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Energy As a Metric of Sustainability

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Under what conditions will a technology be able to survive the energy contraction associated with the depletion of fossil fuels? Which types of technologies are sustainable in a world that can only make use of resources that it is producing on its own rather than relying on resources that it inherited from the past? This article, co-authored by Dr. Rodrigo Castro of the University of Buenos Aires, proposes emergy as a physically sound metric of sustainability. Without taking emergy into account, long-term energy analysis may lead to erroneous conclusions with potentially catastrophic consequences.

At The Oil Drum, many contributions have addressed the ERoEI, energy returned on energy invested, as a measure of energy efficiency. It is evident that a technology that consumes more energy than it produces (ERoEI < 1) is not sustainable in the long run. It is also quite obvious that energy resources with a low ERoEI value must be more expensive to produce than resources with a high ERoEI value. However in the short run, it may sometimes be profitable to even produce energy with an ERoEI < 1, if the production of this resource is being subsidized by a local government using tax revenue.

Some readers of The Oil Drum have interpreted the ERoEI as a *measure of sustainability*. They expect energy resources with an ERoEI of 1.03 to be sustainable, whereas resources with an ERoEI of 0.98 are predicted to be unsustainable. Unfortunately, this interpretation is incorrect. The reason is that the ERoEI only accounts for the energy used in the production of energy itself, but not for the energy that had been previously used up to create the infrastructure and equipment needed to make said production of energy possible. It takes a whole lot of energy to produce an oil platform, for example. New oil platforms can and will only be produced as long as there is enough surplus energy available to do so.

The crux is thus the hidden energy that is "contained in" (has been used up in the production of) equipment used for the production of energy. Every good sold or service provided on this planet contains hidden energy. This type of energy has been coined emergy [4]. We frequently read about *gray energy*. Gray energy is emergy traded across (national) borders.

Charles Hall, the prime promoter of the ERoEI (sometimes also abbreviated as EROI) as a metric for energy efficiency, knows about the problem. For this reason, he suggested to consider a technology with an ERoEI < 5 to be unsustainable. Where does this factor of 5 come from? No one really knows, including Charlie. It is simply a safety margin introduced to account for all of the hidden energy cost not included in the computation of the ERoEI. Yet the hidden energy cost may vary from one technology to another. One technology may be perfectly sustainable with an ERoEI value of 2, whereas another may not be sustainable at any ERoEI value (e.g. if it relies on the extraction of a non-renewable raw material). It is thus important to be able to quantify the hidden energy cost of different energy producing technologies.

These same concepts apply not only to the production of energy, but in fact to the production of all goods, including e.g. food. In the Middle Ages in Britain, soils were only being used for agriculture if the so-called harvest factor (the amount of grain produced divided by the amount of seed grain planted) surpassed a value of 1.6 [3]. Otherwise the soil was not used for agriculture. The safety margin of 1.6 accounted for the loss of harvested grain to different types of pests and the need to appropriate some of the grain for consumption.

Many of our readers may consider gray energy irrelevant to the discussion at hand. In the context of the peak oil debate, we are looking at the world as a whole, and in a global context, gray energy does not exist; it is a zero-sum game. All gray energy imported into one country is true energy used up elsewhere.

It is said that China has meanwhile surpassed the United States in terms of energy consumption. China is claimed to now consume more energy (in absolute terms, not per capita) than the United States. This is however incorrect. China has become the largest energy *user*, but not the largest energy *consumer*, because China produces lots of goods for export. Much of the energy used up in China is being exported to Europe and the United States in the form of gray energy. China has become the largest net exporter of gray energy on the planet.

Why is gray energy (emergy) important even in a global context?

Japan, a nation with a high population density and few resources of its own, is currently producing a large percentage of the automobiles driven all over the planet. Will Japan still be able to export (e.g. plug-in hybrid) vehicles after the energy contraction? Will Japan not rather use its limited energy resources to satisfy the needs of its own populace than producing goods for export?

The issue here is that the export land model, another favorite topic at The Oil Drum, does not only apply to energy trade, but to trade of all goods, because of their hidden energy (emergy) cost.

Unfortunately, all of these factors influence the sustainability of any energy production technology negatively, as it is not sufficient that the ERoEI of a technology is high enough. For a technology to survive the contraction, enough energy and all other material necessary for the production of said technology need to be available *locally* where and when the production is supposed to take place. In a post-contraction scenario, the lifecycle of all engineered equipment should be considered in terms of the energy required for its maintenance, clean disposal, substitution, and potential recycling.

In developing countries, energy is the main means through which industrialization can take place, hopefully leading to the abatement of poverty. Here the concept of "needs" changes noticeably. Which energy technologies should be considered as locally beneficial to lift average welfare to a level that can be sustained? It seems to be clear, within an energy contraction scenario, that mimicking the path of industrialization followed in the past by developed countries can only lead to failure in the long run. Therefore, possible balances between development and sustainability should be carefully studied in order to maximize development without neglecting physical constraints. In so doing, ignoring the concept of emergy may lead to unpleasant surprises in the future that could turn out to be irreversible in a post-carbon era.

How can the emergy of a technology be quantitatively assessed at regional or global scales attaining the required levels of comprehensiveness? Which modeling tools may support such an endeavor? These issues are being discussed in two forthcoming articles [1,2].

References

[1] Castro, R., F.E. Cellier, and A. Fischlin (2013), "Eco-bond Graphs: An Energy-based Modeling Framework for Complex Dynamic Systems with a Focus on Sustainability and Embodied Energy Flows," *Proc. SESDE 2013, Intl. Workshop on Simulation for Energy, Sustainability, and Environment*, Athens, Greece, September 25-27, 2013.

[2] Cellier, F.E. (2013), "Emergy Tracking - Safe Transition from a World of Exponential Growth to one of Sustainability," *Proc. SESDE 2013, Intl. Workshop on Simulation for Energy, Sustainability, and Environment*, Athens, Greece, September 25-27, 2013.

[3] Müller-Herold, U. (2013), personal communication.

[4] Scienceman, D. (1987), "Energy and Emergy," in: Pillet, G. and T. Murota, eds. *Environmental Economics - The Analysis of a Major Interface*, Geneva, Switzerland: Roland, Leimgruber, pp. 257-276.