Peet, John Dr (Presenter)

Resource Scarcity - a Physical, not an Economic Issue

Designing Sustainable Global Solutions theme

University of Canterbury (retired)
87 Soleares Avenue, Christchurch 8081, New Zealand
Ph: 03 384 1281 Fx: 03 384 6281
Email: njpeet@gmail.com Web: www.peet.org.nz/john

Abstract

It is common for geological and technological information on the quantity and quality of resources (e.g. of high-quality energy or fuel) to be translated into economic terms (eg $/tonne, ¢/kWh) in order to be incorporated into decision-making processes. The reason for this is bound up with mainstream (neoclassical) economic theories relating to the nature of production as an economic process, where value is added to inputs of capital and labour, all measured in monetary units.

The underlying reality of economic production is always physical, however, involving transformation of one form of physical resource into a more ordered form, using high quality energy and matter via an appropriate process. That the process involved is in fact entirely physical does not deny the existence of social or economic "drivers" or consequences, but must nevertheless be central to any policy of resource use; economic assessments alone cannot incorporate all of the physical or biophysical information. In this paper, the importance of examining resources in physical and biophysical terms and taking the results all the way to the decision-making stage is exemplified using the net energy criterion Energy Return on Investment (EROI).

The paper concludes by describing how such measures can be incorporated into long-term decisionmaking frameworks via the concept of the Steady State Economy (SSE) as a model for sustainability of the social-economic-environmental system in which we all live. To make the transition towards a SSE, a fundamentally-modified (biophysical) economics is essential.

Some Conventional Paradigms of Sustainability (Peet, 2004)

The circular flow diagram in Figure 1 describes the mainstream model of the economic process, where goods and services made by Employers/Firms ("producers") are sold to Households ("consumers"), who in turn obtain money by selling their labour or renting their capital. Exchange relationships between capital and labour (the factors of production) are primary.

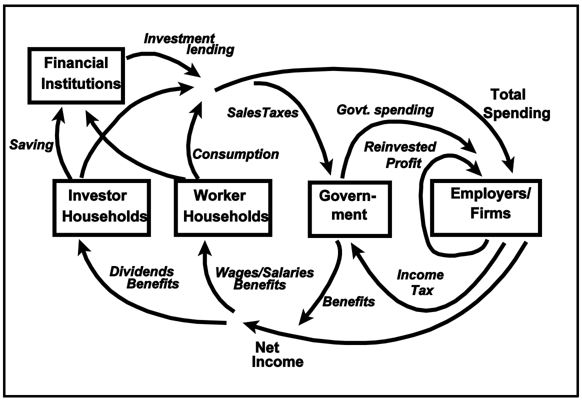

Figure 1 The circular (monetary) flow model of macroeconomics

Within this mainstream economic paradigm, according to Common (1996): ***Economics*** *conceptualises the sustainability problem as that of maintaining a constant level of per capita aggregate consumption [of goods & services] for ever.*

In this model, as explained by Daly (1999), it is not explicit or even obvious that there could be such a thing as *uneconomic* growth of the macroeconomy (i.e. growth beyond a point at which costs exceed benefits). Growth, usually understood as growth of GDP, the total of flows of exchange value in Figure 1 (labelled "Net income") is the central aim of economic policy, and should be continued without limit.

The circular flow model of Fig 1 can, however, be seen in a different and more useful way by incorporating the essential part played by the linear flows of raw material and energy resources from the environment, through the economy as energy and matter, and out to pollution, as shown in Figure 2.

Figure 2 is a thermophysical model of economic activity, and clearly acknowledges the part played by physics, especially thermodynamics, in the processes of economic production and consumption. The material-energy ("metabolic") interactions of the industrial economy with its environment are subject to the same physical laws as those of every living thing, every ecosystem and every economy. All are open systems, existing in a *steady state* far from equilibrium.

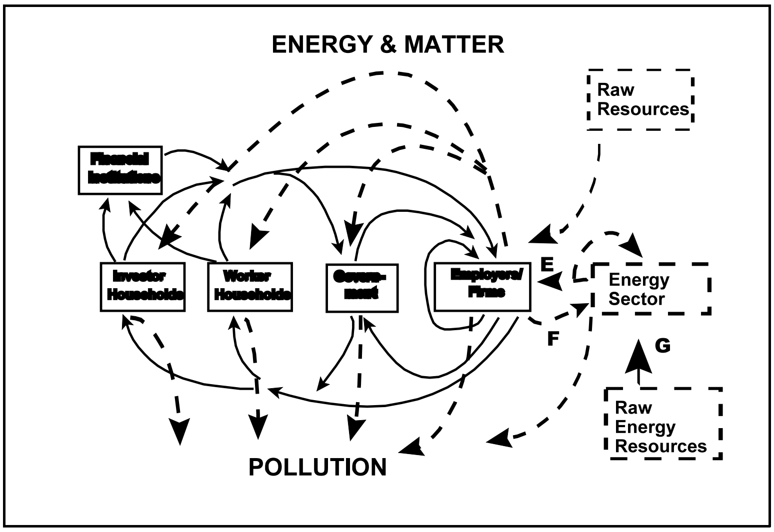

Figure 2 Thermophysical macroeconomic model

Net Energy Criteria

Figure 2 also enables us to include the place of high-quality energy in a way that is very similar to that of cost-benefit methods in economics. Just as the *net* benefit available from a monetary investment is a vitally-important criterion for evaluating its desirability, so too with energy. The energy sector is delivering no *net* flow to the economy unless the ratio E/F is greater than 1 (or E - F is positive). In practice (as in economics) the ratio (or the net flow) should be substantially greater, for example 5 - 10 times F. The ratio E/F is known as the Energy Return on Investment (EROI); (E - F) is the Net Energy.

Recent data from workers in the field of energy analysis (Hall and Lambert (2008), Cleveland 2008), for example) show that whereas in the early-to-mid-20th Century oil could be extracted and delivered to the economy at an EROI of around 100, by the early years of the 21st Century, at the margin in many places this has come down to around 10:1 and is steadily decreasing. Since it is the very high net energy surplus that has made oil so unique as a source of high-quality energy over the last century, the steady decline in EROI is a matter of deep concern. Alternative fuels, such as shale oil (EROI around 5:1), tar sands (EROI 3:1 or less) and coal liquefaction (EROI around 3:1) are well-known technologies whose EROI data are markedly inferior to those of petroleum, even today. Ethanol from corn in the US with a current EROI of at best around 1.5:1, and commonly 1:1 or less, is another example.

The decline in EROI is also related to the issue of Peak Oil, in that for obvious economic reasons, oil companies generally exploited easily-accessible, sweet crudes first. Although Peak Oil's imminence implies that as much oil remains as has been extracted, that remaining oil is, in general, of lower accessibility and of poorer quality. At the same time, the EROI of any conceivable substitute is far less than that of oil for the foreseeable future, meaning there is no practical substitute, at the quantities the world is currently using.

Add to this, the fact that oil is being used at a rate that is 4 to 5 times greater than it is being found, steady industrialisation and population increases particularly in developing countries, and it is clear that the world faces the inevitability of having to use much less - and soon. This will obviously impinge on the widespread political-economic expectation of continuing economic growth, but very little serious attention is currently being paid to this issue. We humans have constructed a civilisation based on cheap oil (and gas) which is a finite resource. No obvious replacements exist to maintain even current consumption levels. Transition to a markedly-different framework for political-economic decisionmaking is essential.

A serious point, very relevant to this issue, is made by Hall, Powers and Schoenberg (2008). They argue that, with a move to significantly lower EROI values, the investment flow of resources from the economy (denoted by F in Figure 2), must increase substantially, if the net energy flow (E - F) is to be maintained at anything like its present level. The Gross Fixed Capital Formation proportion of the GDP of the economy will be correspondingly large, relative to the present day values, meaning the economic output available for other, including discretionary, consumption, will be proportionally less. The consequences for both economic growth and quality of life (and they are not the same thing) will be very substantial.

Wider Perspectives

Again quoting Common (1996): ***Ecology** sees the problem [of sustainability] in terms of maintaining the resilience, or functional integrity, of ecosystems.* This understanding is clearly at variance with that from economics quoted earlier. It is clear that a wider perspective of both is needed, to address the sustainability of the whole system.

The biophysical "real" economy model of Figure 2 shows clearly that human activity actually exists within its ("super-system") global biophysical environment, with a multitude of connections to its environmental sources and sinks, as shown in Figure 3 (Hall & Klitzgaard, 2006 - reproduced with permission).

Working from left to right in Figure 3, the diagram includes:

- energy sources that are essential for the environment and hence for any economy
- the raw materials that circulate through natural and other ecosystems
- the human-dominated processes of transformation in the economy, including mining, processing, manufacturing and consumption.

Some flows - for example the hydrological cycle - are central to an ecologist's understanding, in that nothing of importance in the living world happens without the ready availability of water. The net energy concept enables us to understand that it is the solar-energy-powered thermo-biophysical "engine" that enables the hydrological cycle to function, along with all other cycles and processes in the living global ecosystem.

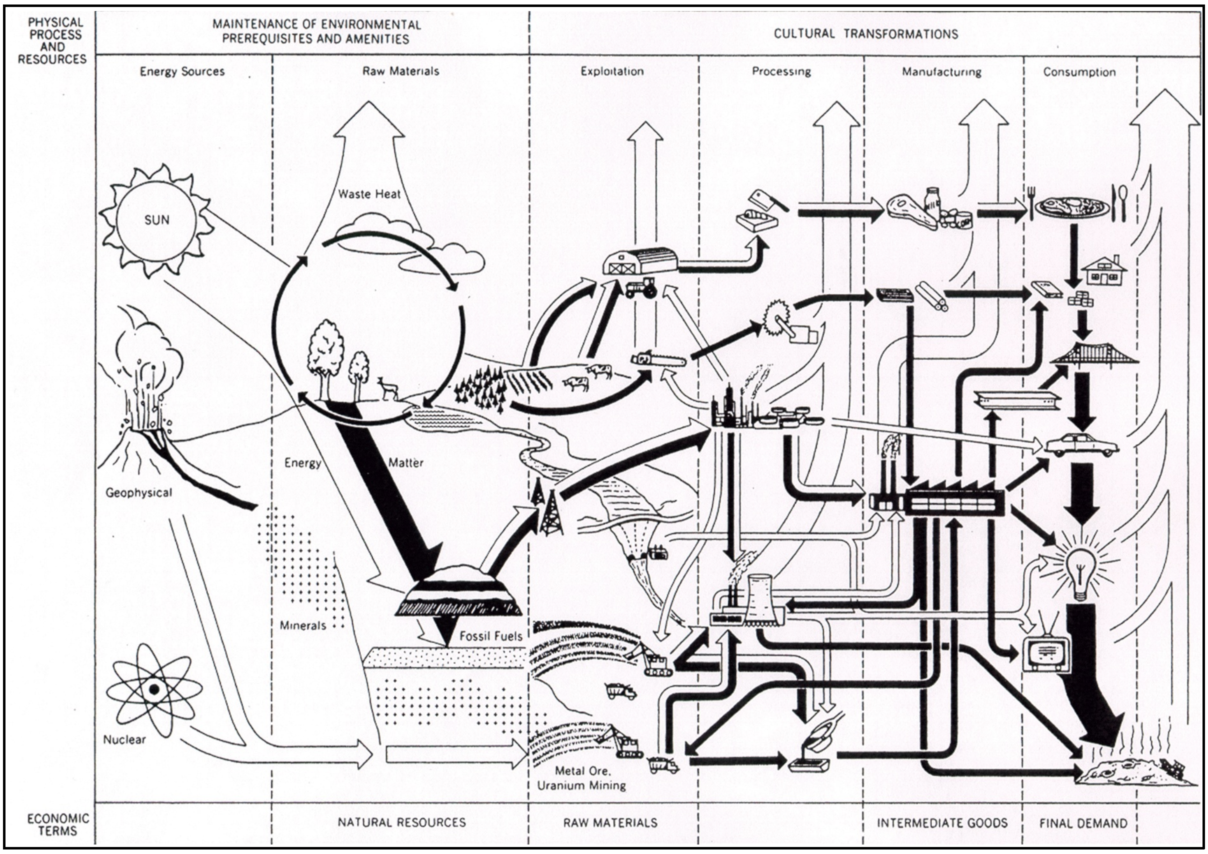

Figure 3 - The "real" economy within its environment

In contrast to the model of Figure 2, Figure 3 shows the economy as a subset of (and both implicitly and explicitly a creation of) the social system which created it and that in turn exists within, and is inextricably dependent upon, the wider ecosystem that gives it life (and which is forever fixed in terms of its material size and its energy input from the sun). It also acknowledges both the laws of physics and the understandings of human behaviour that govern and constrain the activities of people.

Limits to Green Processing and Eco-efficiency

In this context, eco-efficiency and green processing have the potential to achieve very substantial benefits, as has been shown in several studies over recent years. The longer-term problem remains, however, as long as perpetual growth in GDP remains the *sine qua non* of "development". While the material or energy resource component of a dollar's worth of production has decreased in many countries, the absolute amount of resources consumed has in most cases continued to increase as a result of a proportionally greater rate of (monetary) economic growth. Since it is absolute amounts that are significant in ecological (i.e. sustainability) terms, the problem remains, albeit somewhat alleviated from what it might otherwise have been.

However, unless the way of thinking that promotes growth as the response to human needs is changed, all that improved technology will achieve is a breathing-space, in that resources "freed up" by efficiency improvement are then available for further growth, resulting in a "rebound" effect, known as the "Jevons Paradox" (Polimeni et al, 2008).

If demand grows, so too must supply. No matter how much industrial processes are improved, they are still subject to the laws of physics, especially the second law of thermodynamics, meaning that for any physical transformation to take place, at the very least some degradation of high quality energy resources must occur. For that reason, *de*materialisation of industrial production is not possible; *reduced* materialisation is the best we can hope for.

Unless the full spectrum of human welfare needs - physical, social, psychological and so on - can be satisfied without overloading the global ecosystem's capacity to supply resources and receive wastes, into the indefinite future, then SD remains a dream, rather than a realistic policy option.

The Reality of Complexity

It is worth remembering that technology arose largely from motivations that included the improvement of living conditions of people. The understandably utilitarian goals of this process were achieved via adoption of mechanistic, reductionist approaches based on the simplifying assumptions of, firstly, nature seen as a machine and secondly, nature's complexity understood by investigating the properties of its parts. Both assumptions came together in the pursuit of means to manipulate nature for human benefit. Conquest and colonisation of other countries and especially indigenous peoples also provided large quantities of cheap resources for industrialised countries. The short-term outcomes have in many cases been spectacularly successful, but at the cost of significant impacts on the poor and the weak, together with severe effects on the long-term options available for future generations. It is time for a more sophisticated approach, to reflect the markedly-different imperatives and constraints facing us in the early years of the 21st Century (Nadeau, 2006, 2008).

A human society with its associated economy is a special form of biophysical system. Such systems can only maintain the ordered structures necessary for life by taking in resources (negentropy) from their surroundings and rejecting waste (entropy) in the reverse direction. The complex behaviour of such far-from-equilibrium systems means that their future form is inherently indeterminate, and the processes that give rise to it are subject to what is sometimes termed chaos. For this reason, adoption of the Precautionary Principle as a guiding ethic is an essential first step.

Breaking the Mould - a Biophysical Economics of Sustainability

Nothing that has happened in relation to energy, resources and environmental problems over the last 30 years has surprised those who have paid attention to the relevant scientific literature. Although regularly put before policymakers and the general populace, it is only very recently that the existence, let alone the imminence, of biophysical constraints on economic and social activity have become evident.

While yet to be explicitly acknowledged as such, issues such as accelerated climate change, peak oil, land degradation, fresh water depletion etc. actually illustrate facets of the biophysical reality of limitations to Carrying Capacity - the ultimately-severe constraints on the ability of any population to grow continuously, within a finite land area. While the 18th Century prognostications of Malthus and the 20th Century "Limits to Growth" scenarios have often been contemptuously dismissed, they are actually looking more and more realistic with every year that passes (Meadows et al, 2004).

It is the main point of this paper that the mainstream (neoclassical) economics used for policymaking over recent decades is seriously flawed, and is a central driver of the environmental problems that face us (Nadeau, 2006, 2008). To address these problems, and acknowledge the existence of biophysical limits, abuse of the biophysical environment in the pursuit of economic growth must be considerably reduced, to a level that is safely within the long term carrying capacity of local, regional, national and global ecosystems. Such an economy would be described as a Steady State Economy, in contrast to a growth economy. It is desperately important to make a start by taking on board some simple rules to guide transitional macroeconomic behaviour to fit within the constraints that are inherent in a biophysical economics of sustainability. Starting at the local level is a valuable first step.

Daly has put forward two rules to describe the relationship of an economy or a project to its environment, if *strong sustainability* (i.e. genuine sustainability, rather than the outward appearance of, commonly termed *weak sustainability*) is to be achieved (Daly, 1990) :

The Output Rule	*wastes ... should be kept within the assimilative capacity of the local environment:*
The Input Rule	*for renewables harvest rates of renewable resource inputs shall not exceed the regenerative capacity of the natural system that generates them.*
	for non-renewables depletion rates shall equal the rate at which renewable substitutes are developed by human invention and investment.

Closely-related criteria have been published by The Natural Step ™ (www.naturalstep.org/). Regrettably, few countries have anything to celebrate, in terms of their current performance in relation to these criteria.

Conclusion - Towards a Steady State Economy

Criteria and understandings such as those described above make it clear that (inter alia) the flows of energy and matter through any social-economic system must be subject to constraints. Existence of these constraints will require a substantial change in economic, social and environmental policies for the future. There is a significant literature on the topic, of which Daly's writings are probably the most accessible and useful (Daly, 1991, 1996).

The Centre for the Advancement of the Steady State Economy (CASSE) (<www.steadystate.org>) has published a Position on the issue, of which the following excerpt summarises some key points:

- *A steady state economy (that is, an economy with a relatively stable, mildly fluctuating product of population and per capita consumption) is a viable alternative to a growing economy and has become a more appropriate goal in large, wealthy economies, and;*
- *The long-run sustainability of a steady state economy requires its establishment at a size small enough to avoid the breaching of reduced ecological and economic capacity during expected or unexpected supply shocks such as droughts and energy shortages, and;*
- *A steady state economy does not preclude economic development, a dynamic, qualitative process in which different technologies may be employed and the relative prominence of economic sectors may evolve.*

It is the conclusion of this writer that a philosophical position such as this, together with a biophysics-based economics of sustainability, are essential policy needs for a stable future, for New Zealand and the world. The process of transition cannot be delayed much longer.

In conclusion, it is important to comment that the models described in this paper come from a Western scientific viewpoint, and are intended to address only the topics discussed in this paper. They are still in many respects seriously incomplete. In particular, they do not address the richness and complexity of human social, cultural and intellectual life, other than acknowledging the physical basis for that life. In the context of society in Aotearoa New Zealand, the *tangata whenua* have yet another way of looking at that reality, which acknowledges the left-hand side of the model in Figure 3, while interpreting the "Cultural Transformation" section on the right-hand side in a markedly different manner (Peet, 2006). Sustainability has many dimensions, which as yet societies have not managed to address in a whole-system manner.

References

Common, Michael (1996), *What is Ecological Economics?*, Land & Water Resources R & D Corporation Occasional Paper Series 09/96, GPO Box 2182, Canberra, ACT 2601

Daly, Herman E, (1990), *Sustainable Development: From Concept and Theory Toward Operational Principles*, Population and Development Review, 1990. Reprinted in HE Daly, *Steady-State Economics*, 2nd edn p 256.

Daly, Herman E (1991), *Steady State Economics,* 2nd edn, Island Press, Washington DC and Covelo CA.

Daly, Herman E (1996), *Beyond Growth: The Economics of Sustainable Development*, Beacon Press, Boston.

Daly, Herman E (1999), *Ecological Economics and the Ecology of Economics: Essays in Criticism*, Edward Elgar, Cheltenham UK, pp 12-13.

Nadeau, Robert (2006), *The Environmental Endgame. Mainstream Economics, Ecological Disaster, and Human Survival*, Rutgers University Press

Nadeau, Robert (2008), *Brother, Can You Spare Me a Planet? Mainstream Economics and the Environmental Crisis*, Scientific America, (original version: 298: 4: 42; extended web version www.sciam.com/article.cfm?id=brother-can-you-spare-me-a-planet)

Peet, John (2004), *Economic Systems and Energy, Conceptual Overview,* Encyclopedia of Energy vol 2 pp 103-115, 2004, Elsevier Inc.

Peet, John (2006), *Systems Thinking and Common Ground*, International Journal of Transdisciplinary Research Vol. 1, No. 1, 2006 pp 88-99.

Polimeni, John M, Kozo Mayumi, Mario Giampietro and Blake Alcott (2008), *The Jevons Paradox and the Myth of Resource Efficiency Improvements*, Earthscan, London.