the changing role of the agricultural subsystem. The effect of different cropping practices, namely two-stage rice cultivation, rice-grain rotation, and multi-cropping, of agricultural land use in Changhua County on resource utilization and environmental sustainability were also analyzed. The results of analysis indicate that the role of the agricultural subsystem in the county's overall socioeconomic system has gradually diminished over time. However, the operational efficiency of the agricultural subsystem was not adversely affected by this reduced role, and instead exhibited signs of improvement. Among the three different cropping practices, multi-cropping received the highest emergy inflows from economic system and resulted in the highest emergy density, while rice-grain rotation had the lowest. Although higher economic investment of multi-cropping influenced environmental loading and sustainability, its impact was relatively minor in the context of the entire County. This study uncovers the transition of the agricultural subsystem in response to regional land use changes. For regions experiencing severe land use changes, particular attention should therefore be paid to the adaptation of the agricultural system within the overall regional socioeconomic system. After the preliminary emergy evaluation of different cropping practices in the study area, this paper also proposed some afterthoughts of the study. In the future, in-depth study will require more detail assessment on the difference of inputs needed for different cropping practices. What's the difference of the need of fertilizer between mono-cropping and multi-cropping? For example, planting green manure crops or rotating with grasses can increase nitrogen-based fertilizers, that can reduce the amount of fertilizer applied and mitigate pest and disease outbreaks. When cropping practices undergo transitions, the functional integration of the system also changes, and the ecosystem services of agricultural lands and their implications for resource efficiency and environmental sustainability should be assessed.

4. A new approach to emergy accounting on networks

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Abstract

The set of rules that govern the behaviour of emergy flows on networks is known as emergy algebra. Across the years, this algebra has not been uniformly applied. Indeed, different researchers have posed arguments for one or other emergy accounting scheme along the edges and nodes of the networks that constitute the emergy systems diagrams. These diverse views are mainly related to the treatment of feedbacks from splits. After shortly reviewing the literature on this theme and exposing the problem at hand, we introduce a new framework that helps to cast further light on the implications of the various accounting schemes. We draw on concepts such as time distinguishability of the sources, observation time and discretization of the emergy flows. Our framework leads us naturally to a new proposal for emergy accounting on networks. We show that our proposed scheme solves the difficulties that have been pointed out in the past related to the application of emergy analysis to processes that feature recycling. We establish connections to previous approaches and show that our proposal is intimately connected to the co-emergy method.

Keywords: Emergy, Emergy algebra, Emergy accounting, Feedback cycles, Recycling

5. Convergence of Valuation Paradigms? EcoCalculator Software to Determine Odum Transformities and Sraffa Prices in Coupled Economy and Environment Systems

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For some time it has been suggested that a bridge between economics and ecology lies between the work of Italian economist Piero Sraffa and American systems ecologists Odum. Judson (1989) argued the embodied energy theory of value (attributed to Odum) "… is very similar to neoRicardian economics…" (attributed to Sraffa). Both approaches measure prices/transformities from physical input output data, which contrasts to the mainstream economics approach of attributing value using subjective preference methods. Unashamedly both Odum and Sraffa are "objectivists" leaving no room for subjective methods of valuation. Further it can be shown that when it comes to calculating transformities by solving simultaneous equations that measure the flow of energy/mass in economic or ecological systems, the mathematical solution methods used by Sraffa and followers of Odum, are in many cases identical mathematical methods.

The EcoCalculator computes transformities and specific emergies from data that measure the flow of energy and mass in a specified economic or ecological system. Some data is preloaded, or the user can upload their own data. All of the solutions methods are based on matrix algebra, with the possible exception of the reflexive method which involves matrix algebra and a convergence method. The main matrix algebra methods are: eigenvalue- eigenvector (traditional method), matrix inversion, singular value decomposition which is a more flexible and assumption free method, and an overdetermined eigenvalue eigenvector method.

As it turns out, the key factors in determining the most appropriate solution method are:

(1) dimensions of the matrix – that is the number of rows (processes) and the number of columns (energy/mass quantities).

(2) whether we want to assume that the emergy efficiency is the same in all processes. One of the so-called 'rules' of emergy analysis assumes that all processes have emergy efficiencies equal to one. (Brown and Herendeeen, 1996). We would want to caution readers about making this assumption of equal emergy efficiencies, even though it is a key assumption of the so-called 'rules' of emergy accounting.

(3) whether we wish to avoid negative transformities/prices. When there is prevalent coproduction (joint production) solving the simultaneous equations often generates negative transformities/prices – the reflexive method has been specifically designed to avoid transformities/prices, which are prevented by invoking the Perron Frobenus theorem

The strength of the EcoCalcualtor is that it can determine transformitites/prices for a wide range of different data matrices – typically many of the traditional solution methods are only applicable to square matrices (number of quantities = number of processes), where as in the real world this very typically is not the case, and other methods for example also assume equal process efficiencies or equal profit rate which is unrealistic.

There is lively and ongoing debate about the convergence of ideas of Odum and Sraffa which still remains largely unresolved. There is no doubt that the mathematical solution methods are the same, but that does not mean that the same methodologies converge on theoretical and philosophical levels. This paper briefly compare the differences and commonalities between the two methods (Sraffa and Odum) as well as modern day attempts to draw a common thread between these schools of thought such as by Verger (2015).

The EcoCalcalutor is available free of charge at: https://ecocalculator.nz

6. Redefining notion of primary and alternative energy resources for rural areas using emergy perspective

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Abstract

The pursuit of alternative energy resources and sustainability has emerged as the most pressing concern of our time. The term alternate should be used based on the temporal and aerial availability of any resource. One energy resource may exhibit superiority over another in specific locations but not universally. India is one of the agriculturally oriented countries with a wealth of available biomass resources, and the potential of these resources, when considered, is truly promising. Emergy is a potent and complete instrument that analyzes sustainability by simultaneously addressing society, environment, and economics. It serves the objective of assessing sustainability effectively. Since biomass is a naturally occurring resource and the additional energy required for the transportation and storage of fossil fuels can be avoided, it can be utilized as the primary resource in local regions instead of fossil fuels. The emergy of bioenergy is lower than that of fossils. However, when the emergy of biomass is calculated holistically, including its generation, emissions, and mitigation technology, it is more sustainable than that of fossils. Bio-energy is regarded superior since it has a higher energy concentration per photon. The entire cycle of production, consumption, and mitigation renders fossils a carbon-positive process, while the utilization of localized resources as the principal energy source is genuinely a carbon-negative process. Furthermore, the utilization of indigenous resources can enable rural regions to achieve self-sufficiency and energy independence, offering a promising future for energy sustainability.
The utilization of fossils in remote regions has significant ecological and economic ramifications. The addition of transportation will lead to an increase in emergy, and mitigation measures will be introduced to limit the impacts, which will further contribute to the total emergy. Thus, the concept of emergy plays a crucial role in redefining alternative energy resources in the context of rural regions, underscoring the potential of biomass as a primary energy source. Additionally, the reduction of procurement waste allows for the efficient utilization of all input energies, which contributes to the development of a sustainable approach to energy production and utilization in rural areas.This study aims to redefine the concept of alternative energy resources as primary energy resources, considering various factors, using the emergy concept. This strategy lays the foundation for a more sustainable future in energy consumption by challenging the idea of alternative energy and presenting biomass as a practical and sustainable primary energy source.

Keywords: *Alternate energy resources, bioenergy, emergy, sustainability*

7. ESMAX – a model for designing landscapes to maximize empower through ecosystem services

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Abstract

Emergy theory, grounded in the Maximum Empower Principle, provides a framework for determining the sustainability of human-natural systems. However, there a pressing need to move from the analysis of to the design of sustainable systems. This work presents a method combining Geographic Information Systems (GIS) with emergy diagrams to integrate emergy theory into the spatial design of human-natural systems, such as agricultural and urban systems. The method involves two steps: first, the GIS-based model ESMAX quantifies and visualizes regulating ecosystem services (RegES) provided by different spatial configurations of natural and built components, such as trees and water bodies. Examples of RegES include local climate and air quality regulation, moderation of extreme events, and biodiversity support. As indicators of renewable emergy utilization, RegES represent high levels of work performed by self-organizing systems. Second, transformity values are used to convert these RegES into emergy values (solar-equivalent joules, sej), allowing for visual mapping of emergy flows and identification of high-performance multifunctional spatial arrangements of human-natural systems. A case study of a 6-hectare agricultural field in New Zealand demonstrated how different tree arrangements optimized RegES such as cooling, flood mitigation, and habitat provision. By enabling precise visualization and quantification of emergy flows in spatial design, this approach provides a more effective tool for land managers, designers, and policymakers to create sustainable agricultural and urban landscapes. This approach maximizes renewable resource use and could lead to enhanced resilience of urban and agricultural systems, advancing emergy theory beyond analysis to actionable spatial strategies for a ‘Good Anthropocene’.

8. Use of emergy instead of money in comparing future energy options

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Abstract

World is currently in transition to renewable energy sources in an attempt to decarbonize the energy sector. These sources cannot be used directly – they must be converted to suitable energy carriers such as electricity, hydrogen, hot water, synthetic fuels etc. The choice of a suitable energy carrier for a particular application must be made based on a multitude of criteria, such as efficiency, safety, environmental impact, convenience, availability of critical materials needed, but eventually they all come down to cost. However, estimating the cost of future energy carriers, their supply infrastructures and technologies for their use is not an easy task. Often, projections are made based on the past trends, learning curves, economies of scale, etc., but there is no scientific way to predict future prices of anything. Another method that is also used in comparing future energy options is net energy or energy return on energy investment. Net energy is calculated assigning energy intensity to all the inputs and outputs – energy, materials, goods and services, where published energy intensities are usually calculated by the input-output matrix analysis. The input-output analysis is somewhat similar to emergy analysis, however it does not take into account the inputs that come from the nature, and in some cases it double counts the embodied energy of the feedback loop of human services. Emergy analysis, therefore, may be a better way to evaluate and compare future energy options than usual cost or net energy analysis. This will be shown on an example of evaluating future proposed fuels produced from renewable energy for long-haul (oversees) maritime shipping, such as hydrogen, methanol, or ammonia.

9. Comparing the environmental sustainability of two gold production methods using integrated Emergy and Life Cycle Assessment

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Emergy analysis and combined emergy and Life Cycle Assessment (EM-LCA) were used to evaluate the sustainability of Colombia's open-pit and alluvial gold mine. The emergy is the work done to support the gold production separated into renewable and non-renewable energy and those associated directly with the mining and those due to imported resources. The EM-LCA is a new extension of emergy that incorporates the work done by the environment to assimilate airborne and waterborne pollutants. Emergy Sustainability Index values<1 indicate an unsustainable practice, those between 1 and 5 indicate a sustainable contribution in the medium term but not necessarily in the long term, and those>5 can be considered sustainable. The open-pit and alluvial mines were found to have Emergy Sustainability Index values of 0.02 and 0.04, respectively, using emergy accounting, and 0.002 and 0.035 using EM-LCA. The low values from the emergy analysis are mainly due to the large amount of imported resources required for gold production. The open-pit mine uses a more highly industrialized process and relies more on imported and less on renewable resources. Open-pit mining also generates more emissions, hence its comparatively low EM-LCA rating.

The results demonstrate the need to implement management policies that encourage a higher dependence on renewable resources and to reduce reliance on imported resources, as well as the need for technologies that lower emissions. It is also concluded that the novel EM-LCA approach can potentially extend emergy analysis to incorporate emissions. The study also highlights the limitations of emergy accounting for coherent assessment of mining projects.

10. Can high-tech revolution deliver a sustainable future? A case study to compare battery electric vehicles (BEVs) vs. internal combustion vehicles (ICEVs) using Emergy analysis (EMA)

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ABSTRACT

This study was initiated to explore why humans are so reliant on high-tech solutions in their pursuit of a modern lifestyle. Battery Electric Vehicles (BEVs) were introduced as a promising solution to address climate change. Using the Emergy Analysis method, we scientifically compared Internal Combustion Engine Vehicles (ICEVs) to Battery Electric Vehicles (BEVs). Our findings suggested that high-tech products like BEVs have a minimal impact on reducing the overall environmental footprint of cars. Furthermore, the inequalities and conflicting agendas in policy formulation became evident when evaluating the shift from ICEVs to BEVs. This study aims to promote reflexivity and raise awareness of well-being, fostering a move toward more sustainable living.

11. From Niche to Norm: Strategies for Mainstreaming Emergy Accounting.

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Abstract
Emergy Accounting has been around for several decades and several scholars from all over the world have carried out several studies on the subject but it has remained popular mainly within the academic space and very little is heard about emergy accounting in the mainstream. Considering the depth of emergy related studies that have been carried out, it is safe to say that it is about time for emergy accounting to become mainstream. But the question is how can emergy accounting become mainstream. What are the opportunities and challenges that are likely to be faced by promoters of emergy accounting as they seek to make it mainstream. How can emergy accounting become more appealing to the younger generation, businesses and government institutions. What opportunities do emerging technologies present to promoters of emergy accounting. These and many more issues will be addressed in the course of this presentation. The world needs emergy accounting now more than ever before and this presentation explores the future directions of emergy accounting as a tool for measuring sustainability.

12. Assessing the implementation of circular economy in the construction and demolition sector by means of emergy accounting indicators

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Abstract:

Since the first European Action Plan for the Circular Economy (2015) the adoption of the CE model has received a high attention due to its potential of improving the whole sustainability of particular sectors such as construction and demolition (Interreg Europe, 2024). The main CE principles (namely preventive design, reuse and recycling) aim to reduce the high resources' use of the conventional linear construction model. Over 32% of municipal waste is generated by construction activities worldwide (Ginga et al., 2020). In the EU, approximately 35% of total waste originates from construction (EU, 2018).

Public authorities are important stakeholders in stimulating the adoption of CE in the construction and demolition sector by means of the approval of legislative measures and policies but also implementing other tools such as Green public procurement. However, in spite of large efforts for circularity implementation and appropriate legislative measures, still policy making is slowed down by the lack of suitable methods capable to approach the construction and demolition sector in an integrated and comprehensive way. What is needed is the ability and competencies to evaluate materials, energy, environmental services, labor and soil use by means of appropriate space and time scales and comparable quantification units. The Emergy Approach offers such an opportunity, thanks to its broad look at resource generation and processing patterns. Widening the set of tools measuring circularity in construction industry would certainly be very useful for a more comprehensive understanding of the construction sector circularity (Zou et al., 2024), in order to support public decision making (De Pascale, 2021).

This study investigates innovative circularity indices and indicators by means of the Emergy Accounting approach and options for their application to a construction and demolition case study of the Metropolitan city of Naples. This administrative area is one of the most populated in European Union and Italy and represents an interesting case study for large space and time scales assessment (Brown, 2023), to provide new tools and ways for circular policy making at urban level.

13. Social needs and desires modeled research over History. What is required now?

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Abstract
Along time, human groups have reflected about their interactions with their surroundings and obtained agreements to reconfigure the form they interact with their environment and with their social organization. At each critical epoch it was possible to discover obstacles and possibilities for human evolution that allowed them to modify their systems for obtaining resources, preservation, consumption and recycling to allow a better interaction, to allow survival for extended periods. But it was not always the case, many groups choose to extract as much resources as possible in the shortest time, without any concern for the next generations future, avoiding decay or collapse. It was three centuries ago that fossil fuels were incorporated to the economy (at very low cost even their productive potential is very high); since then, technologies based in non-renewable resources have been developed and supported a huge growth of industry, agriculture and transport sectors. As result of these changes, the preserved areas and the biodiversity decreased, as well as the ecosystem´s functions. At the same time, the population moved from rural to urban areas and adopted new forms of living. Nowadays, the global system has entered into a complex and huge crisis, therefore it is time to reflect deeply on trends and risks and to analyze how the research and education system could be reformulated based on completely new objectives.

14. Human vs. humanity metabolism: diabetes, climate crisis, food and emergy

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Why is it so difficult to solve the problem of unsustainability? Why don't we take action against the climate crisis? We argue that the climate crisis (CC) for humanity has the same characteristics as diabetes (D) for humans:

1) Both CC and D mainly involve energy metabolism (of humanity and individual humans, respectively): fuels on the one hand and sugars on the other are the main triggers.

2) Both CC and D are systems "pathologies", there is no local cause-effect relationship, the entire system is affected. CO_2 in the atmosphere is a global pollutant: we can emit nothing and receive the effects of CC; D is a global pathology: the organ interested by hyperglycemia might have no direct "fault" (e.g. eyes have problems not because there are eyes problems per se).

3) The business as usual situation is exactly what triggers both D and CC. It is a behavior repeated over time that leads to the disastrous effect.

4) Patients with D have traditionally been difficult to treat since their perception of the illness is poor. There are no physical signs of the pathology. Patients do not like to change their habits, regardless of the fact that this could lead to a more favorable condition. Often awareness only arise when the negative effects have already occurred. Humanity is reluctant to agree to act because many would have to change their habits, regardless the fact that this could lead to a more favorable condition.

The parallel may continue: CO2 in the atmosphere plays the role of glycemia; fuels of sugar, trees of insulin. But while diabetes is sometimes due to genetic factors and therefore very difficult to avoid, the climate crises is triggered by humanity's diseased metabolism. Emergy (and especially the non-renewable part of it) is the potential indicator of humanity metabolism with which we can develop a "diet" for humanity and measure its effects.

15. An emergy informed spatial decision support system for sustainable planning

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Abstract

A Spatial Decision Support System (SDSS) is a specialized type of decision support system designed to assist in solving problems that have a spatial or geographical component. It combines geographic information system (GIS) tools, analytical models, and data management capabilities to analyze spatial data and help users make informed decisions about territory management and development.

Emergy analysis may play a crucial role in the development of SDSS focused on sustainable development and increase the response capabilities of the system. In this research emergy analysis on a very small spatial scale is used to inform a SDSS referred to a coastal area of Liguria region (NW-Italy) and to investigate paths of development toward a better sustainability considering the specificity of the territory and its wide range of characteristics. Moreover, the SDSS provides interactive maps, visualizations, and scenario analysis to aid in understanding the spatial implications of various decisions and help decision makers to develop better and more accurate strategies of development.

16. Building Resilience: The Role of Emergy Analysis in Developing Tools for Sustainable Food Systems in Brazil

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Abstract

In 2022, approximately 125 million people (58.7% of the Brazilian population) lived with some degree of food insecurity, highlighting critical public health and social issues. Within this group, over 61 million (28.6%) faced moderate to severe food insecurity, with around 33 million (15.4%) suffering from severe food insecurity alone. This alarming situation led to Brazil being re-added to the United Nations' Hunger Map, marking a significant setback compared to 2014, when Brazil had been removed following substantial progress in reducing hunger. Interestingly, Brazil's agroindustry plays a crucial role in its economy, with total agricultural production reaching approximately 319.86 million tons in 2022, including 154.6 million tons of soybeans and 131.9 million tons of corn. The country exports a substantial portion of its agricultural products, underscoring its important role in the global agricultural landscape. On the other hand, subsistence farming remains vital for local food security, particularly among family-run establishments that contribute significantly to the production of staple foods. However, quantifying subsistence farming is challenging because it is intertwined with the broader context of smallholder contributions to the national food supply, which complicates assessments of improvements in food production efficiency. Food losses and waste (FLW) occur at various stages of the life cycle, with approximately 42% of the country's food supply lost or wasted annually—around 26.3 million tons. The distribution and consumption phases account for the highest losses, with estimates ranging from 10% to 30% of total meals produced being wasted. Notably, fruits and vegetables represent about 50% of discarded food. Therefore, despite Brazil's agricultural prowess, there is a significant disparity between production capabilities and access to food. Strengthening family farming and integrating sustainable practices to reduce and combat FLW are essential for addressing both food security and environmental challenges in Brazil's diverse agricultural landscape. In this context, Emergy Analysis (EMA) can support the fight against FLW by bringing into the sustainable assessment of initiatives both direct and indirect energy inputs, offering a holistic understanding of resource use and environmental impact, and

enabling more informed decision-making and policy development. The Bridges Project is structured to connect various actors and initiatives to accelerate the transition toward more sustainable food systems within circular cities context. Supported by a transdisciplinary team and engaging diverse stakeholders (i.e., citizens, communities, universities, research organizations, startups, industry, public administration, foundations, NGOs), the Bridges Project consists of four phases, with EMA serving as one of the key methodologies for evaluating the sustainability of FLW initiatives:

1. **Knowledge Organization:** This phase involves bringing together existing organizations (e.g., researchers, enterprises, startups, social and public organizations) with knowledge about FLW to identify the current scenario and root causes. It also aims to map FLW flows, and previous initiatives focused on preventing FLW and promoting food equity;
2. **Performance Indicators Analysis**: This phase evaluates social, environmental, and economic perspectives to create an integrated evaluation tool designed to assess the sustainability of both current identified actions and future initiatives;
3. **Case Studies Application**: In this phase the evaluation tool is tested and validated through various real case studies;
4. **Pilot Implementation**: During this phase, a "Zero FLW City" will be implemented in Pirassununga (SP/ Brazil), a hub of innovation and sustainability that hosts one of the best universities in the country, enabling valuable feedback into this virtuous ecosystem.

Acknowledgements: Special thanks to the All4Food Network[1] for cultivating an inspiring environment and forging connections that advance our agenda.

[1] http://all4food.com.br

17. Long-term changes in fishery sustainability in a Management Exploited Area for Benthic Resources (MEABRs) of a population of the surf clams *Mesodemsa donacium* located in central Chile: An emergy approach

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The surf clam, *Mesodesma donacium*, is a filter-feeding species distributed from Sechura, Peru to south of Chiloé Island in Chile. This species is located on the intertidal and shallow subtidal zones in sandy substrates exposed to strong waves. In Chile, this species is commonly known as “macha” and it is one of the most important benthic fisheries for the artisanal fishing sector. Their extraction is mainly carried out in the Management Exploited Areas for Benthic Resources (MEABRs). In the Maule Region, there are 20 decreed MEABRs, of which only two include the “macha” resource, which is one of the main benthic resource stocks at the national level. The objective of this study is to evaluate long-term changes in the sustainability of this fishery, based on Emergy indices of the “macha” population in the Putú MEABR. For this purpose, annual time series were analyzed for renewable energy sources (necessary for the production and sustenance of “macha” populations in the intertidal zone), biomass (the natural capital), management work (the professionals needed to review technical reports and the cost of technical reports delivered by fishermen’s organizations) and fishing effort (the fishermen's work), from 2000 to 2022. Landing/effort ratio (analogous to the net emergy yield ratio), the Emergy Investment Ratio (EIR) and Used Emergy (Y) were employed. The results show that the trend of the ratio, Landings/fishing effort, and yield (Y) reached a maximum in 2007, and subsequently decreased strongly exhibiting a fluctuating behavior over the last 10 years, in contrast EIR showed a decreasing trend reaching a minimum for the same year 2007, then increasing sharply in the following two years and finally decreasing in the last years. The findings suggest a transition in “macha” management from a sustainable period (2000-2007) to one of decreased sustainability (2008-2022). This indicates a need to reassess management feedback mechanisms, including technical report methodologies, additional studies, and quota allocations. Additionally, natural factors affecting sandy beach dynamics, such as sand impoundment and disembarkation, have not been adequately addressed in technical reports focused solely on biomass. Ultimately, a systemic evaluation approach is essential for understanding the trends and interrelationships within the MEABRs regime, taking into account various dimensions influencing the sustainability of the resource.

18. Simulating community sentiment for large-scale data center development using generative AI personas

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University of Maryland

Data centers are rapidly expanding worldwide to meet demands in sectors like gaming, cryptocurrency, AI, and entertainment. These facilities consume vast energy and natural resources, impacting local communities. Our study uses generative AI to model community sentiment toward data center development by creating fourteen demographically diverse AI avatars. These avatars, designed to convey emotion and strong opinions, represent various residents' views on topics such as energy and water usage, traffic, resource conservation, and local economics. The avatars' feedback highlighted data centers as "master variables" with significant effects on natural systems and community life. Coupling this sentiment analysis with emergy analysis may provide valuable insights into community responses to large-scale developments and reveal emergy-based principles about human-environment relationships. Data centers are rapidly expanding worldwide to meet demands in sectors like gaming, cryptocurrency, AI, and entertainment. These facilities consume vast energy and natural resources, impacting local communities. Our study uses generative AI to model community sentiment toward data center development by creating fourteen demographically diverse AI avatars. These avatars, designed to convey emotion and strong opinions, represent various residents' views on topics such as energy and water usage, traffic, resource conservation, and local economics. The avatars' feedback highlighted data centers as "master variables" with significant effects on natural systems and community life. Coupling this sentiment analysis with emergy analysis may provide valuable insights into community responses to large-scale developments and reveal emergy-based principles about human-environment relationships.

19. AI-Driven Strategies to Predict Wildfire Suppression Difficulty and Mitigate Mega-Fire Spread

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Climate change is leading to more frequent and intense wildfires, which release significant greenhouse gases (GHGs). Mega-fires emit roughly 70 tons of GHGs per hectare on average. The 2022 Uljin wildfire in South Korea burned 16,000 hectares, releasing an estimated 1.5 million tons of carbon, or about 93.75 tons per hectare. With forests covering 63% of South Korea, rapid and effective initial response strategies are essential to minimize wildfire damage and reduce emissions. This study combines AI models with the Analytic Hierarchy Process (AHP) to assess suppression difficulty, enhance initial response, contain large-scale wildfires, and reduce emissions. The AHP framework estimates the weights of factors influencing suppression and classifies into natural, social, topographic, strategic, and forest-type elements through pairwise comparisons. Study findings indicate that carbon emissions can be varied by fire types: broadleaf ground fires release around 15.86 tons/ha, pine ground fires 14.83 tons/ha, and pine crown fires 22.71 tons/ha. A timely initial response of wildfire is critical to prevent small fires from escalating and to limit various emissions. This research advances the effectiveness of AI-driven suppression models as tools for early intervention and response, managing mega-fire spread, and reducing emissions. Efficient fire-fighting resource allocation emerges as a practical strategy for enhancing climate resilience in high-risk areas.

Keywords: Wildfires; Greenhouse gas; Wildfire Suppression; AI; AHP

Acknowledgement : This research was supported by the Forest Science and Technology Research and Development Program (Project No. RS-2024-00402509) through the Korea Forestry Promotion Institute (KOFPI), funded by the Korea Forest Service (KFS).

20. Emergy Insights for Sustainable Strategies on Tourism-Driven Islands

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Geographic isolation drives islands to depend on external inputs and consume internal resources to stimulate economic growth. Tourism-centric islands like Jeju(South Korea), Hainan(China), and Hawaii(the United States) require the assessments of total resource consumption covering both residents and visitors. Emergy analysis quantifies and compares the environmental capacities of diverse energy forms by converting resources—energy, materials, information—into a unified solar energy reference point. This ecological method evaluates environmental impact and sustainability potential within energy use. The study aims to estimate the environmental carrying capacity of Jeju, Hainan, and Hawaii and compare resource consumption patterns through emergy analysis. The study outcomes provides emergy- based evaluation of environmental carrying capacity, insights into island-specific resource use, and strategies for sustainable tourism.

Keywords: Emergy analysis, Tourism-driven islands, Environmental carrying capacity, Resource consumption

21. Environmental impact assessment of iron production in Pakistan using emergy analysis

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Abstract

Iron is one of the main elements that support the growth of industrial construction projects of Pakistan in construction and manufacturing sessions. But it is surprising how much the environmental impact of iron extraction and processing remains hidden. To fill this gap, this study uses emergy-based environmental accounting method to estimate resource consumption and environmental impact of iron production in Pakistan. Through evaluating both direct extraction of iron from its ore and the recycling of it, we determine the sustainability of the sector. However, the results of the study prove that today's flow of iron production in Pakistan is highly rationalized, and has severe drawbacks of resource waste and environmental harm, which is not compensated by the difference in prices from market prices. Of particular importance, the environmental load from recycling is considerably lighter than that of the primary production, which might point to the fact that more attention should be paid to recycling. Based on the outcome of the study, different policy actions have been recommended such as; enhancing circular economy strategies to encourage recycling practices in the country thus reduce the rate at which it imports scrap iron, more investment in recycling infrastructure as well as seeking to internalize ecological cost to reflect on the pricing of iron in Pakistan.

22. Environmental and sustainability assessment of China's transportation sector: The impact of Li-ion batteries on the transition to electric mobility

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Abstract

Li-ion batteries are crucial to advance electric mobility and achieve carbon-neutral goals for social development. Their use coupled to renewable energy may play a huge role in accelerating the transition to electrification and cleaner global transport sectors, in China and worldwide. This study investigates the Li-ion battery industry chain based on the integrated Life Cycle Assessment (LCA) and Emergy Accounting (EMA) approaches, with special focus on their use in the transportation sector. It evaluates the sustainability of China's transportation sector by simulating different scenarios of Li-ion batteries application within an Ecological Accounting framework. Results show that: (1) Terrestrial ecotoxicity (TEY) is the most significant impact for Li-ion battery industry chain, especially for the upstream cathode. (2) The ELR performance of upstream cathode and battery separator are higher, and the ESI of anode is more higher. (3) If all Chinese vehicles are replaced by electric vehicles, the emergy consumed would be reduced by nearly half. The present research aims at promoting renewable energy use and technologies in the mobility system, within a circular economy design and implementation framework, to overcome the conventional dependence on fossil fuels use in combustion engine vehicles.

Keywords: Li-ion battery; Industry chain; Transportation sector; Emergy accounting; Environmental assessment

23. The updated Emergy database: solution based on Decentralized Autonomous Organizations

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Emergy analysis is a valuable approach for assessing economic and environmental sustainability. To enhance the utility of Emergy outcomes in informing policy improvements, ensuring the precision of each Emergy variant is crucial. Typically, the fundamental variants required for Emergy calculations are derived from the Emergy Database. However, this database is infrequently updated due to the extensive and intricate nature of data collection and other associated challenges. In this study, we introduce a digital solution known as Decentralized Autonomous Organizations (DAO) to address the issue of outdated Emergy databases. We have developed a framework for updating Emergy databases utilizing DAO technology and elucidate the theoretical underpinnings that support the adoption of DAO in this domain. The study also presents an analysis of the benefits and potential concerns associated with implementing such a framework.

24. Agroecological land restoration in the light of Odum’s legacy

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Abstract

At the time of the development of H. T. Odum’s theory, the field of Agroecology was not yet defined as a scientific discipline. Nevertheless, Odum proposed minimodels that describe land restoration processes based on what we now may call agroecological practices. In this work, we review literature from ‘60s -‘70s to nowadays by tracing a red thread to connect Odum’s original ideas with the current understanding of Agroecology and agroecological restoration. In the light of this picture, we review some applications of energy system modeling to describe agricultural land restoration processes. We revisit and apply this scheme to reproduce the dynamics of a real restoration process carried out by a farmers’ family in Mato Grosso do Sul, Brazil. The case study of Sitio Luciana shows the transformation of a degraded land area into a food-producing area by means of nature- based solutions, namely agroforestry systems, human work and local ecological knowledge.

25. Some attempts to advance emergy research

Dennis Glenn Collins

This talk covers some work by Dennis Collins to advance emergy research, mainly through the application of the Author's symmetry studies and conflict charts. I only wish H.T. Odum were still here to discuss these topics, although other researchers in these proceedings, such as Tom Abel and Corrado Giannantoni, have also contributed greatly.

1) periodic table extended transformity (Campbell, Brown, Troncale, and Libb Thims);

2) consciousness template transformity (NYAS contributors) and Collins work on binary octahedral group as subway system template;

3) dream esp transflormity (Collins 1971 copyright "Psychic (or Prophetic) Warp Energy, for example Steinhardt book The second Kind of Impossible;

4) drama triangle pulsing (quantum monotheism, based on God as superposition of states).

26. Comparative Embodied Energy (Emergy) and Life Cycle Assessments of the UMD Solar Decathlon Entries reACT and LEAFhouse

Olivia Patsy[1], Jillian Wimbush[1] and Dr. Peter May[1]

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In both 2007 with LEAFhouse and 2017 with reACT design entries, University of Maryland was ranked as the second-place global winner of the US Department of Energy (DOE) Solar Decathlon competition. As a continuation of a Life Cycle Assessment (LCA) project on reACT, an embodied energy (emergy) and life cycle assessment of both LEAFhouse and reACT were conducted to compare the environmental impacts of energy and material inputs. To determine the emergy of student design and construction of the houses, several interviews and an embodied energy analysis were conducted. By categorizing the houses into five major comparative categories, the environmental impacts of LEAFhouse were directly compared to reACT using openLCA and SimaPRO LCA programs, as well as using Excel for emergy analysis. Prior to the LCA, LEAFhouse was assumed to have greater environmental impact values, due to the usage of more sustainable materials in reACT after a decade of building material upgrades. Additionally, the reliability of openLCA as a free open sourced LCA software was tested against the reliability of SimaPro, a purchasable LCA software. Based on the results from openLCA, LEAFhouse has a greater overall environmental impact when compared to reACT, while SimaPro provided a more reliable environmental impacts assessment of the reACT house materials.

27. Natural Capital Accounting: Developing a Natural Capital Spatial Inventory for Gulf Coast Restoration Projects

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Abstract

Natural capital stocks are the durable physical or biological elements of nature that persist through time to contribute to current or future economic production. In October of 2022 the White House Office of Science and Technology introduced a national strategy to develop statistics for environmental decision making and proposed creating a system of natural capital accounting and associated environmental-economic statistics. While restoration ecologists have used multiple measures for determining the success of restoration projects, it is important that the measures used represent an accurate accounting of environmental capital stocks and flows produced by nature based restoration projects, and provide meaningful accounts of natural capital stocks and flows. We have demonstrated natural capital increases for several nature-based environmental restoration projects in Alabama and Florida using natural capital accounting techniques. For example, for a living shoreline project in South Mobile County, Alabama we have demonstrated a 4:1 increase in habitat benefits, in terms of marsh and food chain production, and 3:1 BCR on a dollar:dollar basis. This accounting considers the value of the ecosystem productivity (primary, secondary and tertiary producers) of aquatic habitats as well as an estimate of the annual services the adjacent marsh habitats generate (ecosystem services or flows). For evaluation of future coastal restoration projects, we are compiling these data using GIS to provide a catalog of local baseline natural capital assets, expressed both in organic production (g/m^2-dry weight) as well as in empower density (sej/ m^2/yr) for various habitats. This can be used to estimate the uplift provided by restoration efforts and determine the natural capital benefit:cost ratio for local restoration projects, expressed in multiple metrics (biomass or emergy) to maximize utility in different applications.

28. Updating of NEAD Database

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Abstract:
One of the major obstacles for sustainability evaluations is data availability and accuracy. There lacks a thorough execution of data quality check of national-level statistics, leading to constraints for sustainability assessments. 68% of environmental data for Sustainable Development Goals (SDGs) is missing in 2020, and 33% of data are available for 104 gender SDGs data in OECD countries. Due to the complexity and persistency of gaps in sustainability-related data, methods such as linear interpolation, machine learning and manual adjustments have been deployed. As a key part of emergy data source on a global scale, utilizing such mending techniques could enhance the stability for trade data, especially in developing countries. In this study, we synthesized and calibrated the full global emergy flow data within the 2001-2020 timeframe for 174 countries based on National Environmental Accounting Database. Thereafter several selected emergy indicators (U Total Emergy Use, EMR Emergy-money Ratio, EmSI Emergy Sustainability Index) were extensively analyzed in a spatiotemporal manner. Finally, the dynamics between emergy indicators and socio-economic metrics (urbanization rate, gross domestic products, greenhouse gas emissions) are explored.

29. UEV Library - Characterize environmental support in emergy accounting and Life Cycle Assessment

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Abstract:

In the field of environmental sustainability assessment, there are different integrated metrics used to quantify the total resource use and environmental impacts. In a resource-constrained world, it is essential to quantify the environmental support that these resources provide, that includes the work provided by Nature. An environmental accounting method that provides a means of estimating resource value based on the geobiophysical work required to make and sustain those resources is the Emergy Accounting approach. Emergy is defined as the available energy (exergy) of one kind used up to make and sustain a resource directly and indirectly. Emergy values can be provided to estimate the value of renewable and nonrenewable resources in a common energy unit (solar emjoule, sej). Based on the consensus global emergy baseline 1.2 E25 seJ/y, the unit emergy value (UEV) library was developed for quantification of the environmental support associated with elementary resource use in emergy accounting and life cycle assessment studies. The library provides emergy characterization factors (EmCFs) for different types of renewable energy sources, minerals and metals, land occupation, water flows and storages, biomass, soils, and fossil fuels. Only elementary resources are included, while refined commodities and manufactured goods and their EmCFs can be calculated based on the elementary ones and a sufficient knowledge of each production process. The UEV library is released to the public and will provide a consensus set of emergy values for emergy accounting, LCA and various other analyses.

30. Emergy and the rules of emergy accounting applied to calculate transformities for some of the primary, secondary, and tertiary exergy flows of the Geobiosphere

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Abstract

Emergy is a concept that is important for understanding problems in accounting for the health and integrity of ecological and social systems. Success in the evolutionary competition among systems depends on maximizing the emergy captured by a system that is then fed back to bring in more exergy. For this reason, "emergy" in the form of maximum empower (i.e., maximum emergy flow measured in solar emjoules or sej/unit time) provides a unified, thermodynamically controlled decision criterion by which the behavior of all systems is constrained. The fact that maximum empower and not maximum profit is nature's decision criterion makes it critical that more people become familiar with emergy evaluations and how to use the results of these analyses in decision-making. A new approach to emergy evaluation is proposed that focuses on developing more accurate assessments of the spatial and temporal emergy accounting required for the creation of products and services. These emergy evaluations include the accumulated past action of exergy in creating key system components such as vegetation biomass and the accumulated knowledge of workers in the economy, which will result in emergy assessments that better reflect the capacity of the products and services to do work in their systems. An analysis of the Geobiosphere is presented as a "white box" model of the secondary and tertiary flows of wind and water in the global system. The key factors identified are the separation of wind into two components: a factor controlling vertical diffusion with transformity of ≈715 sej J^{-1} and a second transformity governing surface friction of ≈1,215 sej J^{-1}. Also, water systems are fully defined with transformities of 302,900 sej J^{-1} to 1,440,000 sej J^{-1} for geostrophic flows. Past emergy analyses show that managers should develop policies that will maximize the empower flowing through their systems. The problem of maximizing the empower captured occurs within the context of a set of forcing functions impinging on a system from the next larger system, and since these forcing functions are always changing, maximum power should not be thought of as a fixed endpoint but rather as a constant state of seeking this goal.

31. Intelligence of Buildings: The power of responsive envelopes

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Abstract

Building on the work of Ulanowicz (Hirata 1984, Ulanowicz 1997), Hwang Yi applied information measures to buildings using the emergy flow between nodes to account for resource flows and investments in structure and infrastructures. (Yi 2016, Yi et al 2017). Expanding on that work, we have applied the measures of AMI, entropy (H), and Fitness (F) to the thermal regulation of buildings, specifically to evaluate the effect of responsive elements such as ventilation shutters and window shading.

As a case study, we selected the Esherick House, a much studied building by the architect Lou Kahn, built in Philadelphia, PA in 1961. Fig. 1. It exhibits many of the features of the first generation of solar buildings from the 1940s and early 1950s and is characterized by large south facing windows and operable shutters for rapidly ventilating the building. Though the building-as-built is neither efficient or comfortable, our studies have shown that with improvements to its envelope and climate responsive operation of the ventilation shutters and window shading, the building could be kept comfortable up to 80% of the time. The conventional measure of building performance is the use of purchased, high-quality energy, but we sought to a more general way to evaluate the effect of bioclimatic design, in particular the responsive regulation of the envelope.

We focused on three measures, Average Mutual Information (AMI), Entropy (H), and Fitness (F). In Ulanowicz's approach, self-organizing systems seek a trade-off between the gross consumption of resources and the complexity of the network. He developed a number of ways to capture that quality and the one that translates most directly to buildings is Fitness, which is a normalized factor of the effective accumulation of useful energy. We used Energy Plus to simulate the energy flows through a typical year in a variety of scenarios, converting them to emergy values, and then calculating AMI, H, and Fitness for each hour. Figure 2 shows a comparison between the original, uninsulated building with a gas furnace and conventional AC, with an average fitness of about 0.3, which ranges up to 0.5 in the swing seasons when the climate is comfortable, but down to 0.1 during the summer. In contrast, the improved version with adaptive ventilation and shading, is comfortably 75% of the time and has a consistent fitness of about 0.5. Figure 3 shows the same comparison, but with adaptive management of shading and ventilation in the original building, which regularly brings the fitness up to 0.5, but with much lower fitness through the winter when shading and ventilation provide not advantage.

The measurement of system organization and complexity provides a valuable new tool for understanding the bioclimatic behavior of buildings.

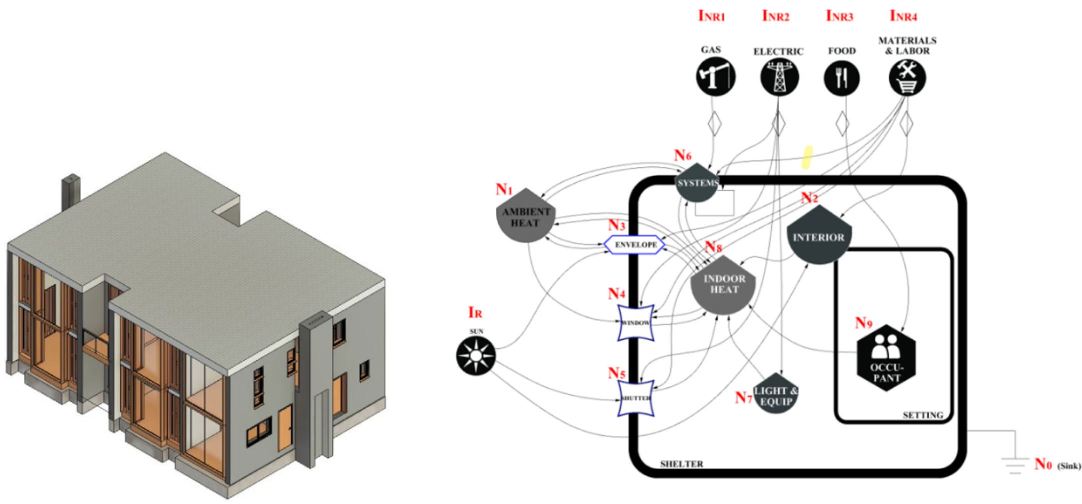

Figure 1. Esherick House (Kahn, 1961). Emergy diagram of thermal exchanges

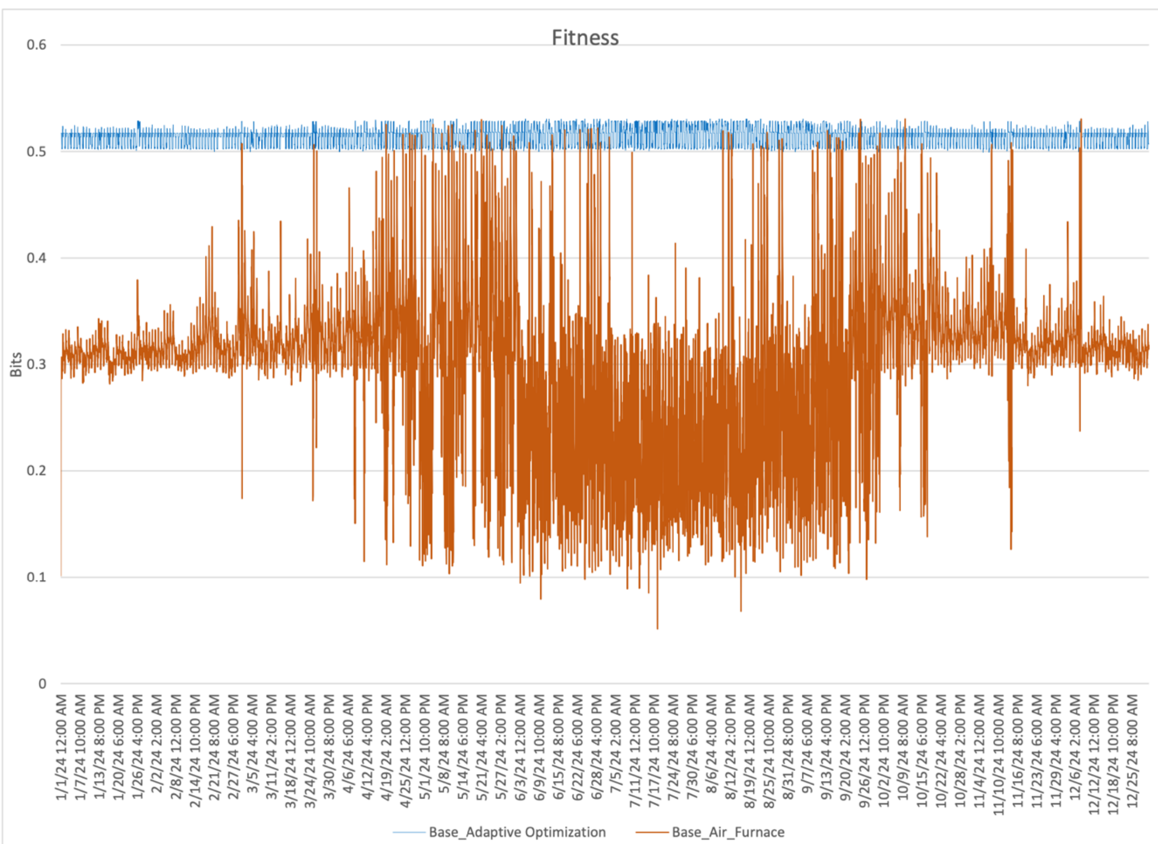

Figure 2. Fitness (bits) of original building with gas furnace (orange) and improved building with adaptive shading and ventilation (blue)

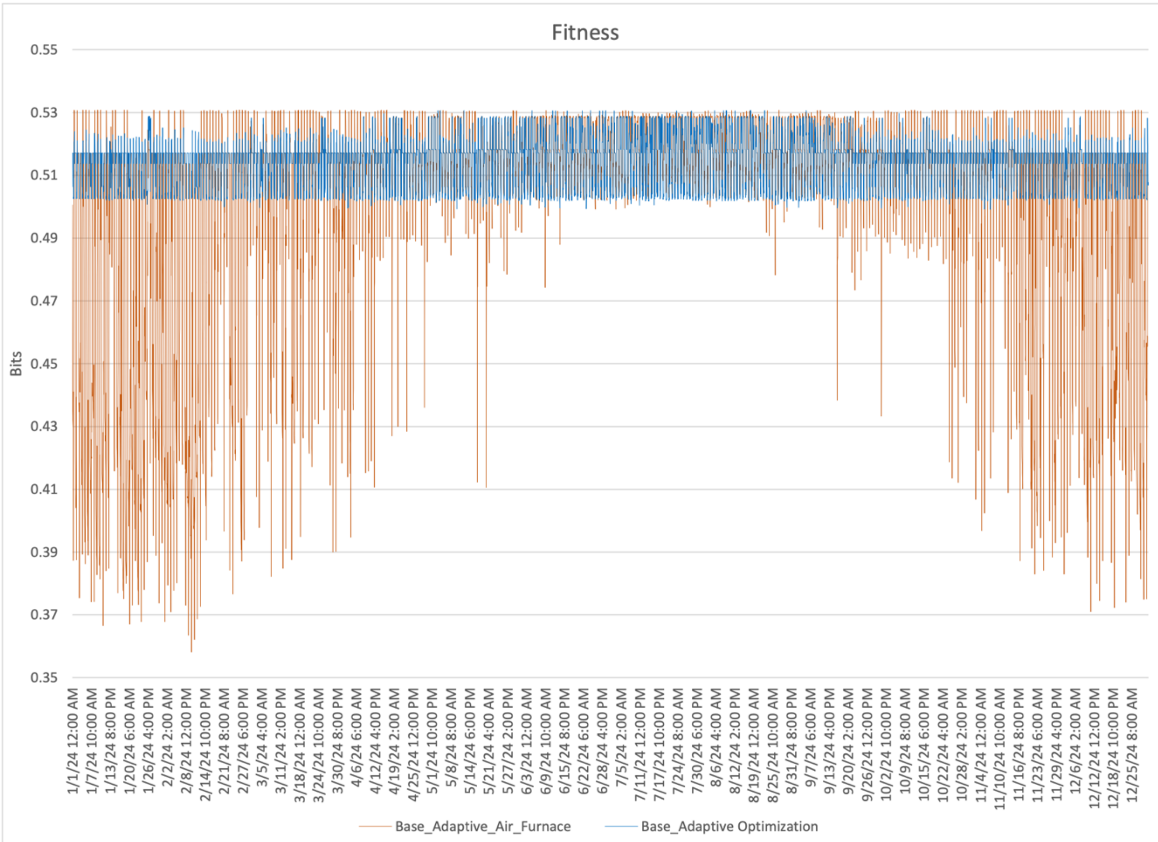

Figure 3. Fitness (bits) of original building with gas furnace and adaptive shading and ventilation (orange) and improved building with adaptive shading and ventilation (blue)

References

Hirata, Hironori and Robert Ulanowicz. 1984. "“Information theoretical analysis of ecological networks.”." *International Journal of Systems Science 15, 3 (1984): 261-270.*

Ulanowicz, Robert E. 1997. *Ecology: The Ascendent Perspective*. New York: Columbia University Press.

Ulanowicz, R.E. 2019. "Information Across the Ecological Hierarchy." *Entropy* 21 (10): 949.

Yi, Hwang. 2016. "Information in Environmental Architecture: Ecological Network Analysis and New indices of Building Performance." Doctor of Philosophy (PhD), Architecture, University of Pennsylvania.

Yi, Hwang, William W. Braham, David R. Tilley, and Ravi Srinivasan. 2017. "A metabolic network approach to building performance: Information building modeling and simulation of biological indicators." *Journal of Cleaner Production* 165: 1133-1162. https://doi.org/https://doi.org/10.1016/j.jclepro.2017.07.082. http://www.sciencedirect.com/science/article/pii/S095965261731510X.

32. Enhancing Urban Sustainability: An Emergy-Based Framework to Support Green Infrastructure Planning

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Abstract

Green infrastructure (GI) is a vital strategy for climate change adaptation and urban sustainability, yet integrating its multifunctionality remains significantly challenging. This study develops a sustainability-oriented optimization framework for GI systems, incorporating emergy analysis, multi-objective optimization, and regional climate models. It highlights a sound cross-domain assessment and addresses real-world challenges such as limited data availability and tight timelines. This framework is applied to two cases across different countries and reveals that GI project sustainability varies by site-specific factors and national contexts. Common findings underscore the high priority of green roofs, which, combined with rain gardens or sunken greens, are eco-friendly, cost-effective, and multifunctional. Permeable pavements, despite previous economic advantages, show lower sustainability. Sensitivity analysis reveals the importance of parameters related to green roofs and the emergy money ratio. This research provides robust decision support for stakeholders and advances GI planning, offering novel insights into sustainable urban practices under climate change.

Keywords: Green infrastructure; Emergy analysis; Multifunctionality; Cross-domain assessment; Sustainability-oriented planning.

33. The impacts of everyday life - investigating lifestyle-related CO_2 emissions and emergy budget and their relationship

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This proposal is inspired by the "1.5 Degree Lifestyles" report series of the Hot or Cool Institute, which chiefly explore the average emission budget for individual lifestyle to keep the global society within the 1.5 °C temperature increase, as determined by the Paris agreement.
Following the calculation framework of the emission budget on a per-capita basis, proposed in the reports, the Emergy supporting individual lifestyles is estimated. Four domains that directly affect everyday life, namely mobility, housing, food and consumption of goods and services, are identified and quantified in terms of the flows feeding a given population. In the calculation of lifestyle emissions, the Life Cycle Thinking / Carbon Footprint approach and emission factors are adopted; in the case of Emergy evaluation, the flows characterizing lifestyles are converted into sej by means of UEVs. The two procedures can be conducted in parallel and the results may present consistency at least for two reasons: items selected for the calculation of CO_2 emission and emergy are almost the same (excluding possible different or missing information due to lack of specific data) and the "footprint" approach (carbon in one hand and solar in the other) is similar, to a certain extent. The findings of the two methods can be considered as two layers of the same representation, providing complementary information to better understand the consequences of lifestyles on the environment.

Here, new calculations for Italy are presented as a case study.

Some implications emerge from this case, including: (a) a relationship between CO_2 and sej can be investigated for lifestyles and single categories/items in order to determine the trends of CO_2 emission and Emergy flows in line with consumer choices; a two axis diagram based on CO_2 emission and Emergy helps design and assess possible policies or measures aimed at improving the environmental performances of the same system; (b) the calculation at country level can be further specified by investigating the feasibility at the sub-national level, which would also facilitate more punctual solutions taking into account site-specific features; (c) the global budget proposed in the 1.5 Degree reports is a cap for CO_2 emissions. This budget could be a reference point in order to find a limit for a possible emergy budget or emergy cap for a system.

34. Emergy Accounting and Green Chemistry languages: the case of lactic acid

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Environmental sustainability assessment is commonly addressed using different languages, depending on the framework and the context within which the assessment is performed. Different semantics produce indicators that may be used inappropriately, weakening the power of scientific analysis in directing consumption and global development. This is especially relevant in systems that span across academic and production fields, such as the evaluation of chemical processes (chemistry) based on renewable resources (agriculture and ecosystem management) – which constitute the basis of the bioeconomy humanity needs to adopt. Through the Emergy approach, H.T. Odum's has provided both the conceptual framework and the operational tool to address this issue.
To contribute to bridging this gap, this work compares the two languages of Emergy Accounting (EMA) and Green Chemistry (GC), used in the case study of a chemical production process. Two production routes for racemic lactic acid are compared: the first based on the fermentation of glucose from biomass, and the second based on the fermentation of glycerol, main byproduct of the biodiesel industry. Using EMA, transformities of lactic acid are calculated (lactic acid from glucose: 1,42E+14 sej/kg; lactic acid from glycerol: 2,84E+14 sej/kg). With a green chemistry approach, the main green metrics are calculated (atom economy, E-factor, reaction mass efficiency, mass intensity) and a semi-quantitative evaluation with EcoScale is performed. EMA and GC are shown to provide non-overlapping, but easily complementary, information about the same system, giving a new insight on the significance of environmental sustainability evaluations for chemical processes.

35. An Emergy analysis of the Guano Trade in 19th-century Peru

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Abstract
Extensive research in the social and natural sciences has examined the guano (bird dung) trade between Peru and Britain (1840–1880). However, no study has yet explored the emergy associated with this trade. This analysis aims to fill that gap by calculating the emergy of both the guano itself and the labor system used to mine and transport it from Peru to Britain, continental Europe, the Caribbean, the United States, and other regions. Additionally, the study compares the emergy drain caused by the guano trade with its economic flow, revealing that the ecological value of this trade, measured in terms of emergy, was greater than its monetary value. This comparison underscores the importance of emergy as a more accurate metric for understanding the true wealth extracted through ecological imperialism, highlighting how ecological costs are often concealed behind economic flows.

Keywords: Emergy; guano; labor; ecological imperialism.

36. What might Odum say about the rise of generative artificial intelligence: perspectives of an ecological and general systems scientist?

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H.T. Odum, a pioneer in systems ecology and ecological economics, developed the concept of emergy and made lasting contributions to understanding the energy dynamics of both natural and human systems. His insights into systems thinking, drawn from his work on ecosystems like coral reefs, wetlands, and forests, offer a unique platform for considering the rise and impact of generative AI in society.

This talk applies Odum's general systems thinking and emergy-based methods to explore the following aspects of generative AI:

1. Comparing Odum's diagrammatic representation of sentences with generative AI's use of word embeddings to model linguistic relationships.
2. Investigating the energetic hierarchy of language, where words have transformities, potentially guiding more energy-efficient AI training.
3. Evaluating the emergy basis of language models, considering the energy and resource intensity of training AI systems across global data infrastructures.
4. Assessing how generative AI reshapes information cycles, offering higher-level interactions to generate more shared knowledge and pathways to connect it across multiple human-techno systems.
5. Directly translating hand-drawn macroscopic mini-models into working numerical simulations offers a mean for broadening their appreciation among scientists who desire a quantitative perspective on system interactions and implications.
6. Exploring ecosystem analogs as models for AI development, reflecting the energetic and hierarchical structures of natural ecosystems.
7. Analyzing the development and integration of AI into society through the lens of the maximum empower principle reveals a balance between empower and efficiency.

The rise of generative AI poses significant societal and environmental challenges, but Odum's nature-based systems frameworks offer valuable insights for guiding its development. By integrating emergy-based accounting and the maximum empower principle, we can better manage AI's disruptive potential, ensuring its evolution aligns with the sustainability and resilience principles of natural ecosystems.

37. Climate Change is Inevitable or: How I Learned to Stop Worrying and Love Maximum Power

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Abstract
Global fossil fuel use and greenhouse gas emissions continue to increase after a brief decrease in 2020 due to the global COVID-19 Pandemic. Global renewable energy production has also risen rapidly, over 50% just from 2022 to 2023. This shows that on aggregate renewable energy production and energy usage efficiency improvements are not substituting for fossil fuel use, these factors simply contribute to greater overall energy use. This is expected based on the Maximum Power Principle, where a system will self-organize to maximize energy throughput, and Jevon's Paradox, where any energy efficiency improvements will be offset by increased energy usage in a system. While renewable energy sources are approaching or have exceeded in some cases parity with fossil fuel in terms of net emergy (or energy) return, the maximum power principle indicates that as long as fossil fuels are providing a sufficient positive return on energy invested relative to alternatives humanity will continue to utilize these resources. While global governance accords have and will likely continue to guide party nations to transition to lower carbon emissions per unit of economic activity, this will more than be offset through offshoring of carbon intensive activities like manufacturing and direct export of fossil fuels, continuing the overall growth in global emissions. This work attempts to provide a first order estimate of the tipping point for remaining fossil resources to be utilized, and the resulting climate impacts from that utilization.

38. Direct and Indirect Human Labor in an Emergy perspective. How to correctly introduce socio-economic aspects into environmental accounting.

R. Santagata, M.T. Brown, S. Ulgiati

Abstract

Emergy is defined as "the available energy of one kind directly or indirectly used in a system for transformations leading to a product or a service". It accounts for different categories of supporting contribution to systems, including renewable and non-renewable energy and material resources, imported resources, information, and know-how. H.T. Odum developed and proposed the idea of Emergy as based and strictly linked to the concept of energy hierarchy, explaining how the natural and societal systems are tied and connected in a network of flows of energy, matter, and information, to perform all transformations. Odum theorized that all energy transformations of the geo-biosphere could be arranged in an ordered series to form an energy hierarchy. The Unit Emergy Values (UEVs) or transformities, when their unit is expressed as sej/J, are used to convert all the inputs into emergy flows. They also express the quality and the complexity of the input flows, as part as of the global hierarchical network of transformations. Emergy also accounts for the contribution coming from direct and indirect (i.e. services) human labor. Emergy practitioners often tend to include labor and services (L&S) as their economic cost. This however may represent a "consumer side" distortion within a "donor side" method, bringing uncertainties and fluctuations related to the economy market and willingness-to-pay perspective. Direct labor has been also accounted for as annual emergy per capita of workers. However, these UEV factors have been calculated by simply dividing the annual emergy driving different countries by the population, disregarding age, education and type of work, among other aspects. Another important consideration, for example, is regarding informal, unpaid and care jobs, that are failed if the accounting is performed based on economic aspects. Furthermore, trying to lower the environmental performance of any transformation process by reducing the emergy of the L&S input flows can be a double-edged sword, as it may mean the loss of revenue or a reduced need for human labor, translating in burdens on the society from the socio-economic level. For all these reasons, this work aims to propose and stimulate the debate on how to appropriately account for L&S and how to correctly include them in emergy accounting works, keeping the value added coming from socio-economic insights and considerations.

39. The Prosperous Way Down? A decade of student opinion data collected on their views of "The Future" after reading and discussing HT and EC Odum's 2006 paper The Prosperous Way Down

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Through a decade of teaching University of Maryland's Environmental Science and Technology Department upper-level classes in Ecosystem Ecology and Ecological Design, undergraduate students were exposed to and discussed HT and EP Odum's now classic paper The Prosperous Way Down. An intentional multiple year extra credit question was given at the end of each final exam which asked the student what kind of world and society they believed would exist in 50, 100 and 1,000 years. Not all students answered the question although through 13 semesters of final exams quite a few responses have been generated. Data is presented on the responses with groupings of sometimes unique points of view and a surprising/unsurprising majority result.

40. How structural non-renewability affects results of emergy indicators

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Among Emergy indicators renewability is one of the most utilized and the one that most distinguishes Emergy evaluations from other environmental assessment methodologies.

Renewability indicator is expressed as the ratio of the sum of all renewable inputs to the total emergy of the output of the analyzed production system.

This kind of aggregation may imply a loss of information stemming from overlooking the variety of the inputs and their respective nature, i.e., renewability. As a consequence, renewability might provide misleading results (potentially supporting greenwashing) deriving from acting on the numerator and denominator of the ratio.

For instance, using an enormous amount of seawater – a renewable resource - to cool down fossil-fueled power plants might result in a certain %R. However, the same %R could be obtained when considering the non-renewable inputs of a wind turbine to capture a totally renewable resource, that is wind energy.

To avoid misinterpretation, we suggest distinguishing between structural inputs and collateral inputs.

Non-renewable structural inputs are the actual determinants of the renewability of the system: the coal power plant is practically 100% non-renewable due to the essential use of coal. Instead, the non-renewability of wind turbines is not structural but rather incidental since more renewable materials could be used, e.g., engineered wood.

We show that for systems mostly relying on “collateral” non-renewable inputs the previous interpretation of renewability indicator still holds without causing potential misinterpretations, while systems relying on structural non-renewable inputs require caution on the conclusions that should be drawn from interpreting renewability only from the output viewpoint.

This specification is in line with the concept of quasi-sustainability introduced by the third sustainability principle of Daly suggesting the temporary investment of non-renewables to generate renewable substitutes.

41. Emergy Evaluation of the USA Aquatic Food Supply Chain

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ABSTRACT

In this research project, we used a life cycle approach to evaluate the emergy required by the main fisheries that supply USA seafood consumption. The study, funded by the US Department of Agriculture under the National Science Foundation's Innovations at the Nexus of Food, Energy and Water Systems (INFEWS) program, investigated energy and water consumption in the USA seafood supply chain. The study used surveys, semi-qualitative interviews, models, trade data and the literature to estimate weighted averages of the top 10 species groups in the U.S. Ranked in order of supply the top 10 species are: shrimp, salmon, tuna, tilapia, catfish & pangasius, Alaska pollock, cod, crab, flatfish and scallops.

Using a life cycle inventory approach, we evaluated both direct and indirect inputs along the entire supply chain from production to the consumer plate. For direct inputs we relied on primary data collected from businesses and secondary data from the literature. For indirect inputs (emergy embodied in infrastructure, equipment, vehicles etc.) we relied on SimaPro software version 9.0.0.30 (https://simapro.com/), the Ecoinvent database version 3.6 to construct life cycle inventories which were then multiplied by Unit Emery Values (UEVs) to obtain emergy.

We computed emergy required to produce 1 kg of edible food by species. Emergy per species varied from 3.2×10^{13} to 1.1×10^{14} sej/kg (mean 5.9×10^{13} sej/kg). Transformities ranged from 3.4×10^{6} to 1.3×10^{7} sej/J (mean 6.9×10^{6} sej/J). We also computed the emergy required to produce the average annual per capita USA aquatic food consumption calculated as the sum of the emergy embodied in each species multiplied by the share that species group contributes to the average per capita diet. In the U.S. aquatic food system, we estimated that 53.6×10^{12} sej of emergy were embodied in 1 kg of edible aquatic food for the USA average diet.

The percent renewable emergy per species by production method (farmed vs. wild caught) varied from a high of 52% for wild caught pollock to a low of 2% for wild caught shrimp. Percent labor emergy was highest at the production stage of all species with wild caught shrimp and cod having 12% and 24% labor emergy respectively. Services contributed between 43% (wild caught tuna) and 20% farmed shrimp.

The breakdown of total emergy was as follows: Production (fishing & farming) contributed 74% of total emergy. Of this 57% of the emergy in production was from the aquaculture sector and 43% from the capture fisheries sector. The processing stage was responsible for 12% of total emergy, while international and domestic transport contributed 7%. International transport and domestic transport made up 94% and 6%, respectively of total transport emergy. Wholesale, retail food service and home preparation accounted for the remaining 7% of emergy required per kg of aquatic food consumed.

Average transformities for farmed vs wild caught aquatic food increased 44% and 31% respectively from the production stage to final consumption. Average transformities for farmed species at the production stage were 2.45 x 10^6 sej/J and for wild caught species 3.65 x 10^6 sej/J. At final consumption these increased to 3.53 x 10^6 sej/J and 4.79 x 10^6 sej/J for farmed and wild caught respectively.

The average U.S. aquatic diet requires 53.6 $\times 10^{12}$ sej/kg at the final consumption stage and generates approximately 0.61 million metric tonnes of FLW, representing about 3.3 $\times 10^{22}$ sej/year (equivalent to ^{em}\$30 billion). For perspective, the emergy embodied in wastes exceeds the total annual emergy consumption of the 53 lowest-ranking countries in the world in 2020.

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42. Emergy Assessment of a sustainable Solar Still for water desalination and purification

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Abstract

Climate and ecological emergencies are exacerbating the problems related to provision and control of water resources. Water scarcity, droughts, floods, pollution and extreme weather events are especially threatening isolated and poor communities. In this work, we present the emergy accounting on an innovative solar still for water desalination/purification. The solar still, named SOLWA®, can reach comparatively very high yields in the delivery of drinking water, and was designed to supply safe fresh water in small, isolated communities and in urban situations where electric network connections or conventional energy sources are not available. SOLWA® is portable and made by "poor" materials and elements, with a total cost of about 1,000 USD. It does not require maintenance and is powered only by solar radiation. The solar still has already drawn the interest of several nongovernmental and intergovernmental organizations, including the United Nations, which included SOLWA® in their Innovation for Development and South-South Cooperation programme (www.ideassonline.org). Based on the emergy accounting method, we calculate some sustainability indicators, and compare the specific emergy of the produced drinking water to that from other conventional systems of desalination/purification. It is worth stressing that this work highlights the use of emergy accounting for integrated sustainability assessment. This is paramount in the scientific and philosophical legacy of Howard T. Odum, as emergy appears more and more the metric to be used for the definition of sustainable policy making procedures.

Keywords

Solar still. Emergy accounting. Water desalination and purification. Sustainability assessment.

43. Math and Puerto Rico Interactions with H.T. Odum

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ABSTRACT:
This talk covers my interactions with H.T. Odum (ecology), who was a super mentor to me, standing above Willis Boyd (history), Marvin Mundt and H.L. Pearson (math), Marvin Johnson (Ind. Eng.) and David Scienceman (sociology and religion). His lectures on Energy Systems Modeling at Salisbury State University, MD June 1-5, 1993, were an inspiration. His organizing abilities, inherited by some of his followers, were fantastic. I remember working on eigenvalues with him in his garage with his system of bins. As far as known, besides Elizabeth Odum, I am his only co-author in the Emergy Synthesis Proceedings, such as "Calculating Transformities with an Eigenvalue Method" (Chapter 22, vol 1), 1999. He lent me $50 (repaid) to survive the ISSS (of which he was a past president) Conference in Toronto, ON July 21, 2000, when the bank rejected my credit card as out of country. During a visit to Puerto Rico reviewing his Rain Forest studies, May 15-18, 2001, he taught my son Glenn the Spanish card game BRISKA, wherefrom an attempted application of the eigenvalue method to dengue appeared in Emergy Synthesis 7. He is certainly missed.

44. Emergy Accounting and Resource Policy Making. A Review of Case Studies from Market to Nature-based Transition Patterns

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The increasing world population is placing a huge demand on energy and material resources. Demand for resources is linked to different aspects and components of human lifestyles and behavior, in support to better housing, nutrition, health, and education, but also in support of industrial development, mobility, economic competition. The value of resources is still measured in terms of their market cost. Resource trade among countries, cost of industrial inputs and outputs, mobility tickets and any kind of goods and services available in the market are all valued by means of their economic cost, which in turn depends on the strength of an economic player in the national market and the strength of a country´s economy in the world competition. This means that resource value depends on the ability of market players to compete in terms of quantity, quality, trade, political power, no matter how important is a resource´s contribution to the biosphere dynamics and the well-being of its different species and ecosystems. As a consequence, international trade and national economies are based on exchange of goods and commodities versus money flows, the latter having different purchasing power in the different countries or international market and therefore generating inequality and unsustainable relations among trade partners.

The transition from market-based dynamics to nature-based solutions requires a different way to assign value to resources. The Emergy Accounting approach (EMA; Odum, 1996) assigns value depending on the time and spatial scales of the biosphere work in generating resources. In so doing, the basis for environmental evaluations and economic exchanges is no longer their monetary value but instead the available energy supporting environmental and human dominated processes, converted to solar emergy and expressed in terms of the same biosphere work unit, the solar emergy joule (sej). This allows a more appropriate use of resources (environmental efficiency), a circular approach (selecting production and consumption patterns that respect resources turnover), a prosperous way down according to “optimizing efficiency” instead of “maximizing efficiency” within a pulsing paradigm, a shared responsibility in resource use to improve trade, mobility, education and information, and finally collaboration instead of competition.

A review of results from emergy assessment of systems and sectors towards more sustainable and resilient patterns is presented.

45. Howard T. Odum's Contributions to Evolutionary Theory and Maximum Power

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Abstract

In 1922, Alfred Lotka defined maximum power in terms of natural selection. Decades later, HT Odum expanded upon this foundation to include both living and nonliving systems, and at all scales of size and time. He included ocean currents, earth mantel gyres, weather systems, and material cycles. He included the origin of life, the place of humans in the systems of life, the role of information, both genetic and cultural, the dynamics of succession, the dynamics of 'pulsing', the contributions of hierarchy, and the implications of 'energy quality'. Reasons that mainstream evolutionary theory has failed to adopt his theoretical framework include those conventional individualist positions that for many years denied various 'expanded synthesis' approaches such as multilevel selection. Odum's approach goes beyond multilevel selection to principles of selection for universal processes of energy transformation. One reason that it is less well known among evolutionists may be that Odum did not draw together his principles of maximum power into a comparable framework that was focused on evolution. This paper is an initial effort to do so, and it will include the anthropologists' passion for 'cultural evolution'.

46. Loop Reinforcement as a Mechanism of Self-Organization

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The process of self-organization is critical to understanding the Maximum Power Principle. Self-organization is the process whereby the parts or components of a system become organized so that power (e.g., metabolism when the system is an ecosystem) of the whole system is maximized. H. T. Odum wrote extensively on how self-organization takes place but his conception lacked experimental verification and mechanistic rigor. In other words, he never scientifically demonstrated how self-organization works. In Odum's thinking, self-organization was a selection process, with similarities but also differences with Darwinian natural selection. He sometime referred to it as a "trial and error"-type process. This presentation reviews Odum's thinking on the loop reinforcement mechanism of self-organization, which was the main mechanism he discussed. Loop reinforcement in ecosystems means that the species that feeds back energy to bring in the greatest energy (to itself and to the ecosystem) will be selected for in ecological interactions during succession. Thus, the species that brings in the most energy from sources downstream of itself within the networks of the system will be selected for, and as a result the metabolism of the ecosystem will be maximized relative to alternative configurations of the networks. A review of the ecological literature on topics such as herbivore effects on plants, mutualism, keystone species, facilitation, ecosystem engineers and indirect effects is suggested to support, at least anecdotally, the existence of loop reinforcement in ecosystems. Also, a model demonstration of loop reinforcement in emergy units is given for a plant-herbivore interaction from the literature to provide additional perspective on the existence of the mechanism. The presentation concludes with speculations on how Odum might have derived his understanding of self-organization without conventional scientific demonstration.

47. Applying HT Odum's Models to Novel Ecosystems

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ABSTRACT
With the arrival of anthropogenic biomes and the increasing concentration of human populations in urban centers, society has become accustomed to novel ecosystems, though perhaps without recognizing or naming these systems. These novel ecosystems are characterized by self-organization and strong human influence, with the biological communities comprised of new combinations of species and new pathways such as energy flows and feedbacks. The concept of novel ecosystems is not entirely new, with the term being coined decades ago but the concept existing in the works of HT Odum decades prior. However, with increasing focus on climate resiliency and adaptation as we approach, or perhaps have surpassed, the 1.5°C temperature threshold, society may wonder what role novel ecosystems play in a changing future. This study seeks to explain examples of novel ecosystems within the constructs of HT Odum's systems framework. There are connections with maximum power, steady-state, public policy, city greens, and refreshing water and landscapes.

48. The ecological modeling of Howard T. Odum and its perspective inheritance in cancer biology and medicine

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Abstract

Complex systems—such as ecosystems—display non-linear, self-organizing behaviors that go beyond simple cause-effect relationships among individual components. Driven by empower intake maximization, the presence of feedback networks enables responses and adaptations that can only be understood by "zooming out" to wider perspectives. In this regard, moving from general systems theory and thermodynamics, H.T. Odum made lasting contributions in developing a quantitative approach for establishing the nature of these fundamental relationships and the dynamical representation of their emergent properties. Of all the realms in which his work was source of novel and disrupting ideas (ecology, economics, social sciences, ...), a novel possibility, still much underexplored, appears: applying this energy language to the challenges faced by molecular biology and medicine. Complex diseases, such as for example self-immune diseases and incurable cancers, arise as systemic features, manifesting the malfunctioning of regulatory control processes and the interactions/cross-talk between cells and their micro-environment. In this work, we provide a conceptualization on how Odum's heritage can help us address the complexity of these malignant, complex and fascinating ecosystem, putting the basis for an analytical, dynamical representation of the evolutionary scenarios for these class of diseases at different time-scales. Some preliminary results will be also presented, showing the potential of an energy-based description of the bio-medical complexity. Thanks also to the possibility of substantiating our models with data coming from cutting-edge experimental techniques (3D cell cultures, Organoids), we are working to explore the possibility of using energetic diagrams and maximum empower principle in medicine, hoping to contribute in developing a truly "holistic" approach for patients treatment and general individual care.

Keywords

Complex diseases, Stock-flow dynamic representation, Odum's energy language, Cancer

49. H.T. Odum´s contribution to policy making

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Economies still rely on a "*user value*" concept, i.e. a resource or a good is valuable if the market competition assigns to them a huge monetary value based on demand or if their work potential (exergy) is higher and therefore makes them more "useful" within technological and economic processes, no matter how much work was invested by biosphere to generate them. The innovative Odum´s emergy concept (Odum, 1996) reverses the assessment, by making value to rely on the biosphere work to generate and make available ("*donor value*") resources and services used with our economies. Further, such assessment is performed by converting all driving flows of available energy (exergy inflows) into flows of solar equivalent energy (emergy), that becomes the new value assessment currency, depending on nature dynamics, not on market.

Such reversed theory of value has not yet been understood nor accepted by stakeholders and policy-makers. That a resource is taken as "valuable" because it is considered capable to address specific needs (work potential) and generate an increased market demand (monetary value) is only partially true. An appropriate evaluation of value should take into consideration the present and future availability of resources, their renewability and therefore the sustainability of a society relying on them. Odum´s "*donor-side*" approach is a real innovation in policy-making, in that it includes space and time scales assessments for the evaluation of the value of a resource. Market (monetary) evaluations depend on demand (*user-side*) and demand (and currency) is different in each country and among countries; instead, the evaluation of space and time scales as well as available energy driving resource generation does not depend on demand nor countries and allows resources to be assessed by means of the same unit, sej (solar emjoule) and gives rise to a set of value and performance indicators based on one unique currency.

To summarize, the emergy method allows to: 1. Assess systems outside of human economies (global biosphere processes): 2. Understand the environmental impacts on human-dominated processes; 3. Develop a donor-side quality assessment; 4. Evaluate direct and indirect flows driving processes; 5. Include time and spatial scales in the assessment, in so assessing their renewability and availability to next generations; 6. Highlight the environmental and social quality of resources that have no market (fresh water, biodiversity, topsoil,…); 7. Understanding the interaction of high quality and low quality resources in economic and environmental processes; 8. Evaluating the environmental support to human labor and services, beyond market evaluation in different countries; 9. Compare processes by means of assessment tools outside of market dynamics. (Brown and Ulgiati, 2004; Odum and Odum, 2006; Santagata et al., 2020)

Developing and comparing emergy-based economic, environmental and social evaluations of human-dominated and natural processes allows a comprehensive evaluation of costs, performance, resilience and sustainability of individual activities, technologies, regulatory decisions, investments, trade, by means of a unique and comparable currency. Therefore, it makes it possible to generate a clear and informed discussion among stakeholders, businesses, policy-makers about the needed transition from a market-based to a nature-based economy. In short, Odum´s emergy approach might be and should be the tool to show to policy makers that a new science-based and nature-based pattern is possible and show how this pattern could be. Are we ready to contact our policy-makers at all levels and explain them such an innovative tool?

References:

Odum, H.T., 1996. Emergy Accounting: Emergy and Environmental Decision Making. Wiley & Sons, New York.

Brown, M.T. and Ulgiati, S., 2004.. Energy quality, emergy, and transformity: HT Odum's contributions to quantifying and understanding systems. Ecol. Model. 178 (1-2), 201–213.

Odum, H.T. and Odum, E.C., 2006. The prosperous way down. Energy, 31: 21-32.

Santagata, R., Zucaro, A., Viglia, S., Ripa, M., Tian, X.u., Ulgiati, S., 2020a. Assessing the sustainability of urban eco-systems through Emergy-based circular economy indicators. Ecol. Ind. 109, 105859. https://doi.org/10.1016/j.ecolind.2019.105859.

50. H.T. Odum's Contributions to Open Systems Thermodynamics

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Abstract

Howard T. Odum made significant contributions to open systems thermodynamics (OST), particularly by applying thermodynamic principles to ecological and economic systems. Odum's work provided a foundation for understanding ecosystems as open systems that exchange energy, materials, and information with their surroundings. His key contributions are as follows:

1. Energy Flow in Ecosystems:
   - Odum pioneered the study of energy flows within ecosystems, treating them as open systems that require continuous energy input to maintain structure and function. He developed models showing how solar energy flows through ecosystems, from primary producers to various trophic levels, ultimately being dissipated as heat.

2. Concept of Emergy:
   - One of Odum's major innovations was the concept of emergy, which quantifies the total resources required to produce a good or service within an open system. Emergy provides a way to account for all energy inputs in a system, regardless of their form, giving a measure of the real costs embedded in natural and economic processes.
   - Emergy allows researchers to assess ecological and economic activities in terms of their true resource requirements.

3. Ecological Self-Organization and Maximum Power Principle:
   - Odum introduced the idea that open systems, like ecosystems, tend toward configurations that maximize power flow through self-organization, a concept he termed the Maximum Power Principle and later the Maximum Empower Principle. According to this principle, systems evolve toward states that maximize the capture and use of energy, optimizing their structure to thrive under given environmental conditions.
   - This idea extended classical thermodynamics by suggesting that systems operating far from equilibrium (like ecosystems) organize themselves to increase their energy throughput, an insight crucial for understanding ecological dynamics and adaptation.

4. Hierarchical Organization and System Feedbacks:

- Odum proposed that open systems like ecosystems exhibit hierarchical organization, where components at different levels interact and influence each other through feedback loops. He used open systems models to show how energy and material flows create a nested hierarchy, with feedbacks regulating the flow of resources across different scales.
- This hierarchy is fundamental to understanding how ecosystems function holistically, balancing energy inputs with consumption and dissipation to maintain stability.

5. Systems Ecology and the Concept of Natural Capital:

- Odum's OST contributions led to the development of systems ecology, which applies thermodynamic principles to analyze how ecosystems function as open systems. He argued that ecosystems and economies both rely on natural capital, resources derived from ecosystem processes that must be maintained through energy flows.
- His insights laid the groundwork for modern concepts of ecosystem services and the value of natural resources, emphasizing the energy inputs required to sustain them.

6. Use of Energy Systems Language and Diagrams:

- To model open systems like ecosystems, Odum developed an energy systems language that uses symbols and diagrams to represent energy flows, transformations, and storages within a system. This language facilitated visualizing complex interactions in open systems, aiding in understanding how energy inputs drive system processes and interactions.
- His energy circuit diagrams remain widely used in systems ecology and biophysical economics, illustrating how resources flow within open systems to maintain their stability and function.

In all, Odum's contributions have been foundational in using open systems thermodynamics to understand ecological and economic systems as energy-dependent networks. His concepts of emergy, maximum power, and hierarchical organization have provided tools to measure and evaluate energy flows within open systems, contributing to a better understanding of the interconnectedness between nature and human economies.