Energy-Flux Density: Global Measure of Economic Progress

by Jason Ross

Over the period 1948-1952, Lyndon LaRouche solidified a fundamental advancement in economic science, a breakthrough which allowed him to become the most accurate economic forecaster of our day.[1] This breakthrough in understanding what Treasury Secretary Alexander Hamilton called "the productive powers of labor" allows him to offer uniquely competent guidance on global economic matters. Here we elucidate several key concepts of LaRouche's economic method, including, most centrally, that of energy-flux density as a measure of economic value.

Starting from Fundamentals: Physical Chemistry as the Origin of Economy

Unlike all other life known to us, human beings are able to discover and apply knowledge of the universe and social functions, to fundamentally transform our relationship to nature and to our fellow man. This occurs uniquely through the process of scientific and artistic creative discovery, and through forms of social organization capable of fostering and implementing those discoveries.

A comprehensive standpoint from which to view such progress is that of physical chemistry, from its most humble origins in the use of fire, to the dawn of extractive metallurgy, to the breakthroughs of chemistry proper, to the more modern developments of electromagnetism and nuclear science. Specific periods of development are sometimes known by characteristic chemical knowledge: for example, the Stone Age, Bronze Age (beginning 3200 BCE), and the Iron Age (which began in 1200 BCE in Europe).

Only human beings have economies, because only human beings change their mode of existence from one generation to the next. The source of these changes, creative discoveries of new scientific and cultural principles, is the heart of economic value, and the proper origin of a science of economics.

Against this naturally human development, stands oligarchism.

Against Mankind: Zeus vs. Prometheus

Neither history, science, culture, nor economics can be understood as disciplines, without an understanding of the most pertinent conflict between outlooks for human culture: the conflict between Zeus and Prometheus. This story, often wrongly considered only a myth, as presented by such as the Greek playwright Aeschylus, tells of the origins of human science and economy, and the opposition, by oligarchy, to such development.

In order to keep ordinary mortals weak and under his control, the Olympian god Zeus forbade man the use of fire (and, in doing so, forbade humanity itself, and all the possible advancements of civilization), re-

1. LaRouche has written extensively on his discovery, including in his 1984 economics textbook, *So, You Wish To Learn All About Economics?*

serving it for his use, alone. The god Prometheus, acting as a friend to humanity, took fire from Zeus's heaven and brought it to mankind. For this act, Prometheus was violently punished by Zeus, in a torment designed to last eternally; yet Prometheus did not regret his actions.

The willful use of fire, the first technology, is what sets mankind apart from all animals. Prometheus describes the state of man before giving him fire and knowledge (from "Prometheus Bound," by Aeschylus, ca. 415 B.C.):

> First of all, though they had eyes to see, they saw to no avail; they had ears, but they did not understand; but, just like shapes in dreams, throughout their length of days, without purpose they wrought all things in confusion. They had neither knowledge of houses built of bricks and turned to face the sun, nor yet of work in wood; but dwelt beneath the ground like swarming ants, in sunless caves. They had no sign either of winter or of flowery spring or of fruitful summer, on which they could depend, but managed everything without judgment, until I taught them to discern the risings of the stars and their settings, which are difficult to distinguish.
>
> Yes, and numbers, too, chiefest of sciences, I invented for them, and the combining of letters, creative mother of the Muses' arts, with which to hold all things in memory. I, too, first brought brute beasts beneath the yoke to be subject to the collar and the pack-saddle, so that they might bear in men's stead their heaviest burdens; and to the chariot I harnessed horses and made them obedient to the rein.

Rather than being slaves to ignorance, superstition, and the arbitrary whims of Zeus, human beings could use these gifts of knowledge from Prometheus to guide their own future, increasing their further power over nature through the powers of discovery.

The greatest of the sciences, economics, treats as its subject matter, that unique capability of our species to increase its standard of living and transform its relationship to nature and itself. How can economic progress be measured?

Energy-Flux Density: Applying Mankind's Fire

Begin with the first of the gifts of Prometheus, fire, from which he says man "shall learn many arts." The archaeological distinction between humans and apes comes with the first appearance of ancient fire pits, used to control the power of fire for the betterment of the lives of those wielding that then-new power.

From that point on, mankind could no longer be characterized biologically, or as existing in biological evolution—the evolution of the creative powers of the mind became the determining factor, and biology decreased in importance, relative to the power of thought.

Since then, the kernel of economic growth has been expressed in the control over successively higher forms of "fire." First came increasingly powerful forms of chemical fire: from wood to charcoal, from coal to coke, and on to petroleum and natural gas. The higher types of power not only allowed greater densities of fire-power; they opened up new domains of control and utilization of matter. Metallurgy, materials development, and physical chemistry all developed in dynamic interaction with the development of new forms of fire.

The revolutionary discoveries of the early 20th Century revealed an immense potential, altogether beyond chemical reactions: the fundamental equivalence of matter and energy, as expressed in the domains of fission, fusion, and matter-antimatter reactions. Each in this series of relativistic reactions (reflecting the Einsteinian equivalence between mass and energy) operates at successively higher energy densities, and the entire set is orders of magnitude beyond the entire successive set of chemical reactions. While this distinction is usefully expressed in the immense difference between the quantity of energy released in nuclear as compared to chemical reactions (expressing weapons in terms of kilotons or megatons of TNT), the measured quantitative difference is an effect of a qualititatively distinct, higher domain of action.

Control over higher energy densities enables the increase in what LaRouche has termed the energy-flux density of the economy, as measured by the density-rate of energy use characteristic of applied technologies, such as the energy concentrated in the beam of a laser used for metal-cutting, compared to a water-mill of the 18th Century. A general value for energy-flux density can be measured as the energy use per person and per unit area of the economy as a whole. This increasing power is associated with qualitative changes throughout the entire society—new technologies, new resources, higher levels of living standard, and, essentially new economies. (See **Table 1**.)

To start with, consider the biological energy usage,

Table I
The Energy Density of Fuels

FUEL SOURCE	ENERGY DENSITY (J/g)
Combustion of Wood	1.8×10^4
Combustion of Coal (Bituminous)	2.7×10^4
Combustion of Petroleum (Diesel)	4.6×10^4
Combustion of H_2/O_2	1.3×10^4 (full mass considered)
Combustion of H_2/O_2	1.2×10^5 (only H_2 mass considered)
Typical Nuclear Fuel	3.7×10^9
Direct Fission Energy of U-235	8.2×10^{10}
Deuterium-Tritium Fusion	3.2×10^{11}
Annihilation of Antimatter	9.0×10^{13}

Fuel energy densities. The change from wood to matter-antimatter reactions is so great that progress must be counted in orders of magnitude, and the greatest single leap is seen in the transition from chemical to nuclear processes.

the power rate of a human body, roughly 100 watts (corresponding to a 2,000-calorie diet). Before the use of fire, all work performed (by human muscle), would be applied at a rate of 100 watts per capita. Compare this rate with those seen in the historical development of nations.

For example, at the founding of the United States, the wood-fire-based economy of the time provided an estimated 2,400-3,000 watts per capita. Thus, each member of that economy represented a potential application of energy up to 30 times greater than a fireless society. Clearly, this was not only more energy, but represented a quality of energy that enabled people to create new states of matter and chemistry, states which could never be created by muscle power alone.[2]

By the 1920s, the increasingly coal-powered United States had a per-capita power use of 5,000 watts, meaning every individual expressed nearly twice the power as members of the wood-based economy. This supported the powered machinery, transportation, and early electricity generation that transformed life, alongside the development of modern chemistry.

By 1970, the per-capita power rate in the United States, which now made extensive use of petroleum and natural gas, and limited applications of nuclear power, had reached 10,000 watts per capita, another doubling over the level 50 years prior.

In each of these transitions, the previous fuel declined in use as a power source, allowing non-combustive uses, such as the use of wood for construction and petroleum for plastics and other petro-chemicals, while the array of resources expanded. In today's electromagnetic, and partially nuclear economies, rare earth minerals have become resources, the excellent fusion fuel of helium-3 on the Moon is being eyed by such far-sighted institutions as the Chinese space program, and the future fusion-based economy will be able to process mineral deposits far below the quality of ores exploited successfully today.

With these power transitions in mind, it is no surprise that per-capita electricity consumption and per-capita wealth (as measured by the admittedly quite flawed GDP) are so closely correlated, as seen in **Figure 1**.

Had the advance of nuclear power not been halted, and had fusion power been realized as intended, it would be no stretch to estimate that U.S. power rates would approach 40,000 watts per capita in the first generation of this new century. Such potential boggles the mind, and drives home how unacceptable the current world average of only 2,400 watts per capita (comparable to the United States over 200 years ago) truly is.

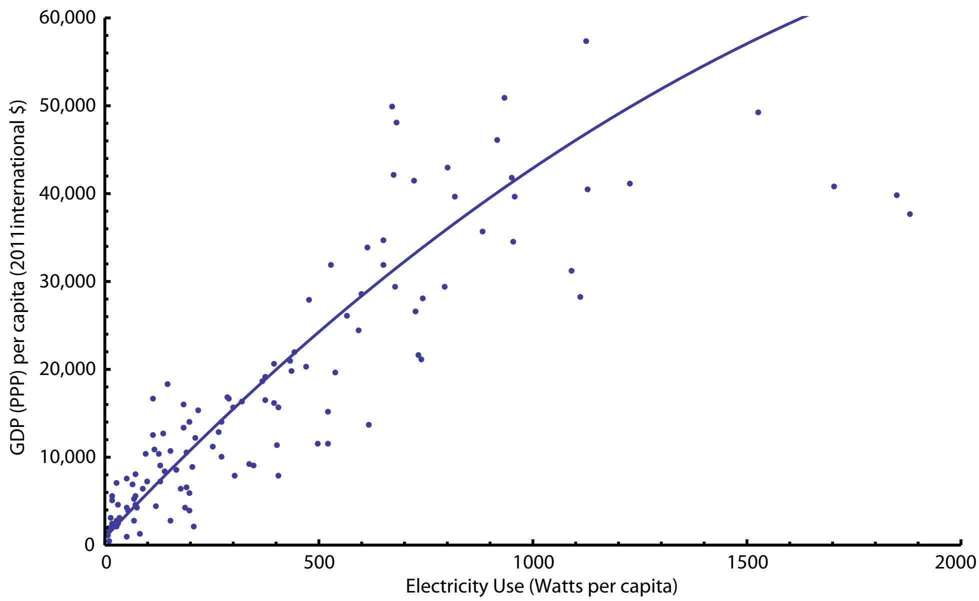
Alongside energy-flux density, a second key economic metric developed by LaRouche concerns the demographics of economies powered by increasing levels of energy-flux density. This brilliant metric side-steps the principal errors encountered in macroeconomic measurements.

A Global Measure of Economy: Potential Relative Population Density

Most economists seek to determine the overall productivity of a national economy through metrics which add together the monetary value of various components of the economy, resulting in such measures as gross do-

2. Could you cook your meat by beating it with a club, or bake bread by banging it with a rock? Can you produce copper from malachite by using your muscles, without a charcoal fire?

FIGURE 1
Electricity Consumption vs. GDP, Per Capita



EIRNS/Jason Ross, using 2010 data from World DataBank.

The correlation between per-capita electricity consumption and GDP is remarkably clear. Insisting that developing nations use "appropriate technologies" is insisting that they remain eternally poor.

All nations with both indicators were included (N=129). Plot range has been cropped to exclude outliers. Trend line is a best-fit cubic.

mestic product. The problems with such an approach are two-fold:

1. Economic activity counting towards GDP may or may not be conducive or necessary to reaching more developed states of the economy, and may indeed be positively harmful even if not currently illegal (such as drugs, solar panels, prostitution, degrading forms of entertainment, gambling, biofuels, and financial speculation).

2. Rather than looking at economic activity per se (which, at its best, GDP might represent), it is necessary to look at economic activity in the context of development overall. Does our measure include within it the economic powers which we are capable of reaching? Does it measure progress itself?

Instead of a bottom-up approach, LaRouche has developed a strikingly simple concept to understand an economy as a whole—*potential relative population density*. The population density aspect is the familiar measure of the number of people per square kilometer of land. This must be considered relative to the quality of the land, and of human improvements to it. With this in mind, we consider the potential level of the relative population density: How many people could a society or economy possibly support in a given area of land? What determines this value?

The potential relative population density (PRPD) is bounded by the scientific principles known to a given culture, and by the capability of that culture to implement such discoveries. The breakthroughs in physical chemistry each transformed the PRPD, by their improvements of the potential productive powers of labor, as have: agriculture (including irrigation); windmills (centuries ago); the forging of modern science by the work of Filippo Brunelleschi, Nicolaus of Cusa, and Johannes Kepler; the germ theory of disease; vaccines; steam-powered and internal combustion engines; the Bessemer and later oxygen steel production processes; and such production techniques as standardization and automation—just to name a few.

The combined set of discoveries and cultural framework for their implementation determines the PRPD. Rather than adding up currently occurring economic activity (including undesired activity) the PRPD measure indicates the potential economic activity and human life an economy is capable of supporting. The rate of growth of PRPD is the best measure of increasing economic value.

Must We Progress? There Are No Limits to Growth

While no intelligent person would deny the necessity of technologies to make the best aspects of modern life possible, some might argue that technological progress need not continue, that we have reached a sufficient level for our needs, and that perhaps increased economic activity even poses a danger, by more rapidly drawing down limited supplies of raw materials. Such were the ostensible concerns behind the publication of *The Limits to Growth* in 1972.

This silly book, which assumed no fundamental advances in technology (such as nuclear fusion), modeled the world economy, and concluded that in a matter of decades, such factors as pollution, resource scarcity, and food shortages would lead to a maximal human population, and then a rapid decline. The authors, who wanted to prevent economic development for reasons outside those discussed in their book, proved, in effect, that without technological advances, mankind was doomed, and then used this to argue for preventing technological advance! Instead, they had demonstrated the necessity of such advance—a process which must continue indefinitely.

Opposed to this necessary progression is the current, foolish practice of hydraulic fracturing ("fracking") to recover hydrocarbons. Since more easily accessible supplies of hydrocarbons already have been or are currently being exploited, it becomes necessary to expend more and more (physical) effort to obtain the same resources. While an individual fracking well may offer a monetary return on investment, fracking as a policy has negative economic value. Consider the opportunity cost, in the broadest sense: It was possible to have built more fission power plants, and invested the necessary resources into making nuclear fusion a reality, giving a whole new spectrum of potential processes and resources. Instead, we are expending more effort to obtain the same resource.

From both the moral imperative to improve the living conditions of the unacceptably large portion of humanity currently in poverty, unable to participate mentally in celebrating and advancing the discoveries that are the common patrimony of all mankind, and from a strict physical standpoint, progress is essential.

An increasing (and increasingly well-educated) population is necessary to tackle the large challenges facing mankind, such as defense against errant asteroids and comets, and long-term management of changing weather conditions. Humans must pick up where the biosphere has left off.

A Lesson from the Biosphere: Development as Fundamental

The "green" ideology holds that most specifically human behaviors are "unnatural," as though the human species is not part of the natural world. Furthermore, many of the supposedly "natural" virtues extolled by green ideologues—tradition, constancy, eternity, stasis, balance—do not describe the biosphere, at least not over evolutionary timeframes. Quite the contrary: The history of our planet, and of its biosphere, is one of evolutionary development that mirrors that of human economic development in surprising respects.

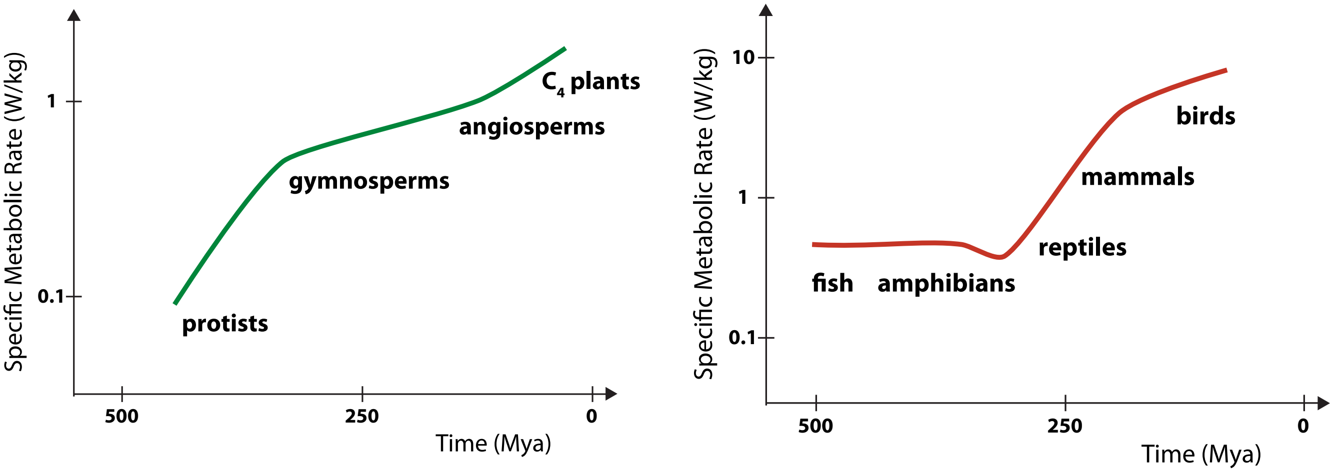
For example, let us apply the concept of energy-flux density to the biosphere. We will measure the specific metabolic rates of both animals and plants, in units of energy flow per body mass (W/kg). For example, a typical reptile uses 0.3W/kg, while a typical mammal uses 4W/kg, an order-of-magnitude difference. As seen in **Figure 2**, the development of new biological "technologies" over time—such as seeds, rather than spores, for plants, and endothermy (warm-bloodedness) for animals—corresponds to higher rates of energy flow per body mass. That is, over evolutionary time, newly developed forms of life require increasingly great rates of energy flow.

This development process did not occur smoothly. As seen in **Figure 3**, the relative predominance of amphibians, reptiles, birds, and mammals over evolutionary time (as measured in the diversity of lifeforms)[3], shows a marked shift from the relative dominance of amphibians, then reptiles, and finally birds and mammals. Not only do the developing forms of life themselves have more internal diversity (mammals have more biodiversity than the previously developed class of reptiles), but these changes do not occur gradually, but instead as shifting eras of life, similar to the Stone, Bronze, and Iron Ages of man.

These very cursory[4] examples of changes over evolutionary time reflect human economy in two essential respects: 1) they show increases of energy-flux density (and diversity) over time, and 2) these increases are not smooth, typically occurring as almost discontinuous jumps with the introduction of new biological "technologies." This is a remarkable parallel to human economic development, which shows a secular increase in

3. This method avoids the difficulty of trying to estimate the total body masses of the different classes, based on relatively scarce fossil remains.
4. For a fuller treatment of the concepts developed in this section, see Benjamin Deniston, "Biospheric Energy-Flux Density" in *21st Century Science & Technology*, Spring 2013.

FIGURE 2



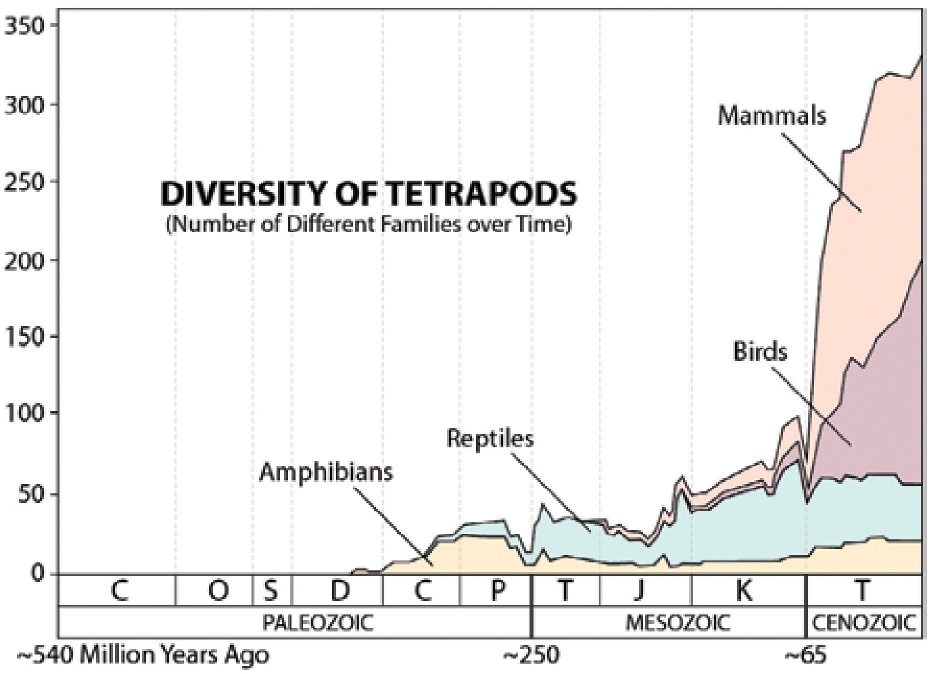
E.J. Chaisson (adapted)

Over time, the rate of energy flow, per g of body mass, for both photosynthesizers and animals, has increased. When this increase is considered in light of specific biological transitions, such as the development of plant seeds, and independence from water and ambient temperature for animals, the transition is understood not as a general increase, but rather one driven by specific improvements in the evolution of life.

energy use per capita, driven by new technologies which transform that rate quite rapidly.

There can be nothing more "natural" than revolutionary changes in applied technologies, as mankind acts as one species, in a way that encompasses the biosphere as a whole. All of nature changes: all landscapes, all climates, all forests, and all life. The world is our garden, ours to develop as is best for our human future.

FIGURE 3



Michael Benton (adapted)

Generalized succession of dominant forms of vertebrates illustrated by the comparative number of known families over geological time.

Conclusion

LaRouche's economic breakthroughs allow him (and those who study his work) a greater insight into economic processes and into history. Those who do not wish to consider themselves as historical actors, with a responsibility to cause the continued development of the human species, may not wish to adopt this method, but those who are serious about improving mankind will find much benefit in approaching economics from the standpoint and lessons of this wise man.