# Sustainable Food System for Sustainable Development

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## What's a sustainable food system?

That's a question for this conference to answer. But I'll show you what it is not. Here's a sobering estimate of the greenhouse gas emissions from eating in a European country, based on full life cycle accounting, from farm to plate to waste [1].

**Greenhouse gas emissions from eating (France)**

| | |
|---|---|
| **Agriculture direct emissions** | 42.0 Mt C |
| **Fertilizers** (French fertilizer industry only, more than half imported.) | 0.8 Mt C |
| **Road transport goods** (within France only, not counting export/import) | 4.0 Mt C |
| **Road transport people** | 1.0 Mt C |
| **Truck manufacture & diesel** | 0.8 Mt C |
| **Store heating** (20% national total) | 0.4 Mt C |
| **Electricity** (nuclear energy in France, multiply by 5 elsewhere) | 0.7 Mt C |
| **Packaging** | 1.5 Mt C |
| **End of life of packaging** (overall emissions of waste 4 Mt) | 1.0 Mt C |
| **Total** | 52.0 Mt C |
| **National French emission** | 171.0 MtC |
| **Share linked to food system** | **30.4%** |

The figure of 30.4 percent is clearly an underestimate, because it leaves out emissions from the fertilizers imported as well as pesticides, transport associated with import/export of food, energy spent storing and preparing food in homes; and emission from electricity is one-fifth of typical non-nuclear sources.

Our current food system is dominated by high agricultural inputs, including pumped irrigation water, and huge volumes of commodity export and import, much of it by air. Taking all those into account could easily increase the greenhouse gas emissions another 5 to 10 percent of total. That gives a rough idea of how much scope there is for reducing greenhouse gas emissions (and energy use) by changing agricultural practices, cutting out agricultural inputs and unnecessary transport, storage and packaging through local production and consumption.

## Sequestering C in soil provide food security and mitigate global warming

Carbon dioxide in our atmosphere has reached an all-time high of 379 ppm (parts per million), giving a total of 807 Gt ($10^9$ tonnes) of carbon in the earth's atmosphere. This is still less than a third of the 2 500 Gt of carbon in the earth's soil, of which 1 550 Gt is organic carbon, and the rest inorganic carbon. The global soil organic carbon pool is almost three times the 560 Gt C estimated in all living organisms [2].

The earth has been losing soil organic carbon to the atmosphere since historic times, a process greatly accelerated within the past 50 years, as agriculture intensifies, and forests are cut down to convert to agricultural land. Estimates for the historic losses of soil organic carbon range widely from 44 to 537 Gt, with the common range of 55 to 78 Gt. That is the amount we can theoretically put back from the atmosphere into the soil as organic carbon, if we get our agriculture and land use right.

There is significant potential for sequestering, or taking carbon from the air into the soil through a set of recommended management practices. On existing croplands (1.35 billion ha), maximise soil organic carbon and fertility through organic inputs, cover crops, conservation tillage and mixed farming; on rangelands and grasslands (3.7billion ha), prevent overgrazing, fires and loss of nutrients, on degraded and desertified land (1.1 billion ha), prevent water and wind erosion, harvest and conserve water and plant forests; and on irrigated land (0.275 billion ha), control salinity, use drip/sub-irrigation, provide drainage, enhance water efficiency and conservation.

In fact, R. Lal in Ohio State University said [2, p.1626], "Soil C sequestration is a strategy to achieve food security through improvement in soil quality", and as a bonus, it offsets 0.4 to 1.2Gt C/year, or 5 to 15% of the global emissions of 7.9Gt C of greenhouse gas due to human activities each year.  Ingrid Hartman will say more soil to-morrow.

## Agroforestry for food security and C sequestration

Another way to cut emissions is to stop cutting down forests. Deforestation contributes 1.6 Gt C emissions or 20% of the annual global greenhouse gas emissions due to human activities [3]. More than 14 million hectares of forests are cleared every year, mostly in the tropics [4]. Brazil alone has lost 47.4 million hectares of its Amazonia forest since 1978 [5], mostly for raising cattle; and in recent years, for growing soya as cattle feed.

Tropical forests are the richest carbon stocks and most effective carbon sinks in the world. The carbon pool in the secondary tropical forests in Mt. Makiling Forest Reserve in the Philippines was assessed at 418tC/ha, of which 40 percent was soil organic carbon [6]; and this forest sequestered carbon at the rate of 5tC/ha/y. An agro-forestry system with cacao trees in a forest reserve in southern Luzon in the Philippines had a mean C pool of 258t/ha [7]. Agroforests in the humid tropics sequester a median of 10t C/ha/y [8]. Replanting forests for sustainable agro-forestry creates significant carbon stocks and sinks, and at the same time, restore livelihood to millions of indigenous peoples who have been displaced and/or poisoned by cattle ranges, soya farms, oil and mining industries.

Tropical rain forests like those in the Amazon also play a most crucial role in mitigating global warming by regulating climate and rainfall [9], which is why they must be preserved and restored at all costs, as Peter Bunyard will tell you to-morrow.

## A profusion of local inventions for sustainable food production

There is a profusion of local inventions for producing food sustainably, increasing productivity while saving energy and water, *and* harvesting energy from farm wastes to reduce greenhouse gas emissions. They are described in detail in successive issues of our must-read magazine. I mention a few.

Jesuit priest, Henri de Laulanie, working with farming communities in Madagascar in the late 1980s invented a system of rice intensification that is now practiced by 100 000 farmers in the country and spreading to other countries in Africa and Asia [9,10]. It depends on transplanting rice seedlings at an earlier age and spaced wider apart than usual, emphasis on organic inputs, and most importantly, keeping the soil moist rather than flooded during the growing season. This encourages the rice plants to put out more side shoots, grow deeper, stronger roots, increasing yields from 2t/ha to 8t within the second year, and 12t/ha or more in later years. These results met with scepticism from the conventional scientific community; but have been confirmed by Chinese crop scientist Yuan Longping, co-winner of 2004 World Food Prize. Other Chinese scientists documented savings on seeds by 60%, 100% on fertilizers, and most of all, saving 3 000 tonnes of water/ha.

Agricultural wastes are a major source of the most serious greenhouse gases: methane and nitrous oxide. The perfect solution is to harvest the methane as 'biogas' for energy, while reducing nitrous oxide emission, saving the nitrogen as organic fertilizer nutrient for crops. How? By digesting the agricultural wastes anaerobically (in the absence of air) with bacteria normally present in the wastes, especially cattle dung. No one knows who first invented biogas. Anecdotal evidence suggests that biogas was used for heating bath water in Assyria during the 10$^{th}$ century BC [11], and the first digestion plant to produce biogas from wastes was built in a leper colony in Bombay, India in 1859. Based on this ancient invention, scientists in the United States and Canada are recently producing hydrogen, the ultimate clean fuel, as well as methane from food and agricultural wastes [12].

Biogas is becoming popular in many Third World countries, and emerging as a major boon, bringing health, social, environmental and financial benefits [13]. Nepal's successful biogas programme saves 625 000 tonnes of carbon dioxide equivalents from being pumped into the atmosphere each year, earning it US$5 million in carbon trading that can be invested back into clean energy to generate yet more income from carbon trading.

As you can see, there is a lot of potential for putting in place post-fossil fuel, minimum-emission food systems, especially in poor countries; but we are stymied by our political leaders' overwhelming commitment to a dominant model of infinite, unbalanced growth that has brought us global warming and the imminent collapse of food production, as I mentioned earlier in my introduction to our Global Initiative.

There are many success stories from the grassroots. You will hear the one about Ethiopia from Sue Edwards to-morrow. I shall describe another showing how science and indigenous knowledge can work wonders together [14], which also illustrates a model of sustainable balanced growth [15-19] that I believe should replace the dominant model.

## Environment engineer meets Chinese peasant farmers

It sounds like a dream, but it *is* possible to produce a super-abundance of food with no fertilizers or pesticides and with little or no greenhouse gas emission. The key is to treat farm wastes properly to mine the rich nutrients that can be returned to the farm, to support the production of fish, crops, livestock and more; get biogas energy as by-product, and perhaps most importantly, conserve and release pure potable water back to the aquifers.

Professor George Chan has spent years perfecting the system; and refers to it as the Integrated Food and Waste Management System (IFWMS) [20]. I call it "dream farm" for short [14].

Chan was born in Mauritius and educated at Imperial College, London University in the UK, specializing in environmental engineering. He was director of two important US federal programmes funded by the Environmental Protection Agency and the Department of Energy in the US Commonwealth of the Northern Mariana Islands of the North Pacific. On retiring, Chan spent 5 years in China among the Chinese peasants, and confessed he learned just as much there as he did in University.

He and many others were inspired, among them, Gunter Pauli, the founder and director of the Zero Emissions Research Initiative (ZERI) (www.zeri.org). Chan has worked with ZERI since, which has taken him to nearly 80 countries and territories, and contributed to evolving IFWMS into a compelling alternative to conventional farming.

### Treating wastes with respect

The secret is in treating wastes to minimize the loss of valuable nutrients that are used as feed. At the same time, greenhouse gases emitted from farm wastes are harvested for use as fuel.

Livestock wastes are first digested anaerobically (in the absence of air) to harvest biogas (mainly methane, $CH_4$). The partially digested wastes are then treated aerobically (in the presence of air) in shallow basins with green algae. By means of photosynthesis, the algae produce all the oxygen needed to oxidise the wastes to make them safe for fish. This increases the fertilizer and feed value in the fishponds without robbing the fish of dissolved oxygen. Biogas is used, in turn, as a clean energy source for cooking. This alone, has been a great benefit for women and children above all [13], saving them from respiratory diseases caused by inhaling smoke from burning firewood and cattle dung. It also spares the women the arduous task of fetching and carrying 60 to 70 lb of firewood each week, creating free time for studying in the evening or earning extra income. Biogas energy enables farmers to process their produce for preservation and added value, reducing spoilage and increasing the overall benefits.

"It can turn all those existing disastrous farming systems, especially in the poorest countries into economically viable and ecologically balanced systems that not only alleviate but eradicate poverty." Chan says [20].

## Increasing the recycling of nutrients for greater productivity

The ancient practice of combining livestock and crop had helped farmers almost all over the world. Livestock manure is used as fertilizer, and crop residues are fed back to the livestock.

Chan points out, however, that most of the manure, when exposed to the atmosphere, lost up to half its nitrogen as ammonia and nitrogen oxides before they can be turned into stable nitrate that plants use as fertilizer. The more recent integration of fish with livestock and crop has helped to reduce this loss [21]. But too much untreated wastes dumped directly into the fishpond can rob the fish of oxygen, and end up killing the fish. The most significant innovation of IFWMS is thus the two-stage method of treating wastes. The anaerobic digestion not only prevents the loss of nutrients, but also substantially reduces greenhouse gas emissions in the form of both methane (harvested as biogas) and nitrous oxide (saved as nutrient) that go to feed algae and then fish.

*To close the circle, which is very important for sustainable growth*, livestock should be fed crops and processing residues, not wastes from restaurants and slaughterhouses. Earthworms, silkworms, fungi, insects and other organisms are also encouraged, as some of them are associated with producing high value goods such as silk and mushrooms.

## Proliferating lifecycles for greater productivity

The aerobic treatment in the shallow basins depends on oxygen produced by the green alga *Chlorella*. *Chlorella* is very prolific and can be harvested as a high-protein feed for chickens, ducks and geese.

When the effluent from the *Chlorella* basins reaches the fishpond, little or no organic matter from the livestock waste will remain, and any residual organic matter will be instantly oxidized by some of the dissolved oxygen. The nutrients are now readily available for enhancing the prolific growth of different kinds of natural plankton that feed the polyculture of 5 to 6 species of compatible fish. No artificial feed is necessary, except locally grown grass for any herbivorous fish.

The fish waste, naturally treated in the big pond, gives nutrients that are effectively used by crops growing in the pond water and on the dykes.

Fermented rice or other grain, used for producing alcoholic beverages, or silkworms and their wastes, can also be added to the ponds as further nutrients, resulting in higher fish and crop productivity, provided the water quality is not affected.

Trials are taking place with special diffusion pipes carrying compressed air from biogas-operated pumps to aerate the bottom part of the pond; to increase plankton and fish yields.

Apart from growing vine-type crops on the edges of the pond and letting them climb on trellises over the dykes and over the water, some countries grow aquatic vegetables floating on the water surfaces in lakes and rivers. Others grow grains, fruits and flowers on bamboo or long-lasting polyurethane floats over nearly half the surface of the fishpond water without interfering with the polyculture in the pond itself. Such aquaponic cultures have increased the crop yields by using half of the millions of hectares of fishponds and lakes in China. All this is possible because of the excess nutrients created from the integrated farming systems.

It is now possible to have 4 rice crops yearly in the warmer parts of the country, grown in floats on the water, with almost total elimination of the back breaking work previously required.

Hydroponic cultures of fruits and vegetables are also done in a series of pipes. The final effluent from the hydroponic cultures is polished in earthen drains where plants such as *Lemna*, *Azolla*, *Pistia* and water hyacinth remove all traces of nutrients such as nitrate, phosphate and potassium before the purified water is released back into the aquifer.

The sludge from the anaerobic digester, the algae, crop and processing residues are put into plastic bags, sterilized in steam produced by biogas energy, and then injected with spores for culturing high-priced mushrooms.

The mushroom enzymes break down the ligno-cellulose to release the nutrients and enrich the residues, making them more digestible and more palatable for livestock. The remaining fibrous residues also can still be used for culturing earthworms, which provide special protein feed for chickens. The final residues, including the worm casting, are composted and used for conditioning and aerating the soil.

## Sustainable development & human capital

There has been a widespread misconception that the only alternative to the dominant model of infinite, unsustainable growth is to have no growth at all. I have heard some critics refer to sustainable development as a contradiction in terms. IFWMS, however, is a marvellous demonstration that sustainable development is possible. It also shows that the carrying capacity of a piece of land is far from constant; instead it depends on the mode of production, on how the use of the land is organised. Productivity can vary three- to four-fold or more simply by maximising internal input, and in the process, creating more jobs, supporting more people.

The argument for population control has been somewhat over-stated by Lester Brown [24, 25], and others predicting massive starvation and population crash as oil runs out. I like the idea of "human capital", if only to restore a sense of balance that it isn't population number as such, but the glaring inequality of consumption and dissipation by the few rich in the richest countries that's responsible for the current crises. The way Cuba coped with the sudden absence of fossil fuel, fertilizer and pesticides by implementing organic agriculture across the nation is a case in point [26]. Julia Wright will say more about that to-morrow. There was no population crash; although there was indeed hardship for a while. It also released creative energies, which brought solutions and many accompanying ecological and social benefits.

For the past 50 years, the world has opted overwhelmingly for an industrial food system that aspired to substitute machines and fossil fuel for human labour, towards agriculture without farmers [27]. This has swept people off the land and into poverty and suicide. One of the most urgent tasks ahead is to re-integrate people into the ecosystem. Human labour is intelligent energy, applied precisely and with ingenuity, which is worth much more than appears from the bald accounting in mega-Joules or any other energy unit. This is an important area for future research.

## Sustainable development is possible

Let me clarify my main message with a few diagrams. The dominant model of infinite unsustainable growth is represented in Figure 1. The system grows relentlessly, swallowing up the earth's resources without end, laying waste to everything in its path, like a hurricane. There is no closed cycle to hold resources within, to build up stable organised structures.

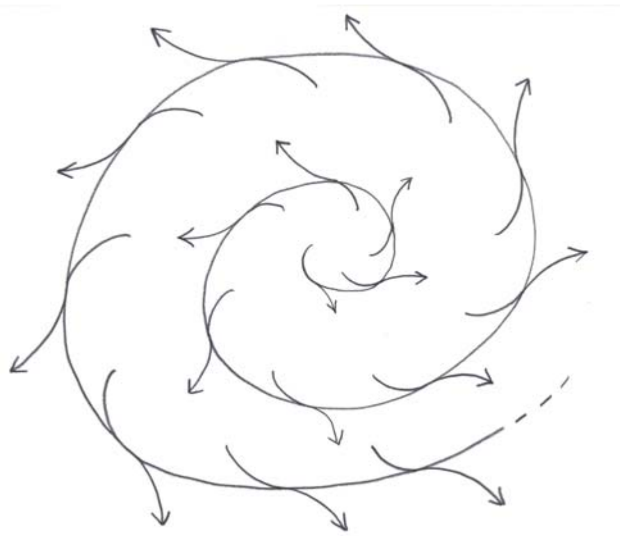

*Figure 1. The dominant economic model of infinite unsustainable growth that swallows up the earth's resources and exports massive amounts of wastes and entropy*

In contrast, a sustainable system is like an organism [15-19], it closes the cycle to store as much as possible of the resources inside the system, and minimise waste (see Figure 2). *Closing the cycle creates at the same time a stable, autonomous structure that is self-maintaining, self-renewing and self-sufficient.*

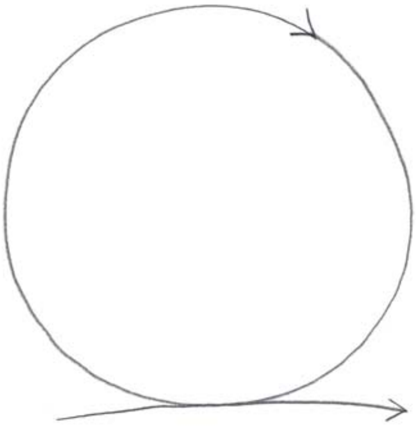

*Figure 2. The sustainable system closes the energy and resource use cycle, maximising storage and internal input and minimising waste, rather like the life cycle of an organism that is autonomous and self-sufficient*

In many indigenous integrated farming systems, livestock is incorporated to close the circle (Figure 3), thereby minimizing external input, while maximising productivity and minimizing wastes exported to the environment.

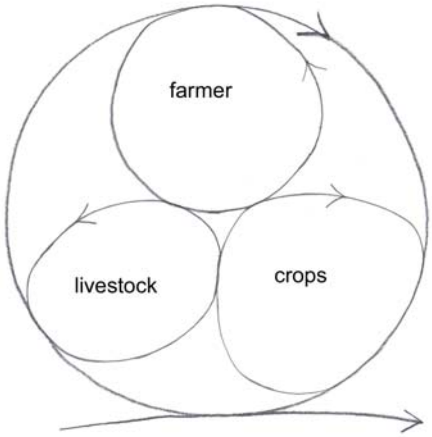


*Figure 3. Integrated farming system that closes the cycle thereby minimizing input and waste*

The elementary integrated farm supports three lifecycles within it, linked to one another; each lifecycle being autonomous and self-renewing.  It has the potential to grow by incorporating yet more lifecycles (Figure 4). The more lifecycles incorporated within the system, the greater the productivity. That is why productivity and biodiversity *always* go together [28]. Industrial monoculture, by contrast, is the least energy efficient in terms of output per unit of input [18], and less productive in absolute terms despite high external inputs, as documented in recent academic research [29].

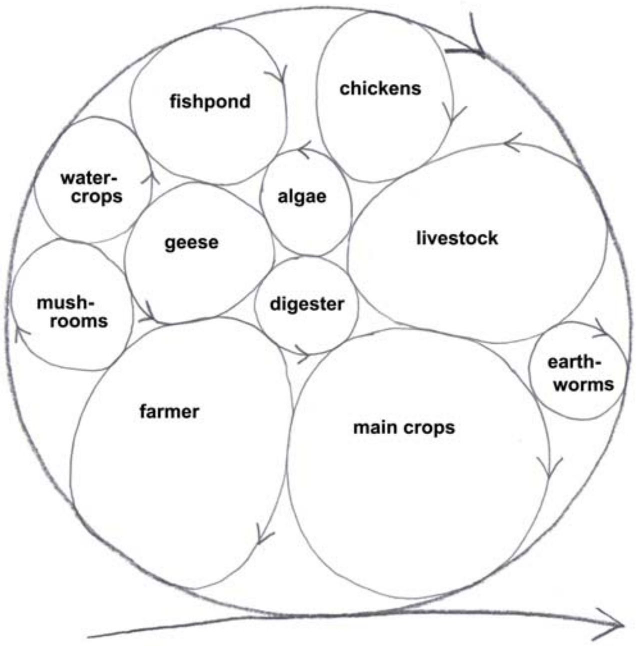


*Figure 4. Increasing productivity by incorporating more lifecycles into the system*

Actually the lifecycles are not so neatly separated, they are linked by many inputs and outputs, so a more accurate representation would look something like Figure 5 [15, 17, 18].

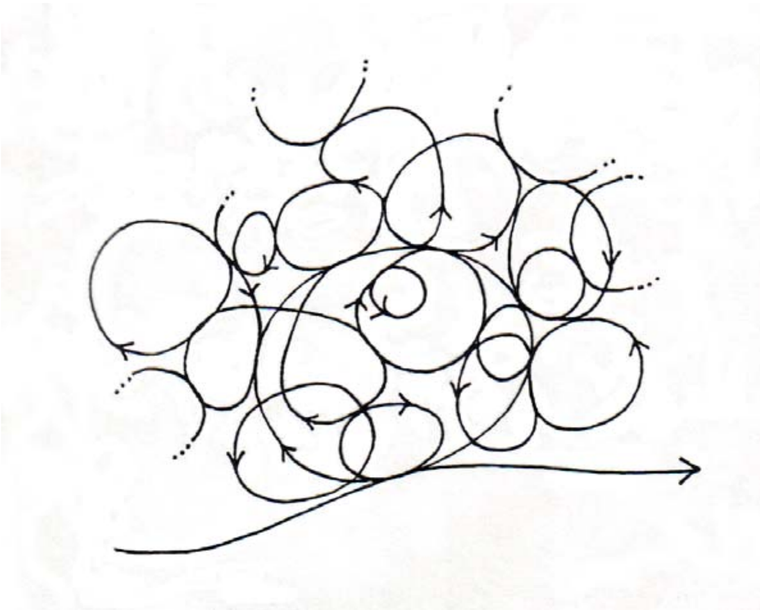

*Figure 5. The many-fold coupled lifecycles in a highly productive sustainable system*

The key to sustainable development is a *balanced* growth that's achieved by closing the overall production cycle, then using the surplus nutrients and energy to support increasingly more cycles of activities while maintaining internal balance and nested levels of autonomy, just like a developing organism [15, 17, 18]. The 'waste' from one production activity is resource for another, so productivity is maximised with the minimum of input, and little waste is exported into the environment. It is possible to have sustainable development after all; the alternative to the dominant model of unlimited, unsustainable growth is balanced growth.

The same principles apply to ecosystems [19] and economic systems [17, 18] that are of necessity embedded in the ecosystem (Figure 6).

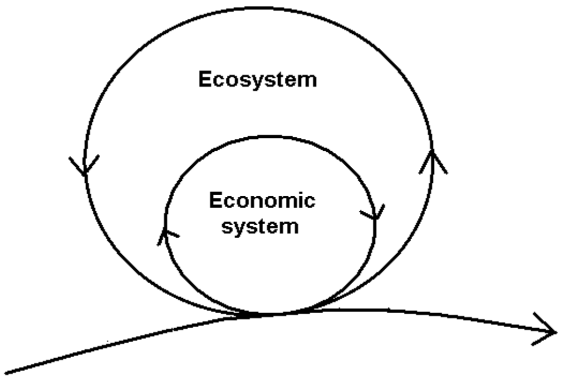


*Figure 6. Economic system coupled to and embedded in ecosystem*

## Deconstructing money and the bubble economy

Economics immediately brings to mind money. The circulation of money in real world economics is often equated with energy in living systems. I have argued however, that all money is not equal [17, 18]. The flow of money can be associated with exchanges of real value or it can be associated with sheer wastage and dissipation; in the former case, money is more like energy, in the latter case, it is pure entropy. Because the economic system depends ultimately on the flow of resources from the ecosystem, entropic costs can either be incurred in the economic system itself, or in the ecosystem, but the net result is the same.

Thus, when the cost of valuable (non-renewable) ecosystem resources consumed or destroyed are not properly taken into account, the entropic burden falls on the ecosystem. But as the economic system is coupled to and dependent on input from the ecosystem, the entropic burden exported to the ecosystem will feedback on the economic system as diminished input, so the economic system becomes poorer in real terms.

On the other hand, transaction in the financial or money market creates money that could be completely decoupled from real value, and is pure entropy produced within the economic system. This artificially increases purchasing power, leading to over-consumption of ecosystem resources. The unequal terms of trade, which continues to be imposed by the rich countries of the North on the poor countries of the South through the World Trade Organisation, is another important source of entropy. That too, artificially inflates the purchasing power of the North, resulting in yet more destructive exploitation of the earth’s ecosystem resources in the South.

Recent research in the New Economics Foundation shows how money spent with a local supplier is worth four times as much as money spent with non-local supplier [30], which bears out my analysis. (Maybe you’ll hear more about that from David Woodward tomorrow.) It lends support to local currencies and the suggestion for linking energy with money directly [31]. It also explains why growth in monetary terms not only fails to bring real benefits to the nation, but ends up impoverishing it [32, 33].

Lester Brown argues [25] that the economy must be “restructured” at “wartime speed” by creating an “honest market” that “tells the ecological truth”. I have provided a sustainable growth model that shows why the dominant model fails, and why telling the ecological truth is so important.

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