EMERGY SYNTHESIS 5:
Theory and Applications of the Emergy Methodology

Proceedings from the Fifth Biennial Emergy Conference,
Gainesville, Florida

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December 2009

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Suggestions for an Emergy Nomenclature

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ABSTRACT

As the number of emergy indices increase and the various names to describe them increases even faster, it is time to consider standardizing some terms and their unit designations. In this chapter, we suggest standard abbreviations for emergy, transformity, specific emergy, and standardizing names for several indices, providing abbreviations where appropriate. Finally we explain several new indices for describing pollution as emergy intensity per unit volume.

INTRODUCTION

It is high time that we standardize the names and associated unit designations that are used to describe many emergy concepts, indices and conversion factors. For instance the term transformity is often used to describe ratios of energy and mass to emergy, or the term “density” as in empower density is used to infer emergy use per unit area and per unit volume. To be consistent with other branches of science we propose here a standard set of names and their associated units for common terms.

Emergy and Emergy per Unit Time

Emergy is defined as the amount of energy of one type (usually solar) that is directly or indirectly required to provide a given flow or storage of energy or matter. We propose that the lower case Greek letter epsilon (ε) be used for emergy. The units of emergy are emjoules (abbreviated εJ) to distinguish them from energy joules (abbreviated J). Solar emergy is expressed in solar emergy joules (sεJ, or solar emjoules). Emergy per unit time is empower, in units of emjoules per time (εJ/time). Solar empower is solar emjoules per time (e.g. sεJ/time). We propose that the combined lower case Greek letters epsilon and mu, (εμ) be used for empower in equations.

Unit Emergy Values

We suggest the term Unit Emergy Value (UEV) be used to describe the class of ratios used to convert energy and mass units to emergy. When the emergy required to make something is expressed as a ratio to the available energy of the product, the resulting ratio is called a transformity. The solar emergy required to produce a unit of available energy is called solar transformity and is expressed in solar emergy joules per joule of output flow (sεJ/J). The transformity of solar radiation is assumed equal to one (1.0 sεJ/J). We propose that the abbreviation for transformity be the letters, capital “T” and subscript “r” as follows: T_r.

Specific emergy is the unit emergy value of matter defined as the emergy per mass, usually expressed as solar emergy per gram (sεJ/g). Solids may be evaluated best with data on emergy per
unit mass for its concentration. Because energy is required to concentrate materials, the unit emergy value of any substance increases with concentration. Elements and compounds not abundant in nature therefore have higher emergy/mass ratios when found in concentrated form since more work was required to concentrate them, both spatially and chemically. We propose that the abbreviation for specific emergy be the letters, capital “S” and subscript epsilon as follows: $S_{\varepsilon}$.

**Environmental Emergy: Fluxes and Concentrations**

With increased interest in quantifying emergy per unit volume as a measure of work potential it is necessary to differentiate between emergy per unit area and emergy per unit volume. We propose using the terms *intensity* for areal emergy and *density* for emergy per volume. The following paragraphs provide background on our choice of terminology for emergy per unit time per unit area, *areal empower intensity* and for emergy per unit time per unit volume, *empower density*.

**Empower Intensity**

In the past we have proposed the term “areal empower density” to describe emergy per unit time per unit area, however in light of our need to define a new concept of emergy per unit time per unit volume, we suggest differentiating between *intensity* and *density* following the lead of physics.

In physics, *intensity* is a measure of the time-averaged energy flux; or in other words, the amount of energy that is transported past a given area of a medium per unit of time. Intensity is the energy per time per area (energy* time* area$^{-1}$); and since the energy per time ratio is equivalent to the quantity *power*, intensity is simply the power per area. Since emergy per time is *empower*, we suggest the termed *areal empower intensity* be used to describe emergy per unit time per unit area (seJ* time$^{-1}$* area$^{-1}$) and that the Greek letters epsilon, mu, iota ($\varepsilon\mu\iota$) be used to denote it in equations.

It should be noted, that *energy intensity* as used in economics, is defined as the measure of the energy efficiency of a nation's economy. It is calculated as units of energy per unit of Gross Domestic Product (GDP).

**Environmental Emergy Density**

In physics, *density* is defined as the ratio of the mass of any substance to the volume occupied by it (usually expressed in kg/m$^3$). *Energy density* is usually defined as the amount of energy stored per unit volume, or per unit mass, depending on the context (usually expressed in J/g or J/L). When considering concentrations of pollutants in environmental systems, it is often appropriate to express them as concentrations (i.e. mg/L, µg/L, ppm, ppb). Since pollutants can be expressed as emergy using their specific emergy (seJ/g) then concentrations of pollutants in the environment, especially in aqueous environments, can be expresses as emergy density (i.e. seJ/m$^3$ or seJ/L). We propose that the terminology *energy density* be used to describe emergy per unit volume (seJ/volume) in environmental systems and that the Greek letters epsilon and delta ($\varepsilon\delta$) be used to denote it in equations.

**Environmental Empower Density**

In engineering, the term *power density* refers to power per unit volume. It is often used to describe the amount of power delivered by an energy source, divided by some measure of the size or mass of the source. In the environment when pollutants are released over time their emergy per unit time per unit volume can be calculated from the pollutant’s specific emergy and the quantities released. In keeping with engineering and physics definitions of density, we suggest the term *empower density* be
used to describe emergy per unit time per unit volume \((\varepsilon J^{*\text{time}^{-1}\times\text{volume}^{-1}})\) and that the Greek letters epsilon, mu, delta \((\varepsilon\mu\delta)\) be used to denote it in equations.

**Emergy, Money, and National Economies**

The ratio of emergy to monetary units has been computed for most economies of the world and is often computed for individual products and human services. The ratio has had numerous names over the years but most frequently is called “emergy dollar ratio”. When describing the ratio of total emergy use of an economy to its Gross Domestic Product (GDP) we suggest standardizing the name to **Empower Intensity of Market Value (EIMV)**.

We define a new term based on the term used for the monetary value of a nation’s total production. The economic term, Gross Domestic Product (GDP) is defined as the market value of all final goods and services produced within a country in a given period of time (generally one year). We define **Gross Emergy Product (\(G\varepsilon P\))** as the emergy value of all goods and services produced within a country in a given period of time, and by definition, it is equal to total emergy use in the economy.

Several indices are used to compare emergy intensity of national economies. Intensity of emergy use can be viewed in several ways: over space, relative to size of economy, and relative to population. Emergy intensities of national economies are the result of summing all emergy use to obtain the \(G\varepsilon P\) and then dividing by area, population, and GDP of each country. Since \(G\varepsilon P\) is emergy use per unit of time it is also empower (emergy per unit time).

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<td>(G\varepsilon P) (capital “G”, epsilon, capital “P”)</td>
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