Peet, Dr John
Department of Chemical & Process Engineering
University of Canterbury
Private Bag 4800, Christchurch
Phone: +64 3 384 1281
Fax: +64 3 384 6281
Email: john.peet@canterbury.ac.nz

Technology for Sustainability - Some Facts and Some Fallacies

Abstract

Sustainable Development (SD) is seen in most countries as a shorthand term for a process whereby techniques such as eco-efficiency, dematerialisation and decoupling will guarantee economic growth continuing without limit into the indefinite future, so that the wellbeing of people will be continually improved without compromising the quality of the environment. This process, where economic growth takes centre stage, is the policymaking priority in most countries.

This paper challenges the appropriateness of that position, for two main reasons. Firstly, there is scant evidence that continued economic growth actually improves people's real wellbeing. Secondly, eco-efficiency, dematerialisation and decoupling involve assumptions about the ability of science and technology to deliver both unending growth in goods and services and environmental sustainability, that are at best highly questionable and at worst potentially disastrous, for society and for the ecosystems of Planet Earth. To be blunt, the current socio-economic systems under which we live are not sustainable for much longer. These systems must be changed before change is forced upon us.

The problem is addressed by suggesting a number of ways in which scientifically-informed, economically-viable and socially-benign sustainable development technology policy options can be created, that could genuinely satisfy the aim of improving the wellbeing of people and at the same time maintain or improve the health of their total environment over the very long term. The major imperatives of our time are to identify such options and initiate a process of re-examining the priorities of economic, social and environmental policymaking in a whole-system manner, not as independent policy areas.

Introduction

The goal of an economy is wellbeing of the people who live in it - in both the short and the long term. That is a final goal. Wealth is an intermediate goal, valuable when it contributes to the final goals - and not when it does not. Growth, efficiency and consumption are similarly intermediate goals, not ends in themselves (Goodwin, 2004). To many nowadays, including many economists, wellbeing is not simply a function of consumption of goods and services, let alone improved by increases in consumption. Wellbeing is a much more complex issue, involving non-material as well as material means of satisfying people's needs. Goods and services largely address material needs; non-material needs have to be addressed differently, many of them only indirectly, if at all, related to economic activity (Peet, 2004).

In this context, I put forward an ethical statement that links wellbeing to policy in a way that is consistent with the above goal. It is one my wife and I developed several years ago (Peet and Peet, 2000 p 3), and found acceptable to several voluntary groups with which we are involved. It came out of extended discussions and summarises the consensus reached. The ethic reads:

All people have their basic needs satisfied, so they can live in dignity, in healthy *communities, while ensuring the minimum adverse impact on natural systems, now and in the future.*

What the term "basic needs" means involves examination of the full social, economic, physical and ecological context within which people live, and goes much further than the simple requirements for survival. A discussion of the meaning of need, from both human and generic systems points of view, appears in a forthcoming paper (Peet, 2004).

The next question is whether this understanding of wellbeing is shared by the policymakers. The NZ Government issued a SD report outlining its present approach in August 2002 (NZ Government, 2002). In a press release accompanying its publication, announced shortly before she left for the WSSD meeting in Johannesburg, the Prime Minister made the following comments (emphasis added):

> *... the government is committed to ensuring that New Zealand is at the forefront of international efforts to be economically, socially and environmentally sustainable.*
>
> *The central issue is how we achieve* ***sustainable economic growth*** *in a manner which enables us to* ***improve the wellbeing of all our peoples without compromising the quality of the environment****.*

In that report (NZ Government, 2002 p 5), the Minister for the Environment further commented on:

> *...* ***priorities ... such as economic growth****, the implications of international population change for New Zealand,* ***decoupling of economic growth from environmental harm****, governance for sustainable development ....*

Similar priorities were stated in a follow-up report in early 2003 (NZ Government, 2003).

In my opinion, the aims of this declared SD policy are admirable, and recognition of the vision and principles are encouraging. The difficulty is that, while both vision and principles are enunciated, there is no explicit or implicit evidence as to whether they are in fact attainable, whether physically, technologically, economically, socially or environmentally. The implicit assumption that economic growth actually equates to improved wellbeing is also an area where major questions are being asked by ecological (and many other) economists (for example, Daly 2003). The further assumption that growth is always economic is another, where serious doubts exist as to the benefits of continuing growth in already-developed nations (such as NZ and Australia) (see, for example, Daly 2003 op cit pp 12-19 and Hamilton, 2003). I also note the labelling, as "sustainable", of what is often nothing more than growth management, as in Auckland.

Sustainability and Growth

I have examined aspects of the issues of sustainability of economic growth and opportunities for technological decoupling and eco-efficiency in a recent paper (Peet, 2003), so will only briefly summarise the conclusions here.

While significant opportunities exist for reduction in the materials and energy used in production and consumption processes in an economy, these are inherently limited by the laws of physics. Nevertheless, governments persist in promoting the notion of economic growth, without connecting with the fact that all that such growth has a materials and energy dimension that is inescapable, since *"that to which value is added*" is always physical. While technologies for decoupling, eco-efficiency and dematerialisation offer opportunities for reduction in demands for resources or in pollution emissions for a while, over the long term the inexorable arithmetic of growth will render such efforts ineffective for other than short-term relief. Overall, the idea of eco-efficiency has been validly described as a temporary statistical bluff.

In any case, as mentioned above, the assumption that if the economy grows the wellbeing of its citizens will automatically improve is in itself highly questionable. This is for a number of reasons, including the fact that GDP growth treats goods and bads as of equal value, and equates any increase in overall quantity of economic activity to improvement in the quality of life. In reality the two are at best only vaguely connected, and in many cases poorly or not at all.

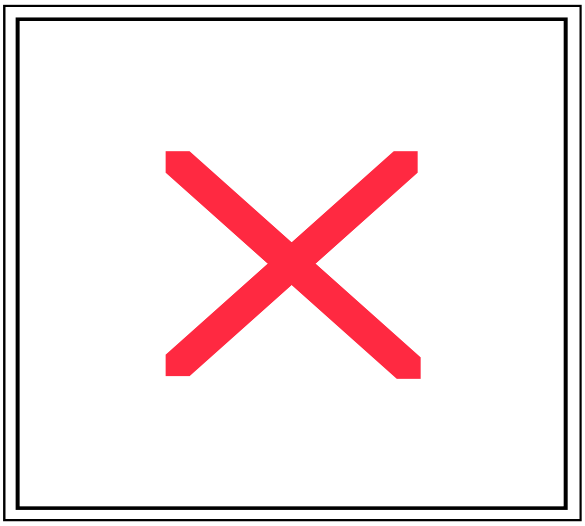
In this paper, I wish to push on with a further challenge - that of analysing our understanding of the mechanisms of conversion of raw materials and energy into products for human use and their possibilities for improvement. I do so because, in my opinion, there is widespread misunderstanding of the full and complex meanings of what are in reality joint processes of Production and Consumption.

To be more specific, a different - and much more positive - picture of the opportunities for sustainable development emerges if two government policy conditions can be satisfied:

- Growth in production and consumption of material goods and services (i.e. GDP) gives way to concentration on satisfying people's material needs materially, and their non-material needs non-materially;
- Nonrenewable-resource-intensive and ecologically-damaging processes are replaced by those which are environmentally and socially benign (see below for further discussion on this topic).

Production and Consumption

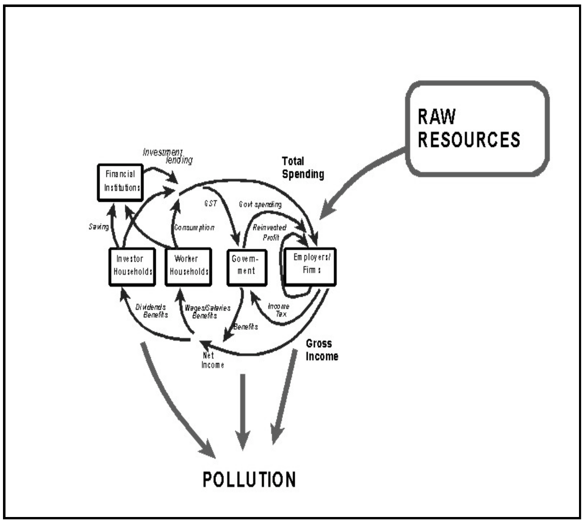
Figure 1 characterises the mainstream (neoclassical) model of the economic process, where goods and services are made by Employers/Firms ("producers") and then sold to Households ("consumers"), who in turn obtain money by selling their labour or capital (NB here, capital means human-made capital, not natural capital). (Import and export flows are not included here, for simplicity). The sum of flows in the lower half of the figure is Gross Domestic Product (GDP).



1 Figure 1 - Circular, monetary flow model of conventional economics

Exchange relationships between Capital and Labour (the Factors of Production) that give rise to Value Added are primary in this model. Underlying physical production relations are largely ignored. A consequence is that ***that to which value is added*** (i.e. the physical resource being transformed by capital and labour into a consumer good or service) has no obvious part in the theory. (Daly has pointed out that this is rather like asserting that a loaf of bread may be produced by means of the cook's labour and a kitchen, without any reference to flour, water, yeast or fuel to heat the oven!)

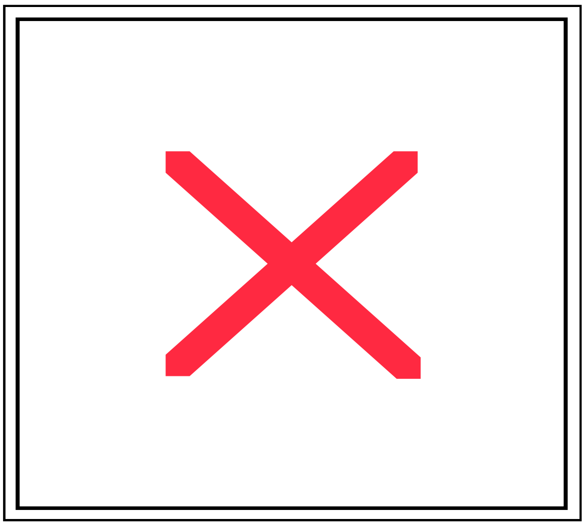
Physical aspects of production and consumption can be introduced via a model such as Figure 2. In this model, although money flows in a circular pattern, resources enter at one place and end up somewhere else.



2 Figure 2 - Resource requirements of economic activity

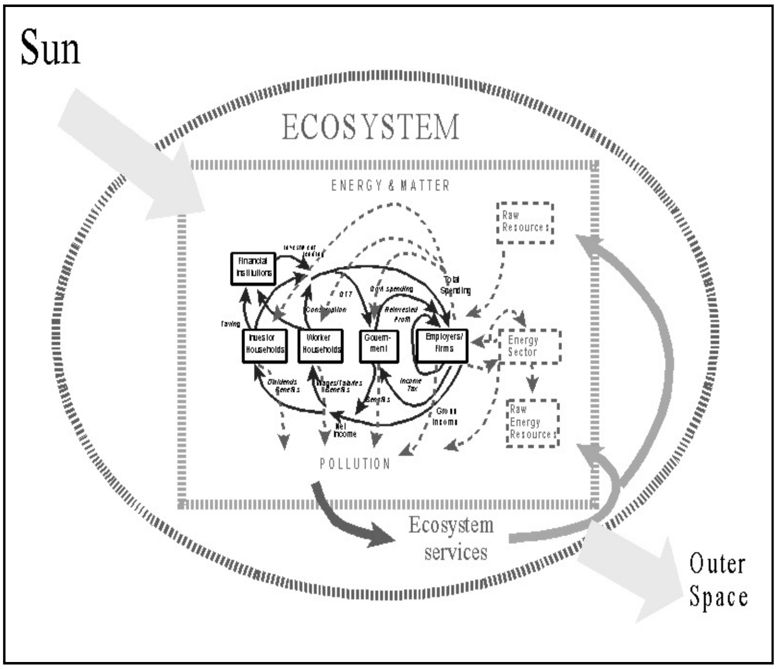
In the process, a lot of high-quality energy (exergy, or low-entropy energy resources) is expended and disposal problems are generated. The model therefore illustrates the "throughput" or "metabolic" model of economic activity, in which the economy is "fed" by raw resources from the environment and "excretes" wastes back to that environment. Such a system is known in science as an open or dissipative system, since it depends upon continuous flows of low entropy resources in, and high entropy wastes out for its survival.

From this perspective, it is clear that value is added ***to*** the throughput flow of natural resources, ***by*** the transforming services of capital and labour (in the formal economy). A coherent model of SD should incorporate both, as well as acknowledging that while resources provide *that to which value is added*, and are therefore probably benefits, pollution and waste are inevitable consequences which mostly involve costs. The latter are seldom charged to the transformation processes that create them. Nor is depletion of nonrenewable resources addressed by investing in renewable replacements. If these views were to be fully incorporated into economic perspectives, it would be possible to identify a level at which costs may exceed benefits, and hence the optimal (i.e. sustainable) scale of economic development, after which further growth may be undesirable.



3 Figure 3 - Thermophysical macroeconomic model

The model of Figure 2 may be further improved by acknowledging the essential part played by the separate linear flows of material and energy (exergy) resources from the environment, as shown in Figure 3. This is a thermophysical model of economic activity.



4 Figure 4 - Biophysical model of the economy within Planet Earth

Incorporation of the extra information gained from a material or energy analysis inevitably raises problems of commensurability of units, in that activities within the economy are conventionally represented in monetary units, whereas those in ecological and industrial systems are often better represented by material, energy, exergy or entropy flows. There is no clear solution to this problem; multicriteria and multiobjective approaches are inevitable in a context such as this, characterised by a high level of systemic complexity. Of one thing we can be sure, however; simply "getting prices right" will never be more than part of a solution.

A further model, that incorporates biophysical circumstances, is shown in Figure 4, showing that the thermophysical macroeconomic system of Figure 3 exists within, and is at all times dependent upon, the "super-system" ecosystem of Planet Earth, all of whose processes are driven, directly or indirectly, by energy from the sun.

This model also makes clear the necessity to define system boundaries with extreme care when examining issues such as sustainable development. If the mainstream economic model of Figure 1 is used (to a greater or lesser extent, depending upon the political views of the government in power), everything of importance to the physical world (i.e. to full-system sustainability) is reduced to the level of an "economic externality", when it is in reality central to the metabolism of the economy. This is because *that to which value is added* is largely invisible to the economic model. As noted above, only the capital and labour spent on accessing resources from the environment and processing them through to disposing of wastes are normally accounted for. If system boundaries are expanded, as in Figure 4, the dependence of economic systems on the import of net value from, and export of net cost to, external natural systems, becomes clearer. Since there is an upper (physical/ecological) bound upon this potential transfer, absolute scarcity exists and the question of limits to economic growth takes centre stage.

I now move to discuss some ways of addressing this complex issue, by examining the relationship between production and consumption from a wider set of system boundaries than is common. I start by making connections between resource use and consumption, via simple logic:

- ***If*** people have needs that require Consumption of goods and services,
- ***And if*** Consumption presupposes Production of those goods and services,
- ***And if*** Production requires transformation of resources taken from the environment, (i.e. *that to which value is added*),
- ***Then*** the relationships between resource use, transformation processes and the means whereby people's needs are satisfied by consumption of goods and services are central to an examination of the possibility of achieving SD.

These relationships must be made explicit and carefully examined if whole-system opportunities for SD policy are to be clearly identified and assessed.

Efficiency Concepts

Most governments have put in place economic incentives - explicit or implicit - for encouraging production. In order to increase "growth", production has to increase and/or become more economically efficient, since the primary measure of growth is GDP - the sum of the monetary expenditures on production (the lower half of the diagrammed flows in Figure 1). Since growth in GDP is known not to be a good measure of improvements in social wellbeing, let alone bearing much relevance to assessment of sustainability, a more realistic goal is to aim for consumption efficiency rather than economic (production) efficiency. As Princen et al (2002) point out:

> *It is about getting more with less, not more stuff but more satisfaction, not quantity but quality ... it is the level of social welfare and personal satisfaction obtained per unit of energy and materials consumed.*

In Princen et al's discussion, materials include the inputs that reside within non-market institutions such as natural capital. Consumption efficiency is defined from the point of view of demand and not supply, with the logical outcome that producers must internalise their costs and stop those behaviours that result in damage to natural or social systems.

The Danish physicist Nørgård (2004) has developed a valuable way of decomposing the overall process into component sub-efficiencies, that assists one in developing an understanding of what may be the most important questions to be addressed in improving the overall efficiency of manufacture and delivery of those goods and services that address people's needs and satisfactions via the use and transformation of natural resources. It is (as stated previously) not enough to look just at eco-efficiency, dematerialisation or decoupling; these will never be more than useful steps along the way to SD.

In Nørgård's analysis, efficiency is the ratio of desired consequences to undesired consequences, or alternatively, the ratio of satisfaction to sacrifice. He expresses it via the equation:

Overall Efficiency / Satisfaction/Eco-Sacrifice ....(1)

where Eco-Sacrifice represents the totality of that which is taken (as natural capital) from, or damaged (e.g. as pollution) in the surrounding natural ecosystem. In practice this is just as difficult to measure as the Satisfaction gained by people.

Clearly, there are many links in the chain of chain of activities from extraction of natural resources to satisfaction of people's needs, and by separating out each link in the chain we can help to understand promising ways of improving overall efficiency. The following equation illustrates one such separation:

Overall Efficiency
/ Satisfaction/Service * Service/Stock * Stock/Throughput * Throughput/Eco-sacrifice ....(2)

This equation may be rendered slightly differently as the product of four sub-efficiencies:

/ Satisfaction Effy. * Service Effy. * Maintenance Effy. * Throughput Effy. ....(3)

Working from right to left, to explain the different sub-efficiencies in equation (3):

- *Throughput Efficiency* is a function of the throughput of resources (minerals or energy, renewable or nonrenewable, all of which can be measured) and hence to the need to reduce them as one important aspect of improving overall efficiency and reducing eco-sacrifice.
- *Maintenance Efficiency* refers to the amount of stock that can be maintained by a given throughput of resources. This efficiency relates to the durability or repairability of the stock of goods, which is a function of design.
- *Service Efficiency* refers to how much service people obtain from utilising the stock of goods. Services here refer to the physical, and hence quantifiable, flow of services (as in energy efficiency, when the service is that of cooking, heating etc., not the throughput flow of energy or fuel in itself). Careful matching of the service to the stock (and hence to the throughput required to maintain the stock) is the key to improved service efficiency.
- *Satisfaction Efficiency* relates to the satisfaction people obtain from the service provided. While the service may be measurable, the satisfaction obtained is not easily measured.

The boundary between that part of the economic system that is in the hands of final consumers, and that part controlled by suppliers, depends upon the type of consumer goods and services purchased, and hence the position of the marketplace, where producer and consumer meet. Nørgård divides these into three categories: durable goods, services and non-durables, with the overall efficiency composed differently in each case.

- Durable goods are physical goods, whose value lies in having a stock of them at hand to provide services when wanted.
- Services relate to that part of the economy which provides services directly (such as child care, entertainment, education, banking, public transport), and where it is the service that is purchased, not the physical good or artifact that provides a service.
- Non-durable goods, which only serve people when being consumed, such as food, beverages, tobacco, detergents, and energy in various forms.

Improving Efficiencies

Once the Overall Efficiency has been broken down into its component parts, the potential for improvement can be more easily determined, by addressing each part separately. In this approach, the lifetime of durable goods is clearly a vitally-important option to address, via examining issues such as the different forms of obsolescence, repair, recycling, reusing and so on. One important counter-point in relation to encouragement of longevity of durable goods is that of technological improvement, especially in relation to energy efficiency, where it may be better to replace than to continue using. In this case, obviously, the ability to recycle obsolete equipment is of central importance. Where services are concerned, responses would include much better energy end-use efficiency, by such means as insulation, solar water heating, compact fluorescent lighting and so on. These have the opportunity to reduce electricity consumption considerably, while maintaining or even improving service efficiency. Where non-durables are concerned, the issues are different, but can include encouragement of behavioural changes such as not buying air-freighted luxury foods out of season, and drinking local beer and wine rather than imported products.

A final point discussed by Nørgård is that of many people in Northern European countries choosing more leisure over more paid work, because it gives them more satisfaction (i.e. more satisfaction than making more money to be spent on buying more stuff). By including the term for Satisfaction efficiency in our examination, it is possible to focus on the extent to which marginal satisfaction from additional services may be gained. In many affluent countries this appears to be low and declining, sometimes possibly negative. While not usually capable of direct measurement, indirect measurement may be done via elucidation of people's behaviour such as determining (via surveys) their preference for more leisure over more paid work (Nørgård 2004). Since it has the effect of reducing or reversing the growth rate in all three types of consumption, and hence the demands of production for Eco-Sacrifice, the option of more leisure has a powerful influence on a society's Overall Efficiency.

Design Concepts and Biomimicry

Complementary to the Consumer Efficiency approach is that exemplified by the Cradle to Cradle Framework (McDonough et al, 2003). These authors promote the principle of a conceptual shift in engineering design practice towards processes similar to those used in Nature:

> *... away from current industrial system designs which generate toxic, one-way, 'cradle-to-grave' material flows and toward a 'cradle-to-cradle' system powered by renewable energy in which materials flow in safe, regenerative, closed-loop cycles.*

Using their "3 Tenets of Cradle to Cradle", obtained from observation of natural systems (sometimes referred to as Biomimicry):

$ *Waste equals food;*
$ *Use current solar income;*
$ *Celebrate diversity*

they developed a set of *12 Principles of Green Engineering* as a toolbox to be used systematically to optimise a system or its components, as follows:

Principle 1 *Designers need to strive to ensure that all material and energy inputs and outputs are as inherently nonhazardous as possible.*

Principle 2 *It is better to prevent waste than to treat or clean up waste after it is formed.*

Principle 3 *Separation and purification operations should be designed to minimize energy consumption and materials use.*

Principle 4	*Products, processes, and systems should be designed to maximize mass, energy, space, and time efficiency.*
Principle 5	*Products, processes, and systems should be "output pulled" rather than "input pushed" through the use of energy and materials.*
Principle 6	*Embedded entropy and complexity must be viewed as an investment when making design choices on recycle, reuse, or beneficial disposition.*
Principle 7	*Targeted durability, not immortality, should be a design goal.*
Principle 8	*Design for unnecessary capacity or capability (e.g., "one size fits all") solutions should be considered a design flaw.*
Principle 9	*Material diversity in multi-component products should be minimized to promote disassembly and value retention.*
Principle 10	*Design of products, processes, and systems must include integration and inter-connectivity with available energy and materials flows.*
Principle 11	*Products, processes, and systems should be designed for performance in a commercial "afterlife"*
Principle 12	*Material and energy inputs should be renewable rather than depleting.*

Principles such as these seem to present a major challenge to industries, but in many respects they are not beyond current technological comprehension. There are a number of examples (McDonough et al, 2003 op cit) where significant progress towards adoption of several of the principles has been achieved (with generally positive economic results for the industries involved) and the number is expected to increase as others follow their example.

One central problem preventing widespread adoption of principles such as these is the continued refusal of most governments to remove what are often direct subsidies to undesirable industries, let alone require internalisation of known environmental and social costs by all industries. The result is that many "resource-hungry" or "dirty" processes continue in operation, because to penalise them would put at risk political constituencies. But without such a move, those newer industries that promise good economic performance and good jobs with much lower eco-sacrifice have to compete on a playing field tilted heavily against them. The problems, worldwide, of implementing advanced energy efficiency and renewable energy technologies against the entrenched interests of fossil and nuclear industries provide good examples of this. Similarly, rigid institutional structures may also prevent achievement of a level playing field, as in the case of the artificially-constructed market structure that governs operation of the NZ electricity system.

Economic Policy Priorities

If the aim of the economy is, as I asserted at the beginning of this paper, that of wellbeing of its citizens in both the long and the short term, then it is clear that continuing along the policy path of making marginal changes to current policies will not achieve this goal, because the natural systems upon which we depend, locally and globally, are under severe stress and will not continue to deliver the "ecosystem services" upon which we depend for much longer. Substantial changes are needed, to shift the economic priorities of governments towards sustainable development policy options that have a real chance of success.

As is widely known, it is actually the total system of human society, economy and surrounding ecosystem(s) that must be sustainable into the long term future, not just the economy or any single part of the total system. Any "development" of society takes place within the totality, and "sustainable development" has meaning only within that same totality. According to mainstream (neoclassical) economics, a primary purpose of the economy is to achieve (Pareto-efficient) optimal allocation of resources (with its corresponding optimal set of prices). As Daly (2003 p 4) points out, however, the economic problem is rather more complex:

$ *A good **allocation** of resources is **efficient** (Pareto optimal);*

$ *a good **distribution** of income or wealth is **just** (a limited range of acceptable inequality);*

$ *a good **scale** does not generate "bads" faster than "goods" and is also ecologically **sustainable** (it could last a long time, although nothing is forever).*

The first item (allocation) is the main preoccupation of mainstream economics, and is achieved by means of the market mechanism. The second is usually included for the sake of social justice. The third is seldom included in discussion, but as indicated above, is critical for long term sustainability of the total system. All three are central concerns of the new transdisciplinary approach of Ecological Economics, and therefore must be treated jointly if the total system is to have a chance of sustainability, and if the humans within that system are to have the opportunity to maintain or improve their collective and individual wellbeing.

This paper has concentrated on addressing the third item above, that of a good scale. The first is in theory taken care of by free markets, but as indicated above, the presence of substantial externalities where environmental issues are concerned means that the markets cannot function properly. Their allocation outcome is therefore at all times non-optimal. The second item is incorporated directly by governments, usually via socio-economic processes such as redistribution, benefits etc., to a greater or lesser extent that depends upon the political views of the government in power. An important point not treated in this paper (but see Peet, 2004 op cit) is whether the systems of production and consumption in the economy do actually address what I argue is the central issue, that of satisfying the basic needs of its citizens.

Conclusions

As yet, the lack of other than a weak approach to Daly's third item (scale) and the highly-political nature of the second item (distribution) means that the overall process of moving towards the goal of long-term sustainable wellbeing for all is a long way off.

In particular, it has to be said that continued promotion in government policies, of the goal of economic (GDP) growth, militates against this possibility. GDP growth as currently understood is actually more a problem than a solution. Much better means of evaluating and assessing progress in the wellbeing of a society, and in satisfaction of the needs of its citizens, must be developed. These are more likely to involve multicriteria and multiobjective approaches than identification of some "silver bullet" indicator that serves them all.

As indicated in this paper, if changes can be made to some of the ground rules of economic behaviour, substantial opportunities exist for major improvements. These could take several forms. One example would be comprehensive internalisation of costs, which would mean unsustainable processes would become more costly and hence less economically viable - and be replaced by more economically- (and environmentally-) benign processes in the marketplace. Shifting of government taxes away from taxes on "goods" (labour, income etc.) and towards "bads" (pollution, resource use etc.) would have similar effects. Other options include institutional and legal structures put in place alongside the economic, all contributing towards shifting society towards much more sustainable behaviour by individuals, communities, industries, regions and governments.

The social, economic and technological opportunities are there, arguably achievable over a time span of probably one or two generations if adopted purposefully. It is time to start their adoption by means of serious policies that will enable us to collectively change direction.

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