# *Thursday January 12, 2023*
# *Morning Session*

## 1. Em-coin: A new currency for self-management of natural ecosystems

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The tension between nature and civilization is inherent in the concept of "civilization" itself. Everything that humans produce is defined as an aspect of civilization, while nature is defined as "everything else." Yet, nature is often expressed only through the technologies and dynamics of civilization. Natural ecosystems outside of legally regulated human societies (wilderness) seemed to be a "less interesting" refuge for certain non-human entities. This study envisions a future in which natural ecosystems manage themselves through their intrinsic, donor-side value, i.e. their emergy value (Em-coin). The question, then, is if and how could forests manage themselves as "forest (management) people", namely independent and self-managing entities? To answer this question, we attempt to identify autonomous subjects as agents of these natural systems, capable and allowed to use and own technical and ecological resources. Specifically, ecosystems´ natural resources are monitored by drones and satellites, and the market value of the total ecological products is already precisely calculated within human economies. Let´s consider the case of forests. To generate income, a forest subject can be envisioned as capable of selling logging licenses through automated processes, smart contracts, and blockchain technology. Eventually, the forest can repay the debts of the initial investors and become the sole shareholder of its own property. As its own owner, the growing forest would have the ability to purchase more land and continue the cycle. This study evaluates the feasibility of and proposes the creation of an artificial natural system to generate new technology-supported market outside the entangled relationship between nature and civilization. Em-coin, a measure of the emergy value, would be the currency of such independent trade. Forests, rivers, species would be the operators.

## 2. Potential and strategies for low-carbon urban development: an emergy-based assessment of Tianjin, China

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As cities grow, urbanization has dramatically altered land cover, leading to rapid growth in carbon emissions and associated risk of climate change. Cities play a dominant role in energy consumption, and research on carbon emissions at the city level requires further attention. Increasing demand for energy, together with resources scarcity and environmental degradation, are all issues and challenges for low carbon urban development. Tianjin, one of the most densely

expanded urban areas in eastern China, has undergone dramatic changes in land use and energy mix since 1990. As a rapidly developing city, its non-renewable resources are rapidly consumed and its ecological environment suffers from severe pollution, limiting its sustainable development. The assessment of carbon emissions in cities requires the integration of land use distribution with energy consumption patterns. The emergy synthesis method allows to capture the complexity of urban systems from a larger scale, geobiosphere, where the resources originate, in order to understand the interaction of natural and socio-economic factors in the self-organization of the city. Therefore, this study uses the method of emergy synthesis to analyze the current status of land use and energy consumption patterns in Tianjin, and constructs an urban energy model for Tianjin by assessing the interactions between resource flows (renewable and non-renewable) and the spatial distribution of assets, and then assess and predict the potential for low-carbon urban development, and finally proposes the suitable development strategies for Tianjin. The data shows that non-renewable energy consumption accounts for 96.18% of all energy consumption in Tianjin in 2021, and by increasing the development and utilization of solar, wind and biomass energy, the use of non-renewable energy can be reduced by about 24%. In general, there is a strong correlation between energy intensity and land value, and energy value models can provide valuable predictions for urban development strategies.

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### 3. The Emergy of Making

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O. P. Jindal Global University

The emergy analysis of a designed artifact conventionally accounts for the emergy inputs to the environmental processes forming its raw materials, the emergy inputs needed for manufacturing, transportation, and so on, and that of disposing or recycling the artifact (Odum 2002, 53–55). However, there is no method to differentiate between the emergies of different configurations of the same materials manufactured by the same processes. Yet, it is precisely the configuration of the materials constituting and artifact that is specified by its design and materialized in its making. Arguing that the exergy of a population with respect to its environment is greater than that of its inanimate biomass, Jørgensen (1992, 163) used the difference in the exergy of a building and the exergy of a stack of the bricks it is made from as an analogy. Jørgensen remedied this issue in the context of the exergy analysis of ecosystems using an equivalence between the information content of a species' DNA and exergy contribution of its population to that of its ecosystem. However, this work has not yet been applied to the analogous case of designed artifacts. This paper combines Jørgensen's notion of eco-exergy with the design computational framework of making grammars (Knight and Stiny 2015) to find the emergy of making for designed artifacts. O. P. Jindal Global University

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## 4. An Emergy-LCA Analysis of Environmental Sustainability in Urban Agriculture: Evidence from Food-Energy-Water-Carbon Nexus Perspective

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Urban agriculture (UA) has evolved to promote the local food production and become an essential aspect of urban planning and construction. Therefore, quantifying UA's environmental sustainability (ES) is vital to help decision-makers to adopt reasonable urban development plans. However, a systematic methodological framework for assessing the ES of UA multidimensionally needs improving. We construct an Emergy-LCA methodology framework by defining a consistent system boundary of on-farm and off-farm activities to systematically analyze the ES from the food-energy-water-carbon nexus perspective of UA. Two urban farm cases in Beijing are selected as the typical UA modes to test this framework. Case 1 is a conventional greenhouse farm that sells food in supermarkets; Case 2 is an emerging aquaponic farm through express delivery distributing food directly to consumers. Our analyses indicate that the aquaponic farm's emergy input per unit of food is 12.64% of a conventional farm. A lower environmental loading ratio of aquaponic farm also indicates that it is more sustainable than the conventional farm. Specifically, the LCA shows that aquaponic farm has a solid potential to save water, with only 16.21% of the blue water consumption of conventional farm. However, the extensive input of electricity from aquaponic production brings more energy consumption and carbon emissions than the conventional farm. The results also show that UA is more economically and environmentally friendly by using express delivery from the farm to the consumer's home. Supermarket sales consume 5.43 times more energy than express delivery and 2.32 times more water, emitting about 4.92 times more CO2. After taking profitability into account, the aquaponic farm performs better on the economic analysis results. In summary, the emerging aquaponic farm with express delivery is critical to improving urban resilience. This study contributes to optimizing UA management models to play a more significant role in sustainable urban development.

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## 5. Crop switching could be a win-win solution for improving both the productivity and sustainability in a typical dryland farming region-Loess Plateau, China

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Increasing crop yield and reducing environmental impacts are conductive to regional sustainable food production, while integrated evaluation of them is still lacking to fill this gap. A new systematic analysis method was developed to quantify crop yield, economic input and environment impact of farmland. Taking the farmland ecosystems of Loess Plateau (LP) in China during 2014-2018

as a case, this new systematic analysis method was applied to quantify the ecological environment, systematic sustainability, and socioeconomic characteristics (indicators) of the farmland ecosystems in dry farming. Then, by exploring the relationships of these indicators and combining with crop switching analysis, the relatively unsustainable counties in farming and the improving potential of sustainable crop production was clarified, respectively. Several interesting results were explored. (1) The counties with the farmland of gray-water footprints exceeding 500 m3/t or soil erosion empowers exceeding 1.5E+12 sej/ha could be categorized as the relatively unsustainable counties in farming. (2) Maize and sorghum showed superior performance in terms of both environmental sustainability and crop productivity and had promotion advantages in LP. (3) Crop switching could reduce grey water footprint and soil erosion of farmland by up to 27.41% and 35.14% respectively and increase emergy sustainability index and crop yield by up to 10.35% and 19.90% respectively. The integrated systematic analysis method and crop switching method has high application value for regional sustainable crop production, especially for dryland regions with fragile ecological environment and prominent food demand-supply conflict.

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## 6. Information Emergy

**Thomas Abel**
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An ‘Area’ emergy analysis was calculated for the island of Taiwan. The subject of the analysis was the information ‘scale’ of ‘academic research’. A ‘parallel cycles’ diagram was used to direct the research, i.e., to identify the emergy flows and processes that required evaluation. That model was the shell, within which information emergy evaluations were produced. Information objects transformity calculations for Abstracts, Papers, and Books were calculated as paper documents with the energy of paper carriers divided into the total academic research scale emergy. For the ‘information object cycle’, multiple scales (3) are conceived, and each of the scales was assigned the total academic research emergy for Taiwan. Within each scale are many document objects. Each object is a population of objects (such as book copies), each sharing nearly identical information. Transformities for each academic research scale increased as expected, forming a spectral graph. For Taiwan academic abstracts, papers, and books, transformities were calculated as 8.12E10 sej/J, 5.4E11 sej/11 sej/J, and 1.83E13 sej/J, respectively. For the ‘expression mechanism information cycle’, a transformity was calculated for the operating procedures for the research institute of 11.42E11 sej/J. This parallel information is not trivial but equally contributes to cultural production, and thus equally needs to be tested and maintained in information cycles of its own. The two information cycles are linked within the parallel cycles model.

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## 7. Different land use scenarios for food supply: from deforestation to agroecological practices

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What are the biophysical limits to human land cover and land use change (LCLUC) at the regional/local scale? What land use practices are suitable to counteract and prevent further soil degradation, water resource depletion and biodiversity loss? Can this approach be based on the physical principles governing energy transformations in complex systems? Human LCLUC for

food supply chains directly impact the biosphere and the climate from the global down to the local scale. On the other hand, food production is threatened by climate change and ecosystem degradation, with impacts strongly dependent on both the geography and the social structures. In this framework, the human appropriation of net primary production (HANPP) represents one comprehensive ecological footprint indicator to measure global human interaction with the biosphere and its spatial distribution, also used to sketch possible scenarios for food systems development and impacts on terrestrial biosphere and climate. Although global and regional assessments have been carried out to quantify the magnitude and impacts of LCLUC, understanding the response of ecosystemic natural cycles to the changes in energy and material flows that sustain human food supply chains remain challenging and strongly dependent on land use framework. In this perspective, conservation and regeneration scenarios based on agroecological land use practices at the ecosystemic, local, and community scales are hardly accounted for within the analyses. Furthermore, little is known about the short, medium and long-term potentials of agricultural conservative and regenerative practices, and even less on the possible trade-offs that oppose the reproduction of agroecological experiences beyond the farm scale. In this contribution, we try to outline a possible basis to build a comprehensive approach encompassing the non-equilibrium thermodynamics of natural flows, the ecological knowledge and the emergy language, within the contest of different water and land use scenarios.

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### 8. Assessment of long-term changes in environmental indicators of pasture-based livestock systems in northern Spain

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Pasture-based livestock farms are social-ecological systems characterized by a reduced purchase of inputs and large use of local renewable resources through grazing. It has been practiced in Spain for centuries and it is considered a sustainable activity in European mountains and marginal areas. The European Union subsidizes these farms through the Common Agricultural Policy (CAP) to support their social and environmental role. CAP subsidies allow pasture-based livestock systems to remain profitable, but also shape them by bolstering specific agricultural practices. Moreover, these systems are also constrained by their social and environmental context. We aim to analyse how mountain farms have evolved over a thirty-year period accounting for the abovementioned external drivers. To do so, we (i) implemented an emergy assessment on 50 farms in 1990, 2004 and 2018; (ii) compared the emergy indicators between years; and (iii) analysed how the environmental performance of different trajectories of evolution previously identified have evolved. Most farms´ emergy indicators worsened from 1990 to 2004 and stabilised from 2004 to 2018. Environmental sustainability (ESI) evolved from short-term sustainable in 1990 (ESI of 1.5 ± 1.1) to non-sustainable in 2004 and 2018 (ESI of 0.6 ± 0.4 in 2004 and 0.7 ± 0.5 in 2018) (p-value < 0.001). Since the CAP is the major driver, we hypothesise it played a role in reducing farms' sustainability over time. We also found significant differences in emergy indicators across trajectories, signalling that the social and environmental

context is also influencing the evolution of farms sustainability. The emergy signature showed that purchased feedstuffs (13%), services (16%) and subsidies (24%) had the highest contribution of emergy to the system. An increase of grazing to substitute feedstuffs is a strategy to increase farms sustainability. However, the large emergy inflow from subsidies and services reduce their capacity to affect their own sustainability.

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## 9. Emergy accounting of the Construction & Demolition Waste in the Metropolitan City of Naples (Italy) within a circular economy perspective

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Construction and demolition waste (C&DW) are the most important flows accounting by 45% among the total waste generated in Italy (ISPRA, 2020), 36% in Europe and 30% worldwide (Purchase et al., 2022). This sector is the largest consumer of natural resources and, in particular, sand and gravel that are currently consumed far beyond their (slow) generation rate. The adoption of CE is very urgent, given that urbanization processes drive the demand of building materials and increase the amount of C&DW in cities. It is important to link C&DW management to the urban mining concept and CE, by also developing prevention design (Ghisellini et al., 2022). Only few studies can be found in the literature dealing with CE in the C&DW sector by means of emergy accounting. However, these studies provide an important understanding of the different recycling options, such as material recycle, by-product use and adaptive reuse (Brown and Buranakarn, 2003) and approaches (open loop and closed loop) (Yuan et al., 2011). The present study evaluates the annual flows of C&DW collected and recycled in the Metropolitan City of Naples by means of the emergy approach. The annual flows of C&DW in Naples mainly consist of mixed C&DW (47%), soil and stones (25%), iron and steel (7%), concrete (7%), bituminous mixture (5%), dredging spoils (4%) (Ghisellini et al., 2021). The total emergy required to manage the recycling process, and selected emergy-based socio-economic indices (emergy per unit currency, Em$, $/g; emergy per person, sej/worker; emergy yield ratio), environmental indices (environmental loading ratio; landscape development intensity, sej/(m2*yr); emergy sustainability index) are calculated. Finally, appropriate indicators for material/products circularity suggested by Brown and Buranakarn (2003) (Recycle Benefit Ratio, Recycle Yield Ratio, Landfill to Recycle Ratio, Recycle Efficiency Ratio) are calculated and discussed at whole urban level.

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## 10. Emergy analysis for stabilized soils with puzzolans and lime for sustainable road construction.

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The main environmental impacts of the materials used in the road construction industry include high energy consumption, waste generation, greenhouse effect, ozone destruction, among others. Twenty five percent of global CO2 emissions corresponds to the transport industry, requiring 7x106 MJ of energy to build one kilometer of standard two-lane asphalt road. Lime being the most common stabilizer for the support layers of these pavements and responsible for 2-5%

of these emissions. Emergy analysis were performed for stabilized soils with puzzolans and lime for sustainable road construction. Emergy indexes such as EIR, EYR, ELR and ESI using alkali-activated natural pozzolans (PASS) and lime (LISS) for soil stabilization were calculated as indicators for sustainable road construction and public policies.

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## 11. An emergy synthesis accounting model to evaluate beef cattle sustainability

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Current assessment aims to evaluate grass-fed beef cattle production system using the emergy synthesis concept (energy memory of goods). A mathematical cost-based model that considered all the production factors used in Economic Theory was used. Four steps were approached, as follows: i) economic analysis of the production system; ii) construction of a conceptual model; iii) transformation of all resources to the unit of (emjoule [sej]), and iv) analysis of the emergy indexes to evaluate the environmental capacity and comparison with other production systems or with the sustainable ideal. The transformability (Tr) was 2.63E+03 sej/J. The Renewability index was 47.61%. The emergetic yield ratio (EYR) was 1.91. The emergetic investment ratio (EIR) was 1.10. The environmental load ratio (ELR) was calculated as 1.10. The Emergy Sustainability Index (ESI), which is an indicator that measures the environmental load to obtain a specific yield, showed as 1.74. Finally, the emergetic exchange ratio (EER) had a value of 12.45, indicating that the system requires much more emergy than it receives in monetary form. The fuel used for pasture management services is the most non-renewable resource that impacted the model. If pasture management were improved, the system would be less dependent on the market volatility. For the emergy synthesis, such input represented 51.2% of the total energy used, but for the economic analysis, such variable represented 1% of the total production cost only. The system could be less dependent on market variability if improved pasture management practices were adopted, such as using a reasonable pasture-stocking rate. Current model allowed the grass-fed beef cattle system to be quantitatively analyzed from an environmental perspective. In addition, current model also allowed to assess the effects of technology or production techniques adoption on sustainability indicators, which has been worldwide valued by beef consumers.

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## 12. Evaluation of the Sustainability of a Mushroom Culture System in San Miguel Canoa Puebla Based on Emergia.

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In this work, a systematic analysis and evaluation of indicators of the two common cultivation methods in the study area, Cultivated Trunks (TC) and Sawdust as a culture medium (AMC), are carried out, with emergy methods to evaluate and compare their economic and ecological benefits. To perform an emergy analysis in an economic-ecological system, first, the limit of the

system must be identified by collecting the quantity and value of input resources and output products; second, classify the mentioned flows and convert matter, energy, value, etc., into a unified metric through the unit values of emergy (UEV) and emergy/money ratio (EMR). The items invested in mushroom cultivation include mainly soil, strains, facilities, tools, labor, energy, even small amounts of disinfectant and water needed for crops. The highest input for TC and AMC is labor, with 81.28%, 70.78% respectively; followed by fungal materials with 10.27%, 11.06% respectively which makes them the most important items. The proportions of economic and social feedback resources for TC and AMC are 31.56%, 60.26%, indicating that most of the emerging input resources in the production of fungi for TC comes from the local natural environment. Through the calculation of emergy self-support (ESR) and environmental load ratio (ELR), TC is characterized by the highest rate of local land utilization and renewable resources, therefore having the greatest ecological benefits. The AMC is the opposite, having the lowest ecological benefits. The results show that TC has the lowest production efficiency but the highest exchange efficiency.

## *Thursday January 12, 2023*
## *Afternoon Session*

### 13. Truffles industry: the hidden risks of a great potential

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Truffles (*Tuber* spp.) are subterranean fungi cultivated and harvested as high-quality, elitist food in Mediterranean Region, given their high organoleptic and economic value. Truffles also play a key role in ecosystems: since they grow symbiotically with different trees (*Quercus* spp, *Populus* spp, *Tilia* spp, etc), they support the maintenance of several ecological functions, such as forest development and health. Moreover, truffles generate ecosystem services for humans: in addition to food supply, they contribute to regulation and support services (i.e., soil formation, and protection, water regulation, carbon cycle) but also to cultural services by creating a sense of belonging in rural communities. In Italy, truffle business represents a growing industry, causing an increase in harvesting pressure on natural sites. For cultivable species, such as *Tuber melanosporum* Vittad. and *T. aestivum* (Wulfen) Spreng, the cultivation takes place in suited areas, thus partially reducing the impacts. On the contrary, the harvest of species not yet cultivable but with high economic value, such as *T. magnatum* Picco (in 2022 around 6'000 €/kg), could endanger natural sites by generating pressures and impacts that could slowly affect production rate. Shrinking productive natural areas forced Italian authorities to adopt conservation measures, but first of all it is necessary to raise awareness among rural populations. To this end it is fundamental to make manifest and measurable both natural capital stock and ecosystem flows associated to truffles. In this context, the evaluation of natural capital of a cultivated site located in Liguria (Northwestern Italy) is here proposed. Data were collected thanks to over 15 years of collaboration with a local truffle hunters' association. Results represent a first step in order to gradually obtain a mapping and safeguarding of the harvested areas (both natural and

cultivated) together with their natural capital and services provided, towards the enhancement of the truffle heritage.

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## 14. Environmental Accounting Using Emergy: How Do We Make It A Reality?

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Environmental accounting using emergy is examined with the intent to determine why its development over the past 26 years has not served to create a robust system of accounting that allows its general application to solve the difficult problems facing society with regard to the optimum use of resources to support production and to determine the efficacy of plans for the future development of innovations intended to improve the health of society. From an emergy perspective it is clear that accounting is the discipline needed to organize and understand the complex interactions of human economic needs with the resource use required to attain these ends. Furthermore, emergy accounting is also needed to judge the efficacy of any proposed developments, which will cause changes in the environmental systems supporting humanity. Emergy accounting requires the creation of combined balance sheets and income statements where the work of the environment and the work of human beings are both expressed in terms of emergy flows and also in terms of money flows, where such flows are appropriate. The work of people is denominated in emergy through establishing an equivalence between the work done by humans and the emergy of the education and training required to gain the skills to perform that work. The income statement and balance sheet of any system is thus expanded to include the emergy flows of human labor in the production function. The final result gives ExB, which is the total emdollar amount flowing in the expanded income statement.

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## 15. Emergy evaluation of circular economies: benefit allocation and significance of indicators

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Circular Economy (CE) is a model that aims at zero waste and pollution, throughout a product' lifecycles. CE, in principle, is a sustainable alternative to the widespread "take, make and dispose" economic model, optimizing the use of natural resources and favoring a prolonged use of natural resources and a reduction of wastes, in the direction of Daly's conditions for sustainable development. A growing emphasis is currently placed on if and how much this new development model can drive toward a better environmental performance overall, and for the stakeholders involved. Such information is vital to the maturation of the circular network: a proper assessment is needed to detect if a circular system produces lower impacts that a set of linear ones and to allocate the environmental benefits of circularity among its actors. There are several methods and indicators to evaluate the environmental performance of circular systems. However, the scientific literature has already pointed out that most of them are unable to catch the complexity of the systemic, closed-loop, feedback features of CE. EMergy evaluation is intrinsically a systems approach, a key aspect to properly address the possible advantages of circularity. Furthermore,

its algebra does not allow double counting of feedback flows, captures the interactions of system's components across scales, and quantifies, under a common unit, flows of a different nature. There are several examples of EMA applications to evaluate the environmental performance of circular systems. However, there is little discussion on the role of the single components of the circular network and on how to attribute the possible benefit deriving from circularity. We will address the following questions within emergy theory: is it possible to identify and quantify individual environmental advantages gained by the components of the CE network? Is it possible to ensure a win-win situation for each component of the systems? Do “traditional” emergy based indicators maintain their significance within a circular network?

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## 16. Energetic Analysis of Environmental Sustainability in Urban Orchards Based on Thermal Integral in Puebla, México.

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Vegetable food production in urban orchards is an option to improve the population's quality of life, according to the Sustainable Development Goals of the United Nations Development Programme; which was adopted in September 2015. The Agenda for Sustainable Development seeks to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture, as well as ensure healthy lives and promote well-being for all. Establishing an urban orchard would help families tolerate the social isolation of the pandemic by reducing stress on individuals and generating family interaction, making cities and human settlements inclusive, safe, resilient, and sustainable, as well as the preservation of the life of terrestrial ecosystems. As the global urban population continues to grow, the demand for natural resources to maintain human quality of life increases, which negatively impacts natural ecosystems and the survival of species to maintain environmental services. For this reason, it is necessary to measure the autonomy and sustainability of the Urban orchard system as an ecological system, to prioritize environmental management according to sustainable development. For this purpose, there are methods based on monetary value, excluding works in which nature provides environmental services that favor environmental sustainability. This investigation studies a model that allows an accurate environmental accounting that integrates natural and urban ecosystems, finding in the Emergy Analysis an innovative proposal based on thermodynamic concepts with autonomy analysis. The area of study is the city of Puebla, applying a five-phase methodology based on the Emergy analysis method. This research is intended to calculate the Rate of Emergy production - EYR, Environmental Load Index - ELR, and Environmental Sustainability Index - ESI, as well as the energy value of the Thermal Integral within the Urban orchard system.

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## 17. Applying Systems Principles to Natural Capital Accounts

**Elliott Campbell**
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The Biden administration released "A New National Strategy to Reflect Natural Assets on America's Balance Sheet" in August of 2022, representing an important step towards incorporating the value of nature into governmental decision making. However, this strategy is based on an anthropocentric way of thinking using economic quantification approaches. I suggest that application of systems principles and the emergy accounting approach would strengthen this national strategy by clarifying what assets to quantify, clearly considering both stocks (capital) and flows (services) and providing a system of asset accounting that relies on a common unit, the solar emjoule. I present a case study of this approach for the State of Maryland considering natural capital (forest biomass, surface water, ground water, wildlife stocks, fishery stocks, agricultural lands) and corresponding flows, presented as ecosystem services, (forest products, air quality, carbon sequestration, water consumption, wildlife harvest and existence value, fishery harvest, agricultural products and outdoor recreation). Environmental accounting indices are calculated to assess the relative value in emergy and dollar terms of the capital stocks and service flows along with if the capital is being utilized at a sustainable rate.

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## 18. Woodworking Facility

**Mickey Chapa, Qi Zhang, Alex Waegel, William W. Braham**.
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This paper describes the emergy analysis of improvements to a woodworking facility in a rural area adjacent to Philadelphia. The facility was built in stages over the last 50 years, testing a variety of novel and traditional methods of construction, mostly following the methods of light-weight Japanese construction. Each new building was constructed with individual systems, mostly burning oil for heat in the winter and using electricity to power equipment and control humidity, with only modest amounts of summer air conditioning. Emergy synthesis was used to analyze improvements to the facility to both reduce costs and greenhouse gas emissions. The facility was already preparing to install solar photo-voltaic panels on the site, which would reduce greenhouse gas emissions. The bulk of their energy usage is for heating, so the research question was whether it was more effective to improve the individual buildings, by sealing and insulating them, or to replace the heating and cooling systems with a water-loop and heat pump system. The basic system configuration is shown in Figure 1, with the water loop system showing Figure 2. An energy model was constructed for one of the buildings to evaluate the effect of improving insulation and reducing air infiltration, and the water loop and heat pump were assumed to draw from ground source wells, improving the COP to at least 5. Three options were considered, improvements to the buildings, the heat pump system, and the two combined. The clear result was that adding the ground source water loop and heat pump system yielded the greatest emergy reduction. The analysis did not include an estimate of the additional emergy for the materials of building renovation or the water loop. There is also an interesting question about how to account for the heat that is drawn from the water loop, which in a ground source configuration is delayed solar heat stored in the ground.

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## 19. Emergy evaluation reveals the potential of wood for a more sustainable building sector

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Cross laminated timber is a wood-based building material that can substitute traditional materials, like concrete. Life cycle assessment (LCA) has already shown that multiple environmental advantages can be obtained by substituting traditional materials with it, especially considering proper reuse and recycle pathways. In the context of the circular economy, this work aims to analyze i) the emergy required to obtain such material, ii) the role that renewable resources play in its provision, iii) the country-specific variability of these results, and iv) the differences between such material and the most traditional building materials that it can substitute in terms of emergy. We found that the UEV of the studied material is very sensitive to the sources of the national electricity grid and on the country-specific forest features (up to 50%). Renewable resources as well are affected by the geographic context considered, leading to %R values falling in a range with 30% of variability. Renewability is ensured if forests providing construction timber are allowed to regrow and if the lifetime of the constructed building is longer than the time it takes for regrowth – around 75 years in the case of spruce. Emergy evaluation reveals sustainability aspects that LCA studies cannot currently capture: for instance in LCA the role of forests is practically neglected, even for the part of absorption of CO2, according to ISO standards. Emergy, instead, provides insights on the key role that wood can play in the building sector, which presents major challenges in terms of sustainability.

# *Friday January 13, 2023*
# *Morning Session*

## 20. Evaluation of energy and environmental cost of photovoltaic cell and lithium-ion battery industry chains from a perspective of shared responsibility

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Within the rapid development of circular economy, lithium-ion batteries and photovoltaic cells, two key new energy-related products, may play a huge role in promoting the low-carbon transformation of economic society. This research focuses on China and Italy as case studies. China has become the world's biggest market in terms of production and consumption in these two key industrial products, while Italy has recently accelerated its transition to green energy paving the way to environmentally sound patterns of economic and social development in Europe. In particular, the fast development of electric cars adds to the demand for sustainable energy production (solar vs fossil) and efficient electricity storage (batteries), while also raising issues of shared responsibility concerning the actual worldwide availability of the needed minerals for such electronic devices. In fact, photovoltaic cells and lithium-ion batteries require a variety of resources in the manufacturing process, from raw material mining to intermediate products to final recycling, which raises issues of availability and environmental impacts. This study firstly systematically evaluates the industrial chain of photovoltaic cells and lithium-ion batteries production, then uses LCA databases to obtain and calibrate the needed process inventories (to be integrated with locally available industrial data), and finally applies the emergy accounting approach to calculate the biosphere scale environmental cost of production processes through selected multi-dimensional emergy indicators. Recycling options are also investigated within a circular economy perspective. The innovative aspects of the present study are: 1) Combining LCA and emergy accounting data, constructing the industrial chain framework of two key processes in the new energy industry, and developing an accounting model to consider direct and indirect resource consumption; 2) Comparing the resource and environmental benefits of manufacturing and recycling processes in two investigated industrial chains, based on constructed multidimensional indicators. 3) Deepening issues of shared responsibility for worldwide sustainable energy patterns, to include rare resources availability and shared benefits. Taking China and Italy as examples, this study compares and analyzes the viability and environmental sustainability of new energy-related electronic devices in support to vehicle and housing energy demand. The research aims at providing sustainability indicators and a policy framework as reference tools to policy makers, businesses and stakeholders.

## 21. Carbon emission accounting of biogas production system for power generation in China based on Emergy analysis

**Yufeng Sun[1*], Bin Yang[1], Yapeng Wang[1], Zipeng Zheng[1], Jinwei Wang[1], Yaping Yue[1], Wenlong Mu[1], Guangyin Xu[1], Jilai Ying[1]**
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Biogas production has become one of the main renewable energy utilization and waste management modes in Chinese rural areas. In this study, Life cycle assessment (LCA) method was employed to quantify the carbon emissions of the biogas production system based on the case of Weilai energy company, and emergy indicator system based on biogas production characteristics were set up to assess the relationship between the carbon emissions and resource flow. The calculated carbon emission results showed that the biogas production system emitted an average of 6.44 kgCO2eq carbon emissions in the process of utilizing one-ton agricultural waste, which were primally caused by the electricity consumption and fossil fuel from power generation phase. According to the emergy-based carbon emission indicator system, the ratio of total carbon emission to non-renewable resource (1.27E-10 gCO2eq/sej) was higher than that of the renewable resource (4.36E-11 gCO2eq/sej), which indicated that the carbon emission of the system was more depend on the resource acquisition of non-renewable resources. The emergy sustainability index (ESI) and the ratio of the ESI to the output carbon emission intensity (ESIY) were 3.59 and 1.31E-11 sej/gCO2eq, respectively. It was obviously that the system promised sustainable development ability in the case of mitigating carbon emissions.

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## 22. Emergy as a parameter to assess the sustainability of building materials

**A. Praveen,** Professor in Civil Engineering, APJ Addul Kalam Technological University, Kerala, India
**Bincy S,** Research Scholar in Civil Engineering, Rajiv Gandhi Institute of Technology, Kottayam, Kerala, India

Sustainability in resource supply is very essential to ensure undisturbed operations of construction sector especially in a developing economy. The excessive use of non-renewable energy, the over exploitation of natural materials and the exhaustion of abiotic mineral resources are the major problems often linked with the non-availability of resources to support the construction industry. As majority of resources used in the above-mentioned sector are directly extracted locally, framework to assess its environmental implications based on the quantity of resources consumed are needed to forecast the availability of natural material and to assess the technological choices to ensure the resource supply. Among the various techniques developed which utilizes thermodynamic principles for evaluating environmental sustainability, the Emergy analysis could include environmental work provided by the biosphere together with the energy used up in the formation of these resources. The study proposes a reliable indicator that could assess the consumptive pattern of resources in construction sector at a regional level. The variation of available emergy with cost of most widely used construction materials for 25 years is mapped to illicit the time scale impact of resource use pattern using the data collected from published sources. The mapped models indicate the ecosystem resilience, its ability to stabilize and provide a regular supply of resources. Emergy accumulated in the various constructed buildings are always accompanied by corresponding Emergy deficits that the ecosystem would have provided to undertake its various services. Thus, Emergy estimations of the building materials used in a region, based on the market information regarding its quantity procured through the markets, could also simultaneously provide the environmental impacts hence caused by them. The demonstration of these aspects is undertaken by choosing the material like sand which formed the major bulk of construction operations and also undertake various environmental services like ground water recharge, nutrient building, and the support to ecosystem productivity.

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## 23. Emergy-based bio-credit accounting method for biodiversity banking

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Following the United Nations post-2020 global biodiversity framework for the Convention on Biological Diversity, attention is being paid on how new goals and targets for biodiversity conservation and management can be addressed and achieved. Biodiversity offsets are used internationally to compensate for negative impacts of human activities on nature. However, successful biodiversity offsetting requires solving the first and key core puzzle, i.e. the quantification of biodiversity credit. This study attempts to establish a new biodiversity credit accounting framework in multiple ecosystem types (including woodland, grassland, and wetland), and to explore the effects of anthropogenic activities on habitat. We adopted the biodiversity assessment method (BAM) of New South Wales, Australia (ref 1-3), and the newly established three dimensions (potential, species, and human wellbeing) of emergy-based method to evaluate the biodiversity of 157 ecological projects with the total area of 2.46E+08m2. Results show that: 1) The total emergy-based bio-credit lift for whole set of projects from the three dimensions of potential, species and human well-being is respectively 4.96E+18 sej, 6.63E+18sej, and 7.30E+21 sej; 2) project area is the main influencing factor, although the project level, function, construction period and other elements are also critical; 3) In terms of credit lifts per unit area, greenway projects produce less credit than river and lake projects, while, in terms of credit lift per unit cost, greenway projects produce more credits; 4) The correlation of emergy-based credit and NSW bio-credit showed that R2 was greater than 0.86, which means the emergy-based credit is scientifically strong and it can be attributed a sufficient substitutability in quantitative calculation; 5) and finally, the comparison of credit per unit area among the projects shows that the emergy-based credit has more advantages in the differentiation of project types and the accuracy of measurement. The newly developed biodiversity accounting method has potential to provide a clearer picture of the lifts of biodiversity credits under the influence of a variety of biophysical factors and the combination of credits under different dimensions.

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## 24. Emergy-based Valuation of Constructed Wetland Ecosystem Services and Dis-services

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Climate change and urbanization are the hot topics of current environmental and social interests, with unprecedented city growth and more than 1/2 (around 56%) population living in built-up regions. This rate is growing fast and is expected to reach 68% by 2050. As a consequence, swift urbanization is putting huge pressure on wild ecosystems, among which the natural wetlands. Thus, green and blue infrastructures (indicated as GBI hereafter) such as constructed wetlands have been suggested to emulate and replace the functions of natural wetlands. At the complex and smallest scale, constructed wetlands (such as vertical-flow constructed wetland (CW), horizontal-flow CW, free-water surface CW, and hybrid-CW) can be designed to treat grey or toilet water for a small society, but larger GBIs are not limited to this kind of treatment service, being specially designed for water purification. So, we selected eight constructed wetlands that are located around Beijing, and evaluated their ecosystem services (ES), avoided costs for human health and biodiversity damage, growing/maintenance costs, and dis-services by means of an emergy-based assessment procedure. Results show that all constructed wetlands have the ability to purify the wastewater nutrients (e.g., TN, TP, and TSS), while the integrated vertical subsurface flow CW (considered as CW-4 which is located in Olympic forest park) show a much larger wastewater purification capability (1.76E+14 sej/m2/yr respectively) in comparison with other constructed wetlands (such as 6.78E+13 sej/m2/yr, and 2.08E+13 sej/m2/yr respectively). Further, constructed wetlands have been noted not only to improve the quality of wastewater, but also have the potential to mitigate flood, and groundwater recharge, as well as to protect wildlife habitats, while at the same time being capable to sequestrate carbon in a like manner as natural wetlands. However, designing CWs for cities is not exempt from significant problems like greenhouse gases emission, green waste, mosquito issues, and some disorders in the surrounding built-up area, which is very harmful to urban residents. These not-negligible wetland challenges could be solved by suitable CW design and management. In the present study, we compared ecosystem services, disservices, and construction or maintenance costs through a ternary phase diagram: results show that all constructed wetlands provide more benefits compared to costs and impacts. It was also found that CW-4 (integrated vertical subsurface flow CW) represents maximum benefits of 50%, compared to costs and impacts but CW-3 (free water surface CW is located at Wildlife Rescue and Rehabilitation) represents minimum benefits (around 38%) when we compare with other wetlands, and their impacts and cost are about 25% and 37%. In conclusion, results suggest that the emergy approach is a very reliable method to assess the quality of constructed wetlands, to be used by policymakers as a tool for the selection of constructed wetlands in urban zones, for better ecological management.

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### 25. Ecosystem services valuation for shipping impacts to Indonesian coral reefs

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Ifcom consulting

Indonesian is the world's largest Archipelagic state. A large percentage of global shipping passing through these waters and 20-30 grounding incidents occur each year. A good number occur on coral reefs. The resulting insurance compensation outcomes have been highly variable however partly due to the valuation methods and ecosystem services claimed. This article looks at the contentious 2017 Caledonian Sky grounding in Raja Ampat. It has languished without resolution mostly on account of the huge compensation discrepancy between the Parties. An Emergy ecosystem services valuation was done by both Parties in 2022 to help resolve the impasse. Results show highest ecosystem service valuation for 'image': the information storage for the reef

in genetic diversity, local community management and international reputation of the area for global tourism.

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## 26. Towards international standardization for emergy accounting

**Benedetto Rugani, Antonino Marvuglia**, **Tomás Navarrete Gutierrez, Enrico Benetto**
Luxembourg Institute of Science and Technology (LIST)

Emergy accounting (EMA) has been applied in numerous cases of public and private organisations interested in using emergy-based indicators to assess their production performances and sustainability. However, the creation of an international standard for EMA to guide those organisations towards better environmental awareness and improvement has not been consolidated so far. Here we explore the potential of emergy as an impact assessment indicator (similarly to well-known indicators in the field of life cycle assessment-LCA, or the ecological footprint) and prospect the possibility to create a new "work item" dedicated to emergy within an existing Technical Committee (TC) in the International Organization for Standardization (ISO). In order to gather some evidence about the international interest towards EMA, we realised a market study as a combination of an online survey (distributed in Europe and is USA, China and Brazil) and a desk research. The survey was addressed to emergy scholars, as well as stakeholders from companies worldwide already registered to EMAS, or having a certification ISO 14001 or 14025. In collaboration with ILNAS (Luxembourg Institute for Standardisation, Accreditation, Security and Quality of Products and Services) we prepared and submitted to the Secretariat of the scientific committee SC 05 (French member AFNOR) a New Work Item Proposal (NWIP) on the "Principles and framework for emergy evaluation". Delivering a methodological standard within this committee allows benefiting from the established recognition of the ISO 14000 series, given that EMA and its evaluation approach can be "methodologically" linked to some of the existing standards for LCA, such as ISO 14040 and ISO 14044, as a new metric for life cycle inventory and/or impact assessment. After meeting with representatives from the Subcommittee ISO/TC207/SC5 responsible for ISO Standards as 14040, 14044, 14045, 14046 etc. the emergy topic was considered pertinent enough and potentially valuable for consideration as a Technical Specification (TS) within the SC5, useful for a discussion within the existing working group (WG) 12 on LCA. In synthesis, the emergy method and its introduction within the ISO standardisation framework of LCA is considered fully realistic by the SC5, and the WG 12 is deemed to be the most fitting environment for hosting the NWIP. Additional members from the emergy community should be involved to take part in the WG 12 activities and facilitate the NWIP to be voted within the ballots session. To this end, LIST has already many contacts within the international emergy community, which will be shared within the group. If a new working group is initiated, a tailored international network of interested stakeholders (from both academic, policy and industrial sectors) will be created to specifically work on it, under the technical coordination of LIST.

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## 27. Sustainable and resilient agriculture for human wellbeing. The case of tomato (Solanum lycopersicum, L) production worldwide.

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Tomato (Solanum lycopersicum, L) production is one of the most relevant food vegetables, with 16.27% of global production volume, followed by onion with 9%. Tomatoes provide health benefits attributed mainly to their antioxidant content among other contributions. It can be eaten as fruit or vegetable, either fresh or processed (this last manufacturing represents 20.5% of worldwide total tomato production). China is the highest producer with 35% of total world tomato production (186,918,865 t) followed by India, Turkey and USA. Tomato production has some key limiting factors such as water availability and temperature that can impact along the progress of the crop and its yield. Therefore, its production either at field or greenhouse, implies demand of labor and resources (infrastructure, energy for heating and irrigation, water, nutrients, among others), which generate impacts on the environment. These production consequences drive the need to analyze its sustainable and resilience practices in order to promote further and viable production. Sustainability and resilience are complementary aspects that need to be understood in order to promote appropriate production systems and agricultural policy making. This study applies the emergy approach to understand resource demand in the different production systems in selected parts of the world. Recent tomato production processes in Iran, Italy and Argentina (2022) will be compared with previous studies in other countries such as Sweden, France, and Canada. The emergy approach allows the calculation of a set of multidimensional indicators capable to highlight the best production practices (land use, water use, fertilizing and crop rotation options) and suggest improvements. Appropriate use of agricultural and industrial manufacturing residues is also assessed, within a circular economy framework.

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## 28. Emergy of Coalition and Drama Triangle Cycling

**Dennis G. Collins**

UPR-Mayaguez (retired)

The talk will discuss estimating emergy for cases of coalition and drama triangle cycling. For example, a fox represents a certain chaining together of molecules while the fox is alive, representing a decrease of entropy versus random molecules and an increase of emergy. Similarly, a coalition represents a chaining together of activities, causing a decrease of entropy versus each member going their own way and an increase of emergy due to the efforts to pull the coalition together. Drama triangle cycling typically reflects a coalition coming apart due to conflicts. Here four cases are studied: Julius Caesar triumvirate, Augustus Caesar Triumvirate, War II Big Three, and Cuban missile crisis (Norman Cousins "The Improbable Triumvirate"), with periods 12, 18, 30 and 3 years and their emergy considered. An Odum student considered the US Civil War.

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## 29. Analysis of the Sustainability of the Urban Mobility Alternatives in Tuxtla Gutiérrez, Chiapas.

**Wilber Armando Ramos Palacios, Hugo Alejandro Guillén Trujillo.**
Universidad Autónoma de Chiapas, Facultad de Ingeniería Civil (FIC), México.

In recent years the demand of the urban mobility sector has become of a particular interest. The high dependency on mobility and the excessive use of cars in urban areas are matters of concern because the transportation systems are led to unsustainable scenarios. These scenarios make long-term planning very important to help to reverse this growing tendency. There must be an integrated planning based on the development of strategies according to indicators that show if sustainable urban mobility is really sought, while at the same time maximizing its positive effects and minimizing the negative ones. This paper proposes a new method for the calculating of such indexes and sustainability relationship for the long-term decision making, in order to achieve sustainable urban mobility scenarios. You may find a methodical analysis of the flows that intervene in the dynamic functioning principles of urban mobility and its different alternatives, applying emergetic values to the different components to quantify them in identical measurements. With this evaluation we attempt to know the emergetic flows and deposits of the different mobility alternatives. The sustainability indices and other correlations that indicate the degree of dependence on urban mobility were also calculated, the results are shown graphically. Finally, an analysis of the environmental burden is presented, showing how environmentally friendly the current urban mobility system can be.

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## 30. A systems thinking emergy-based perspective of soil interactions for plant nutrient uptake optimization by crops

**L. Conte, S. Cristiano, F. Gonella, M. Signoretto**
Università Ca' Foscari, Venezia, Italy

Nitrogen (N), phosphor (P) and potassium (K) are necessary elements for plant nutrition and play a pivotal role in agriculture, with N being often a rate-limiting element in plant growth [1]. Global demand for N, P and K fertilizers is currently 198.2 Mt, but projected to reach 208 Mt in 2026 [2]. However, the current fertilizing practices are mostly inefficient, as up to 50% of N can be lost in the environment after the application [3]. In this context, the optimization of nutrient uptake by plants could reduce losses, so as to at least mitigate the increasing demand for these limited resources [2]. Many soil bacteria were extensively proven to improve nutrient availability to plants, to directly stimulate plant growth and stress tolerance, and to enhance crops resistance to pathogens [4]. However, many of the current agricultural practices threaten the preservation of soil properties that are necessary for the effective nutrient rotation and overall soil health [5]. Indeed, market-oriented actions to maximize production in the short term may miss a wider look at the ecological systems in which farming is necessarily framed, thus affecting medium- and long-term sustainability. To overcome such shortcomings, Systems Thinking (ST) and Emergy Assessment (EMA) were reported as useful tools to evaluate the environmental loading of current agricultural practices [6]. This study aims at identifying soil networks involved in plant nutrient uptake processes, in order to clarify the potential role of bio-fertilizers in agriculture, at the same time addressing the best agricultural practices for a more sustainable management of agricultural soil in the long run. Therefore, ST and EMA are applied to comparatively estimate the environmental costs of soil systems managed using (a) conventional agricultural practices (i.e. industrial fertilizers, tillage) and (b) alternative agricultural practices (i.e. bio-fertilizers).

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## *Friday January 13, 2023*
## *Afternoon Session*

### 31. The Unit Emergy Value (UEV) Library for Characterizing Environmental Support in Life Cycle Assessment

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[6] U.S. Environmental Protection Agency

Life cycle assessment (LCA) has been extensively used to assess the potential environmental impacts of goods and services over their full life cycles. The traditional environmental impacts in LCA have been focused on impacts of emissions with limited information regarding the impacts of resource uses such as fossil fuel, minerals, land, water and soil. It is critical to not only quantify the impact of uses of these resources in LCA, but capture the environmental inputs to these resources. 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 emergy synthesis. Emergy is defined as the available energy of one kind used up to directly and indirectly make and sustain a resource. Emergy values can estimate the value of renewable and nonrenewable resources in a common energy unit (solar emjoule, sej). In this presentation, we will introduce a library of unit emergy values that was developed for quantification of the environmental support associated with elementary resource use in emergy accounting and LCA studies. A complete list of elementary resource flows from two major LCA commercial databases — Ecoinvent v2.2, 2010 and GaBi v4, 2010 —were extracted and analyzed. The library provides emergy characterization factors (EmCFs) for different types of renewable energy sources, minerals and metals, land use, water use, biomass, soils, and fossil fuels. The EmCFs rest on a common set of estimates and assumptions regarding geobiosphere processes and were calculated in a dynamic model from the ground-up according to consistent algebra, rules and assumptions. Any changes to an underlying estimate or assumption (such as the value of the global emergy baseline) will propagate through the library to update all the factors and avoid any human errors such as typos. The EmCF library will provide a consensus set of emergy values for

emergy accounting, LCA and various other analyses. The global emergy baseline used in this report is 1.2 E25 seJ/y.

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## 32. The assessment of the overcoming of environmental carrying capacity due to tourist flows in an Italian bay

**Rigo I.[1], Paoli C.[1,2], Bordoni R.[1,2] ,Cappanera V.[3], Dapueto G.[1,2], Merotto L[3], Povero P.[1,2], Venturini S.[3], Vassallo P.[1,2]**

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Marine Protected Areas (MPAs) play a major role as destination of seasonal tourism all over the world but ask for particular attention to minimize threats for the natural environment due to uncontrolled tourism flows. Managing the tourism pressures and developing sustainable management strategies entail the acknowledge of the tourism flow and of the carrying capacity of the area. The carrying capacity represents the ecosystem limits, i.e. the maximum number of people that can visit simultaneously a tourist destination without causing impacts to the physical, economic and socio-cultural environment. In this regard, a model to monitor and predict the tourism flow is proposed and applied to San Fruttuoso bay (Portofino MPA - NW Italy), to warn when the carrying capacity is exceeded. During 2018, data regarding tourists' presence in the bay were collected and analyzed via Random Forest regression to investigate which variables influence the tourist flow. Additionally, emergy analysis was applied based on data obtained from questionnaires to estimate the environmental impact of tourists and to compare tourists' resources consumption and the resources offered by the bay. This model highlights an increased attendance of the bay from mid-day to early afternoon (12am-3pm) mainly during August, month in which around 53% of tourists experienced an excessive number of people in the bay, which negatively affected the perceived level of satisfaction. The carrying capacity of the bay was, on average, overcome by twice and, although 30% of the interviewees were willing to pay an annual financial contribution to the MPA management, it would not be enough to offset the overcoming resource demands. Therefore, this study suggests a good forecasting tool to regulate access to the bay, also to avoid exceeding the carrying capacity in a context of management and protection of the study area.

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## 33. MIXED production at the landscape level: an emergy assessment on different agricultural systems under the same management.

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Mixed production – integrated crop-livestock system - at farm scale level is decreasing due to obstacles as costs associated to livestock, decrease on knowledge and changes in regulations (Guillaume et al 2016). On the other hand, mixed production at a landscape level is an interesting way to develop new synergies and to promote socioeconomic benefits to the farmers. Through a spatial organization and land-use allocations it allows several economic opportunities. By

promoting these synergies between farms, it enables the enlargement of product scope and the exchange and reutilisation of materials (i.e., feed, tools, machinery). Montado is a typical Mediterranean extensive silvo-pastoral system with cork and holm oak production and animal grazing. In Alentejo, south Portugal, it is common for farmers to have different farms to offset modifications in regulations – in particular subsidies - and conventional market price fluctuations of different products. In this study, we are evaluating three different farms under the same owner: two farms with Montado and an olive and hay production farm. The first farm produces sheep and the second cattle and pig fattening, both with cork production. Between these three farms, there is a direct raw materials exchange and a temporal and spatial integration between them. Allowing several management conducts to be held depending on actual conditions - both external and internal to the farms. To address these complex systems at a landscape level, we did an emergy assessment to measure and understand its economic, social, and ecologic contributions and implications.

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### 34. The Curse of Technocratic Optimism

**Patrick Kangas**
University of Maryland

In 1988 Peter Taylor, an ecologist turned historian, wrote a paper in which he characterized H. T. Odum's research as an example of a syndrome he described as Technocratic Optimism. This was essentially a derogatory label that, among other things, tied Odum's work to a failed political movement from the early 1900s that had advocated a utopian form of biophysical determinism. In this paper the effect of Taylor's paper on the long-term impact of Odum's energy systems research is explored. A review of the literature suggests that at least a segment of academia has used Taylor's paper to dismiss the contribution of Odum's approach to environmental science and to public policy decision-making. The ways this dismissal might be considered short-sided are discussed and a model diagram of the situation is proposed. Speculations are made on the significance of Taylor's paper to Odum's legacy and to the mission of the Emergy Society.

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### 35. Bioclimatic analysis of location

**William W. Braham**
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Bioclimatic design emerged as an architectural practice in 1963 with the publication of Design with Climate: A Bioclimatic Approach to Architectural Regionalism. It reframed architectural design as the tempering of the local climate to produce a microclimate comfortable to human biology. It has evolved into a standardized form of pre-design analysis, but as currently practiced it overlooks many aspects of local environmental potential and omits any account of the highly concentrated resources that ultimately provide much of the environmental control in contemporary buildings. This paper describes two levels of an expanded bioclimatic method, accounting for the environmental potentials available at a building site. In the first instance it is expanded from conventionally tracked environmental inputs such as solar radiation, wind, and rain to include local heat sources and sinks, such as ground and sky temperatures, and ambient evaporative potential. Since these heat reservoirs are largely steps in the dissipation of incident solar radiation, their emergy intensity is very low. In the second instance the method is expanded to include an account

of local and imported products and services. The analysis uses basic energy analysis of the microclimate and emergy accounting to determine the relative environmental intensity of the different affordances, to serve as a guide for early decision making in design. The Ellis House in suburban Philadelphia is used as a case study, and by expanding the pre-design assessment it makes explicit the choices between resources of different intensity. The choice is between the use of sophisticated, high-intensity control systems capable of navigating the rhythms of the local microclimate, and the dissipation of concentrated resources, like fuels, electricity, and refined materials, to maintain the interior climate. Emergy synthesis provides valuable criteria for evaluating the different environmental potentials present at a location.

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### 36. Integrated Emergy Accounting-LCA approach to prevent environmental impacts and promote environmental and circular economy benefits. The case of leather production.

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The three pillars of sustainable development (economic, social, and environmental) must be managed in an interactive and integrated way to promote systemic changes towards humankind and other species' well-being. Actions towards sustainability must be evaluated from multiple perspectives to account for different dimensions of sustainability and well-being, minimizing the risks of addressing complex systems and circular patterns from a unidimensional point of view. Emergy Accounting (EMA) lends itself as a tool to evaluate the performance of systems and processes by linking natural resources to economic dynamics as well as social and environmental balance, sustainability, and resilience. EMA captures the environmental load of a process quantifying the use of non-renewable versus renewable resources, suggesting a measure of a process's distance from environmental equilibrium. EMA's ability to evaluate circular patterns of recovery, reuse, and recycle, or more in general on waste valorization, is enhanced by the appropriate use of the emergy algebra and by integration with other environmental accounting and statistical methods. In this study, leather production in Southern Italy is evaluated through EMA and Life Cycle Assessment (LCA) in a sequential and integrated framework, followed by a structured statistical scenario analysis. A preliminary, ex-ante LCA evaluation of leather production identified some chemicals and water consumption as main hotspots. Improvement scenarios were proposed and assessed through EMA to understand the environmental cost of these potential solutions. Afterwards, an ex-post LCA of all scenarios helped understand which scenario actually removed the hotspots, at least partially. The results of this integrated assessment can have research, managerial and policy implications as they are the starting point of a critical statistical investigation to deliver (i) an improvement of EMA's algebra robustness, (ii) the validation of EMA's assessment of circular economy practices, and (iii) the creation of a policy-making framework based on a comprehensive integrated evaluation.

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### 37. A Comparison of Emergy, Exergy, Entropy and Carbon Accounting: Histories, Definitions, Methodologies, Significance and Synergies

**Mark Ciotola**
San Francisco State University

This paper identifies, compares and discusses various forms of energy accounting. Emergy, Exergy, and Entropy and Accounting are each a type of energy accounting. Carbon Accounting is a proxy for energy accounting in that it often accounts for particular forms of energy, such as the use of fossil fuels. All four of these types are considered and analyzed. Energy accounting efforts have taken place since the early 20th century. Government and industry actors have tracked energy reserves and usage for purposes of strategy, distribution and taxation. Ecologists have tracked emergy for several decades, developing increasingly sophisticated methodologies. Physical scientists, engineers and supporting activists created a North American exergy survey beginning in the 1910s and revisited this effort at Columbia University during the Great Depression. Entropy accounting has been discussed for use for socio-economic, environmental and historical analysis, including in the World Systems community. Carbon accounting gained popularity in the early 2000s during concern about global warming and climate change. These are all different communities who don't communicate much to each other. This project is intended to act, in a small way, as a “Rosetta Stone" between these communities. A history of the development, definitions and uses of each methodology are provided. An analysis of the significance of each accounting type is presented. Synergies between the forms are discussed.

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## 38. The environmental benefits of using secondary materials in industrial processes. An application of the Emergy accounting approach within a circular economy framework.

**Viglia S. *, Carletti R. *, De Marco E. *, La Monica M. *, Mancuso E. *, Cutaia L. ***
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It is widely accepted that the linear economy model should be replaced by a new, so-called Circular Economy (CE) model. Nevertheless, despite the efforts placed at international and national levels, the amount of waste generated is not decreasing. Economic activities in Europe produce in one year about 2.5 billion metric tons (or 5 metric tons per capita a year), and each citizen produces on average approximately half a metric ton of municipal waste per year. To implement the transition towards CE, the valorization of Secondary Raw Materials (SRMs) is a crucial step. SRMs face several challenges in competing with Primary Raw Materials (PRMs), not only because of their present lower availability but also because their recovery/refining processes are most often characterized by lower performances and higher costs. The use of SRMs rather than PRMs can contribute to increase the environmental sustainability at global scale, when the overall energy used for the extraction, valorization, refining, and processing of PRMs is lower than the energy used to collect scraps and wastes (which is seen as “generation point” of SRMs) through the following steps of transformation and refining. Moreover, particular attention should be made to considering the transport phases both for PRMs and SRMs. It is, therefore, crucial to analyze, measure and compare the environmental impacts of PRMs and SRMs to identify both bottlenecks and benefits of using SRMs and suggest potential improvements. This research aims at exploring the suitability of the Emergy Accounting method in highlighting the most promising SRMs and capturing the environmental benefits of CE at a wider scale, beyond unidimensional evaluations and volatile economic values dictated by market dynamics. Selected secondary materials are investigated as case studies towards a standardized procedure in support to sustainable CE implementation.

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# *Saturday January 14, 2023*
# *Morning Session*

## 39. How blockchain thinking helps Emergy Accounting

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Emergy Accounting (EMA) is one of the effective methods for natural resources evaluation. It aims to quantify the contribution of natural resources to the economic system to reflect the system's sustainability. It also can reflect the total amount of resources used for production to provide insights into natural resource demand and management. EMA has been popularly applied at national, regional, and industrial levels during the last two decades. Researchers tried to propose relevant improvements according to the evaluation results of EMA. However, linking evaluation results with actual policymaking is still very difficult, due to the uncertainty that still characterizes results and calculated indicators. It should be noted that uncertainty is an intrinsic feature of natural evolution, driving its “trial and error” dynamics. The quality of original data (the mass or joule value of products) and appropriate Unit Emergy Values (UEVs) are fundamental and essential for EMA. However, there are many challenges to these two types of data. For instance, sometimes, the original data is not available and needs estimates. Another situation is the difficulty to confirm the accuracy of the statistical information, even in public data. Such poor data quality is typical in developing and underdeveloped countries, although mistakes are also possible in more sophisticated accounting systems. Concerning UEV values, published UEV values are limited, so that the current UEV database cannot satisfy the requirements for accounting at diversity levels. Even though the UEV of the product is available, sometimes it is difficult to identify the boundary of this UEV calculation. Such a difficulty would add to the risk of “double accounting”. All these above situations may add uncertainty to the achieved emergy results. Blockchain technology is prevalent in digital management. It can help the different stakeholders solve the original data issues and promote the quality of governance. In terms of its notable characteristics, such as decentralized network, transparency, trustworthiness, immutability, and traceability, it has received particular attention in Agri-Food and Food supply chain management, Natural resource management, Climate change, energy management, and Products and industrial management. According to the literature review, there are not yet published results dealing with blockchain theory application to EMA. Under such circumstances, we try to fill this gap in the present study. The contribution of our work is to find solutions for data availability and uncertainty in EMA in order to improve the quality of its results and provide helpful information to policymakers.

## 40. Promoting coordinated development of a fertilizer production-crop plantation combined system through an integrated emergy-economic-carbon assessment

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Related studies have not been found to address whether controlled-release urea (CRU) can promote coordinated development of crop production based on higher energy efficiency, lower carbon emission intensity, improved environmental performance and economic benefits from fertilizer production to crop plantation. Results could affect reasonable utilization of CRU thanks to a broader picture of the whole production chain, leading to adequate decision-making. This study proposes an integrated set of evaluation approaches, to identify the trade-off between long-run sustainability of crop production and short-term gains of stakeholders. The integrated roadmap includes emergy accounting, economic assessment as well as carbon emission and energy consumption aspects and related indexes. The presented approach was applied to a study case, from Sichuan Province, China, based on three fertilization schemes, i.e., N1 ( single CU ), N2 (single CRU ), and N3 (blend application of 60% CRU and 40% CU) with the expanded analysis boundary from N fertilizer production to its application in rice plantation.. Results suggest that: (1) from energy and economic perspectives, introduction of CRU increases energy efficiency, production efficiency and economic benefit; (2) emergy indicators reveal the CRU application enhances environmental sustainability but increases the environmental load; (3) comprehensive analysis shows that urea application rates affect rice growth: N2 realizes the best-coordinated development, followed by N3 and N1. Mitigating carbon emissions should be emphasized when popularizing CRU use in rice production.

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## 41. Understanding Ecological Engineering Restoration Potential: The Role of Topography Constraints

**Qing Yang[1], Gengyuan Liu[2,*], Zhifeng Yang[3,*]**

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Ecological restoration still is considered as the most feasible way to mitigate climate change and conserve ecosystems. However, the magnitude, intensity, effectiveness and potential of revegetation restoration are restricted by adverse environments, particularly water resource and topography. This study proposes an assessment framework of ecological restoration potential under the coupled limits of water resource and slope gradient, to assess the potential of future revegetation room under multiple limiting factors. Results indicate that 20%, 0.19% and 32% of the area of China's 31 provinces have their vegetation plantation intensity above, equal and below local vegetation threshold allowed by local water resource respectively under the current socio-economic and ecological water use efficiency. The achieved results suggest an additional revegetation potential of about 0.299 billion ha. The ecological restoration potential under the integrated constraints of water resource and slope gradient is 0.4 Pg C, less than half (47%) of the potential (0.856 Pg C) under the single limit of water resource. However, this potential and China's existing carbon sink capacity related to terrestrial ecosystems is estimated to offset up to 8% of its current carbon dioxide emissions. Ecological restoration programs in areas with slope larger than 5° needs extra significant economic investment, which is estimated average around 217 trillion yuan, from supporting Soil and Water Conservation programs. Future sustainable ecological restoration actions need the integration of process-based assessments, field investigations, landscape design, etc. This study can provide technical support for quantitatively assessing ecological restoration potential under the dual limits of water resources and slope gradient, and guidance for sustainable ecological restoration implementation.

## 42. Effects of canopy and understory N addition on the ecosystem services of a subtropical forest

**Yang Tian[a,b], Lang Zhou[a,c] , Yongbiao Lin[a,b], Jun Wang[a], Hai Ren[a*], Hongfang Lu[a,b*]**

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Although atmosphere N deposition addition has been considered as one of the key global changes threating ecological balance in subtropical area, the effects of it on regional forest ecosystem services was kept unclear. In this study, the “People's Republic of China Forestry Standard: Forest Ecosystem Service Valuation Norms” was applied to measure each of the support (soil conservation, nutrient accumulation in biomass) and regulate services (water conservation and carbon sequestration and oxygen release) provided by a subtropical forest under canopy and understory N additions. Then, the total support and regulate services were determined and compared after converted to solar emergy by multiplying with suitable UEVs. Our results found that 6 years N addition significantly promoted the service of nutrient accumulation in biomass (plant N and P conservation), but tend to decrease the service of soil N and P conservation, which finally caused no significant change of the total support service. These results revealed that the relationship between above-ground and underground nutrient accumulation services of subtropical forest was converted from synergy to tradeoff. The service of carbon sequestration and oxygen release decreased significantly under N addition. As the most valuated ecosystem service in the subtropical forest, water conservation was not affected by N addition and sustain a pretty stable status. Due to two orders of magnitude larger of water conservation than carbon sequestration and oxygen release, the total regulate service was not affected by N addition. Canopy and understory N addition had different effects on the service of nutrient accumulation in biomass and carbon sequestration and oxygen release, which indicates the important function of forest canopy on maintain ecosystem services provided by plant community and the simulated method by adding N above canopy was needed to explore the accurate effects of N deposition on the forest ecosystem.

## 43. Emergy-based evaluation of world coastal ecosystem services

**Chang Liu[1], Gengyuan Liu[1,2]**

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The current lack of research on the evaluation of marine ecosystem services makes the value of marine protection, development and restoration underestimated during the decision-making process. Based on the non-monetary ecosystem service evaluation framework, a marine ecosystem service classification and accounting method has been established in this study, and the world’s coastal ecosystem services have been measured as an example. The results show

that (1) the world's coastal ecosystem service value is about 4.13E+23 sej/yr, of which Asia and North America contribute about 55% of the total service value; (2) the top ten countries in terms of the world's coastal ecosystem service values are Canada, Indonesia, Australia, the United States, Brazil, the Russian Federation, Norway, the Philippines, Mexico, and China, which contribute about 60% of the total service value; (3) estuaries have the highest ecosystem service values, followed by mangroves, seagrass beds, tidal flats, salt marshes, and warm water coral reefs; (4) developed countries can make better use of their coastal resources and pay more attention to the marine protection while the opposite is true in developing countries, which means that developed countries still occupy an advantageous position in the process of marine protection, development and utilization. This study assesses the coastal ecosystem service values in various coastal countries from the perspective of ecosystem contributors, emphasizes the importance of protecting them in marine management, and provides a certain reference basis and theoretical support for decision-makers in formulating marine-related protection and development strategies.

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### 44. Dialogue between Scientific Perspectives in the Light of the Maximum Meta-Ordinality Principle: The Case Study of EMA and MOP

**Corrado Ginnantoni**
Rome Italy

EMA and MOP can be considered as being Two "Brother" Scientific Approaches, because they refer to the same H.T. Odum's General Scientific Perspective, based on the "Innovative Concept" of Emergy and the Maximum Em-Power Principle (MEmPP), which has successively been characterized by some further contributions and formal improvements. On the one hand, for example, and among others, the rigorous definition of the "Rules of Emergy Algebra" (Brown & Herendeen, 1996) and the Mathematical Formulation of the MEmPP (Giannantoni 2002). On the other hand, the formulation of the "Rules of Emergy Algebra" in terms of "Incipient" Derivatives (Ginnantoni 2004 on) and the re-proposition of the MEmPP in terms of the Maximum Ordinality Principle (MOP) (Giannantoni 2010).
The "Dialogue" between such Two Scientific Perspectives can surely be developed on the basis of the *Maximum Meta-Ordinality Principle* (MMOP), which is nothing but the re-proposition of the Fundamental *Phenomenological* Generative Processes of Emergy Analysis (Inter-Action, Co-production, Feed-Back), at a *Gnoseological* Level, that is with reference to the Two corresponding "Gnosiological Perspectives" in Dialogue.
As an introductory example of such form of Dialogue at a Gnosiological Level, the Paper will consider the Dialogue between the *subjacent* Perspective to the Description of the Solar System based on Bode's Law (1772) and, respectively, the *subjacent* Perspective to the Description of the same Solar System obtained the basis of the MOP (Giannantoni 2017). The "Exits" of such an example of "Dialogue" will represent a sort of "Reference Guide" for the Analysis of the Case Study of Interest. With respect to which the Author, after having drawn some preliminary Over-Conclusions, will invite the Readers and, in particular, the Emergy Experts, to an active collaboration and participation to such a Dialogue, in order to get all the other Over-Conclusions that already appear as being obtainable, and easily achievable. This is precisely because the Author would like to *Over-conclude* the Analysis in the same atmosphere of "Dialogue" as initially proposed and formulated.

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## 45. Circular economy – options how to include emergy accountings and principles in an urban metabolism case study in Sweden

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Circular economy is an increasingly used concept. In the city of Östersund in the mid Sweden region, an "Urban metabolism" project has recently been started, and a coming case study will address circular economy aspects and options. This paper explores possible use of emergy accounting and principles in this context. The applicability of the following will be investigated in the Östersund project: 1) the suggested performance and efficiency ratios by Brown and Buranakarn (2003): Recycle Benefit Ratio (RBR), Recycle Yield Ratio (RYR), Landfill to Recycle Ratio (LRR), Recycle Efficiency Ratio (RER); and 2) the suggested accounting principles for recycle pathways suggested by Brown (2015).

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## 46. Emergy, urban and regional planning, and architectural design: some steps forward

**Silvio Cristiano**[1] & **TAMassociati**[2]
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Increasing urbanisation, urban metabolism, and "smart" buildings are often considered as inescapable trends, when not quite improbable solutions to the ongoing ecological crisis. Scholar arguments start to timidly flourish about the ideal features of yet context-dependent human settlements and housing in an era of resource scarcity and galloping climate change. Nevertheless, advancements in emergy theory and applications have not shown the same rhythm in urban and regional planning and in architectural design as rather in measuring cleaner production in the industrial sector. After Odum's and Peterson's proto-emergy discourses on energy, complexity, and planning in the 1970s, after the emergy studies on buildings and building materials earlier in the 2000s, and after Srinivasan's and Moe's monograph and the most recent applications to hospitals in deprived geographical contexts, some ongoing developments are presented in the application of emergy research to architectural design and spatial planning. On top of recent calculations, a roadmap is proposed for the construction of dedicated databased (a design- and planning-oriented Emergy Information System) and intelligible tools to support decision-making, adapted from recent proposals based on different approaches and potentially integrateable into leading professional software environments.

# *Saturday January 14, 2023*
# *Afternoon Session*

## 47. Urban metabolism and emergy of China's cities

**Miaohan Tang[1,2], Jingke Hong[1*], Yuli Shan[3*], Rui Xue[4], Franco Ruzzenenti[3], Wentao Wang[5], Klaus Hubacek[3*]**

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Unprecedented pace of urbanization and industrialization caused a massive increase in China's urban metabolic pressure. The trend presents an urgent challenge for detailing the long-term changes and disparities in urban metabolic performances in a wide range of cities. Here, we present empirical evidence of 283 China's cities from 2000 to 2018 based on emergy analysis indicating that China's urban metabolic performance gradually becomes worse. For example, the environmental sustainability index decreased by 81.64% between 2000 and 2018. In addition, emergy-based performances among China's cities show considerable differences. Agricultural cities and light manufacturing cities have better sustainability; energy production cities face high environmental pressure. Scenarios for 2025 show that total emergy use would experience slower growth; and most cities continue their decline in emergy metabolism. To ensure overall progress on urban metabolic performance, heavy manufacturing cities and energy production cities should give more attention in adjusting emergy structure.

## 48. From emergy synthesis and UEVs of agriproducts to database, labelling, and eco-Score

**Federico M. Pulselli[1], Matteo Maccanti[1], Gaia Esposito[2], Valentina Niccolucci[1], Marlyse Meffo Kemda[1], Nadia Marchettini[1]**

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The agri-food sector has significant impacts on the environment due to resource use, land occupation, GHG emission, impact generation; globally, at least 38% of the soil is dedicated to agriculture, and the development of different approaches to food production is now essential. Moreover, finding the most suitable ways to drive sustainable agriculture is one of the targets of the SDG#2 of the UN-Agenda 2030. The work we present is part of a two-year project called 'The Sun in The Plate', funded by the MPS Foundation. Emergy synthesis has been applied to 24 farms located in the Province of Siena (Italy), characterized by different agricultural approaches, and up to 200 products including cereals, vegetables, fruits, legumes, animal products, such as meat, milk, cheese, honey, as well as other processed products, such as wine, oil, beer, and pasta.
The scope of the project was to: a) evaluate the emergy flows and indicators of areal products; b) translate these measures into infographics able to explain values; c) develop communication tools for disseminating the method, the unit, and the results to a large audience.

Moreover, the systematic application of emergy to a variety of productions can be a prerequisite for a number of initiatives able to answer important current calls, namely: the need of datasets made of information expressed in terms of units other than money, which is in general the main aim of the environmental accounting and is extremely useful for both producers and consumers; refining labelling and other communication solutions for transmitting information in an effective way; create an emergy-based Eco-score to inform on the environmental impact of products and, ultimately, their sustainability, in line with EU current trends and matter of study within the Italian PNRR Agritech project.

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### 49. Conservation vs stagnation: the dilemma of an ecologist. Is emergy approach a solution?

**Paolo Vassallo, Ilaria Rigo, Rachele Bordoni, Chiara Paoli**
University of Genoa

Ecological theory states that complex, self-regulating systems, such as ecosystems are expected to evolve changing their structure and species composition in a succession of temporary stages. From an environmental point of view each stage is expected, overall, to be better (more fitted) at competing for survival being the new species able to occupy the ecological niche of the previous one. From a thermodynamic point of view the following stage is expected to be more powerful at exploiting resources and the available energy (maximum power). This framework of possible evolution and species substitution and evolution has to be taken in account when ecosystem management and conservation strategies are proposed by ecologists in a world strongly affected by anthropic pressures and disturbances. Conservation for the sake of conservation may not be the solution to the environmental problems and should be interpreted with the broader view of the system-thinking. Several different eco-systems (both terrestrial and marine) undergoing changes in their structure and functioning are here evaluated accounting for natural capital and ecosystem functions provisioning with the aim of determining if the system is going to evolve or to devolve and finally looking for a solution to the dilemma of an ecologist.

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### 50. Application of a Strong Sustainability Accounting Framework in Cinque Terre Marine Protected Area (NW Italy)

**Bordoni R. [1], Dapueto G. [1,3], Lavarello I. [4], Povero P. [1,2], Rigo I. [1], Valerani C. [4], Vassallo P. [1,2], Paoli C. [1,2]**
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Through the “Environmental Accounting in the Marine Protected Areas” (EAMPA) and “Integrated management of ecological networks through parks and marine areas” (GIREPAM) projects, a new framework for environmental accounting in Italian Marine Protected Areas (MPAs) was developed. The goals of this framework were 1) obtaining an integrated ecological-economic management tool 2) evaluating MPA management in terms of strong sustainability. In this context, three cost-benefit balances for MPAs (ecocentric, anthropocentric and integrated) were designed

following two parallel paths: the ecocentric and anthropocentric one. First of all, the stock of natural capital maintaining the system must be assessed. Natural capital originates ecosystem services (ES) annual flows generating, in turn, costs and benefits from both an ecocentric and anthropocentric perspective. Ecocentric costs are represented by resources used and natural capital removed by users while enjoying ES while benefits are positive impacts on the environment due to protection regime: both are calculated with a donor-side approach using emergy analysis and ex-pressed in both biophysical and monetary equivalents terms. Anthropocentric costs are all the expenditures bored to keep the MPA going while benefits include revenues for humans due to protection regime and the fruition of ES together with financial incomes of the MPA. This framework has been applied since 2015 to Cinque Terre MPA (NW Italy): the purpose of this study is to realize a diachronic analysis of results in order to point out lights and shadows of the proposed framework as well as future perspectives.

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### 51. Environmental Performance of Geothermal Electricity and District Heating and Cooling production: An Emergy Accounting and Life Cycle Assessment Integrated Procedure.

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The global energy consumption is characterized by significant increasing trends and is still projected to grow in the next years, due to the advancement of human societies and of technological development. This comes with the cost of increased pollution and environmental degradation. The energy sector is one of the major contributors to the emissions of significant amounts of greenhouse gas. In this work, a medium enthalpy geothermal system for the production of electric and thermal energy is proposed and assessed for its environmental performances. The investigated case study is set in Campania region, Southern Italy. The system is composed by an Organic Rankine Cycle (ORC) for electricity production and by a grid providing district heating and cooling to residential and office buildings. The environmental performances are assessed by means of the Emergy Accounting (EMA) method, measuring the support to the process from the techno and the bio spheres and the load of the system on the environment, thus providing a holistic understanding of the case study. The calculation of the Unit Emergy Values (UEVs) could benefit from the use of reliable inventories. The databases used within the Life Cycle Assessment (LCA) method provides a huge amount of reliable, peer reviewed inventories used at global level. This work proposes a calculation procedure of UEV values based on the LCA inventories, comparing them to previous calculated ones. The system is also compared to current and to improved strategies for the heating and cooling of the buildings and for electricity production, confirming it as a sustainable energy production pattern characterized by low environmental loads. The calculated UEVs seem to be reliable when compared to literature values, strengthening the bong between LCA and EMA methods. The obtained results confirm the environmental feasibility of the analyzed system and its beneficial environmental performance.

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### 52. An integrated assessment framework to evaluate the environmental feasibility of a Renewable Energy Community

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Within the scenario of the current energy crisis, the development of Renewable Energy Communities (RECs) might play a crucial role in providing renewable and local energy. According to recent Directives of the European Union, now accepted by each Member country, a REC is a bottom-up system to produce, share and manage energy: individual households, enterprises and public administrations may be connected in a network to produce and consume renewable energy locally. Citizens can now shift from being energy consumers to the role of energy prosumers (at the same time producers and consumers of energy), thus playing an active role in the energetic transition. This may generate huge social, economic, and environmental benefits for individuals and the whole community. Of course, benefits must be assessed and measured, to make sure results are worth the efforts and the investments and that the governance of processes is shared, so that it produces real empowerment for the communities. This study deals with the application of an integrated tool to evaluate the environmental feasibility of the RECs. Life Cycle Assessment (LCA), Emergy Assessment (EMA) and Geographic Information System (GIS) were used for quantitative assessment of the environmental impacts and benefits related to the actual or planned constitution of a REC in selected local realities of Italy (Latina, Napoli, Lampedusa Island, among others). The integration of LCA, EMA and GIS accounts for environmental performances of the investigated systems from both user-side (resource depletion, emissions) and donor-side perspective (biophysical support, ecosystem services) within a spatial dimension including the local peculiarity of a territory (land use distribution, renewable flows convergence, built environment distribution, population density). The proposed framework may represent a useful tool to implement a REC and to build a scenario analysis of the best options towards wider environmental economic and social benefits for sustainable local development.

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### 53. Challenging the Orthodoxy: Should Energy Quality be Determined by Forward linkages as well as Backward linkages?

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Energy Quality can be determined using 'system numeraires' (Emergy, Quality Equivalent Methodology), 'thermodynamic numeraires' (e.g., Gibbs Free Energy), or 'economic numeraires' (e.g., Ideal Price Weights). As pointed out by Scubbia thermodynamic numeraires are state functions and hence they are not determined by complicated pathways of energy inputs, which obviously is the case in 'system numemaires' such as emergy. The paper focuses on the Quality Equivalent Methodology (QEM) to show how backward and forward linkages can be used to determine the emergy metrics, in contrast to the approach used in emergy analysis which focuses on backward linkages to determine these emergy metrics. The QEM method does not necessarily replace the emergy method nor is it necessarily contradictory with the emergy method. Case

studies in the paper show how emergy analysts use inaccurate data on the solar energy input into fossil fuel formation that happened millions of years ago, and how they struggle to apportion in an assumption-free way solar energy inputs to hydrological processes – all of this is undertaken to facilitate the application of the 'Emergy Algebra' rules that are used to mechanically calculate 'transformities' or 'specific emergies'. On the other hand, the case studies show that more accurate transformities' or 'specific emergies' can be calculated by using accurate up-to-date data, modern solution methods and greater reliance on the knowledge of forward and backward linkages. It should be noted that there are cases where Odum does resort to calculating solar energy equivalents to drive geological processes. Using Emergy Equations constructed by Odum and Collins, the paper demonstrates by using structural analysis that each quantity always has either backward linkages, or combined backward and forward linkages or forward linkages, which in turn means that they can always be used to calculate transformities and/or specific emergies.

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**54. What the World Needs Now: perspectives for the anthropocene**

**Mark Brown**
University of Florida

Increasingly there are calls for "emergy to say something" about the major challenges of the Anthropocene and to define "…how participatory emergy analysis could perhaps contribute to society and policy makers dealing with this reality in a more optimal fashion. And finally, that "HT Odum's brilliant, revolutionary emergy principles and tools have--after 50+ years--perhaps not achieved an optimal level of understanding and application by scientists and economists of all stripes.

This talk will explore why its not what emergy says, but what Odum's brilliant, revolutionary Systems Principles say and how the accounting technique using emergy may contribute to that.

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