Short version, as read.

2. Energy and Order is the ultimate currency.

CHE Lecture, Ulrich Loening, 25 th Oct 06 Notes.

Everything nature does, everything we do, depends on using energy, in some form or other. Energy is much more fundamental than money in determining what happens or what can happen. To appreciate what it means to "fit our doings into nature's patterns", we need to explore the roles of energy in the world. I'll start by looking at energy in life, then how this leads to the Gaia theory, then how one might use energy as measure, and finally how we might move in better directions.

Energy for Life

All life including human activities exists by the continuous dissipation of energy. You can almost define life by that. Living things are not structures, like rocks, or cathedrals or cars or clocks. Life is energy. Organisms of any sort continuously use energy and dissipate it as waste heat. They are dissipative structures, converting energy to the order of their existence. The whole ecosystem, whole societies and ultimately life on earth, are like that. Life is dynamic dissipation of energy, or it is nothing.

Of course it is the continuous output of light from the sun which drives it all. Compared to all the fuel and power we use in our societies, the energy that reaches Earth from the sun is thousands of times greater. We look first at how life uses it.

Harvesting solar energy is the oldest technology invented by the biosphere. Indeed, the photocell at the heart of the chloroplast, converting light photons to chemical potential, remains the most efficient one can hope for, near to the thermodynamic limit of what is physically possible and at least twice as good as any modern photovoltaic cell. Maybe 30% of the light that actually is absorbed by the green chlorophyll is converted to electrical potential that provides the power to make sugars and all the other metabolites of life.

One may rightly marvel at this invention, the more so in that it was single-celled bacteria-like organisms that invented it, started filling the atmosphere with its first pollutant oxygen, and later became integrated in symbiosis with other cells to evolve into the green plants of today. The chloroplasts in the cells of leaves remain like the blue-green algae from

which they originated. They have still some of their own genetic materials; my colleagues and I showed in the late 1960's how the nucleic acids is like that of bacteria and not of the higher plants. This helped to confirm Lynn Margulis's idea of the symbiotic evolution of the higher cells. Here is a further example of how scientific progress has served to empower our wonder and respect for nature, so different from the popular conceptions of science being the cold destroyer of the perceived marvels of life.

In the course of living, most of the photosynthetic energy is used up, for living, and only 1% or less of the sun's energy finally remains driving the biosphere. The act if living is also one of organisation – Everything in life, the whole hierarchy from the molecules, the cells, the organism, the communities and whole ecosystems, and whole societies, represents order created out of the chaos of the constituent materials. Life creates order from chaos using energy which in the process is dissipated as heat.

Thermodynamics

This flow of energy is only in one direction, from high potential of the light of the sun, converted to high potential in the form of chemical energy in plants and animals, and finally to the waste of low potential. That is the subject of Thermodynamics – a subject I have tried to understand and then to teach for my entire career; it remains hard to share this with others. Yet the issues are actually obvious: a hot cup of coffee can go only one way, without further input of energy – it can cool and it can fall off the table. There is no way that the broken cup can put itself together again, lift to the table top and fill itself with coffee. To do so, requires new inputs of energy. The flow is irreversible; High potential has been degraded to low potential, to disorder and to waste heat – a useless form of low temperature energy. That is the second law of thermodynamics, for those who struggled at school with it. Order and potential go together. And left to itself, everything runs downhill, towards low potential and high disorder or high entropy. It stands to reason, when you think about the cup of coffee.

Civilizations, and indeed all organisms, seek out low entropy or high order from the environment from which they can extract high potential chemicals. And in the process, they degrade that resource to higher entropy and waste useless heat. A bee seeks out its nectar, made and concentrated by the flower using sunlight, and uses the potential of the sugars to burn with oxygen, to run the hive. When we use fossil fuel, we collect it from conveniently ordered concentrated sources, and burn it in

power stations, to provide electric power of high potential and create lower temperature waste heat. About 1/3 makes electricity and 2/3 waste heat. It cannot be done better, because heat can only be converted to higher order potential energy like electricity with an efficiency that depends on the difference in temperature between the furnace and the surroundings. So the huge cooling towers of power stations represent the inevitable losses; they are monuments to the 2nd law of thermodynamics. They are also monuments to folly, because while the necessary waste heat is no longer hot enough to make electricity, it could be used for heating houses.

There are three implications of this irreversibility:

First, you can only use energy once. Money in contrast, remains; you use it again and again. Money therefore cannot be any measure of the real world.

Second, the irreversibility of energy flows connects to our concepts of time. Time also flows only one way; our sense can only be one way; there is no going back.

Thirdly, the irreversibility has ethical implications: when that coffee cup is knocked off the table and breaks, you cannot restore it and entropy has irreversibly increased. The person who knocked down it might express regret and you might forgive. But the deed is done and cannot be undone; atonement is not possible. Likewise, if civilisations continue to knock metaphorical cups off tables, there is no going back; we can recover only by recreating the order with more potential high quality, low entropy, energy. And in a crowded world with many cups being spilled, this clearly must be done by the best means possible. What is the potential and the limits for the biosphere to do this for us?

The potential of the biosphere

The biosphere has stored energy from the sun as natural capital, representing both the chemical energy of being able to "burn", to create more life and waste heat, and to create order. "Burn" is in quotes, because it means that in its chemical sense – leaves, tree trunks, organic matter in the soil, decomposing by the action of fungi and bacteria, are also creating their own lives and burning the organic residues to co2 and water.

That potential for action means that the biosphere is not in equilibrium. When things are in equilibrium they lack, by definition, any potential energy; nothing can happen. Any stored up potentials of energy and order would spontaneously, given time, decay to waste heat and disorder, like the coffee cup. Left to itself, without energy from the sun, the biosphere would burn itself up.

All that being so, Why doesn't everything burn up? What does maintain the so-called balance of nature? Of course it is the continued metabolism of solar energy. But how is it that the temperature of the planet has remained suitable for life, even while the sun has got 30% hotter? How is it that the proportion of oxygen in the atmosphere has remained at 21% for millions of years, the best balance between respiration and burning? How is it that the salt concentration of the sea has not risen, when so much is being put in by rivers? How does the carbon dioxide concentration remain unchanged until we put too much into the atmosphere?

Gaia theory

The answers, as of course we know, came to Jim Lovelock when asked by NASA to devise methods for finding out whether there is life on Mars. The answers showed how the world remains stable and suitable for life. Mars's atmosphere is stable, in equilibrium, with no potential energy. Nothing can react. In contrast, the unstable mix of gases in the Earth atmosphere indicates a huge potential. That tells you there must be something holding those gases in place. Life. It can only be life. If there is life, there will be potential energy: materials in the atmosphere and on the ground, that are not in equilibrium. It's a simple question of thermodynamics. The Gaia Hypothesis was the insight.

The implications of this insight are huge: they mean that life is somehow maintaining the conditions for life. How can life itself know what the conditions for life are? What an absurd idea!

Jim Lovelock was criticized by all sides. The idea that life itself maintained conditions on Earth so that they are suitable for life, seemed preposterous.

So Jim invented an imaginary planet as a tool for thought. A small planet on which grew only daisies, white ones and black ones. Both grew best at 20 o . If the sun warmed the planet too much, the white daisies would grow better because they reflect heat and keep cool, while the black

which absorb heat would suffer. So the planet becomes more covered in white daisies and their reflecting heat back into space would cool the whole planet. If the planet then over-cooled, the black daisies would grow better, and warm it up again. On average, the daisies between them, would maintain the temperature of the planet at 20 o, the optimum for daisies, yet without the daisies being conscious of what they were doing. Here is a self-organising system, built out of the energy from the sun, that maintained conditions best for life, and without mind or purpose.

Note that the daisies constitute a co-operative system. They are also in competition of each other for space on the planet. They are in micro-competition and macro-co-operation. Humans have tried and succeeded in conquering nature, rather than co-operating. We may note also in passing that Adam Smith described the economy like this– with his "invisible hand" guiding the process of the market to macro-co-operation. The daisy-world planet illustrates just how the invisible hand works. And it illustrates how order emerges, given only the constituents of life and energy.

The Gaia theory and Daisy world also illustrates how shallow and inadequate are the frequent criticisms of "reductionist" science, against holistic approaches. I will have more to say in talk 5 about this. Thermodynamics is intrinsically a wholistic science but reduced models have to be invented to explain this to our stupid minds. Daisy world illustrates the emergence of a thermostat, (a whole), from the sum of the parts (sun, planet, daisies).

Finally, daisy-world warns us about how to organise our civilisation to "fit into nature's patterns." By inserting the products of an inappropriate energy economy into the planet's control systems, we might be upsetting the control systems quite strongly, catalysing massive change way beyond the scale of our inputs. That seems to be what we have been doing, merely by injecting a few million tons of carbon dioxide more into the atmosphere than the biosphere does and than can be absorbed.

Lovelock's Gaia theory of course had another outcome – it made thinking globally about the planet respectable: mother earth is to be venerated and adored, treated as a spiritual being; some call the earth alive. Jim himself compared Earth to the trunk of a tree, which is alive outside and dead inside. Now the word Gaia is used everywhere. The idea is scientific, the conclusion leads to reverence for life.

But what an irony it is, that life on earth, which we do not think of as sentient, manages to maintain its homeostasis, its stability, while the sentient and conscious human species manages to upset it so much. This brings us back to civilisation.

Civilisation runs on energy

The true economy must be rooted in the real world. Energy is the most universal common commodity that could be used as the measure, the numaraire. Let me underline again, that money measures neither the ultimate resources of nature nor the ultimate aspirations of humankind. Unlike money, energy loses its potential by being used; it is the more realistic unit to guide society's development.

Let me look at this a bit more closely.
Fredierck Soddy, Professor of physics at Glasgow, wrote in 1905, how the development of civilisations was wholly dependent on energy, at the time on King Coal with all its attendant filth and pollution. And how the product of the use of energy is Order, structure, culture and knowledge. Civilisation would survive only as long as the supply of energy did. Soddy hoped that other supplies than coal would prove cleaner. And among these, the promises of the recent discoveries of radioactivity might provide the ultimate, unlimited source. He hoped but doubted, that mankind would find a way to harness this power. In the 1920's, Vernadsky, who similarly saw the earth as a whole and coined the word Noosphere, warned that the use of atomic power for war or energy required a sufficiently mature society to cope.

But just consider what would happen if humans got hold of unlimited energy – one could wreck the planet even more effectively. Energy of its nature of potential, is always powerful, so can be dangerous. There can be greater safety in harnessing energy but not in using it; Lovins' "soft energy paths" refers to ways of harnessing ambient energy that are intrinsically kinder than nuclear or even fossil energy.

To summarize, Energy is the basic means for turning natural income or capital into cultural capital; the human built environment. I quote from Hermann Scheer, German MP.: "The global economy is fired mainly by crude oil, coal, natural gas and nuclear fuels. Thus, the world's economy and with it the world's society is dominated by pyromaniacs who burn ever more gigantic amounts of fossil fuels and wish to cling to this system as long as possible because of vested interests."

This global fossil economy continues unimpeded by any of the international resolutions supposed to brake or redirect it, like the policies agreed in Rio in 1992. The WTO, signed in Marrakech in 1994 is intended to guarantee a largely unhindered flow of capital, goods and services, globally. The governments which negotiated and signed this treaty had all signed the Agenda21 treaty in Rio two years earlier, without seeing the contradiction between the two. The WTO treaty is supposed to increase productivity of the world's economy; it actually aids the speed of destruction because of the continuing depletion of the world's services and resources.

In effect, we do not live in a scientific age; we live in a technological age, informed only by that science which serves that technology, not by what the science of life on earth tells us. If we followed the latter and chose the technology accordingly, we might approach a solar powered future.

Solar futures

In contrast to the fossil fuels, compare the energy available form the sun. Only a little goes via photosythesis into the biosphere. Most of sun's energy goes to the clouds and atmosphere, to create the climate we have, with winds, waves, water and storms. The light from the sun amounts to about 1 kW per square meter, when shining down fairly vertically from a clear sky. Think how huge this is, by comparing it to Torness power station. Torness has a maximum output of 1.2 GW, that is, 1.2 million kW. That output is the same as the sun shines onto 1.2 million square meters, 1.2 square kilometers, less than a square mile. The sun shines on the Earth many thousands of times more power than all of humans' uses of fossil energy, maybe 10 thousand times more.

Of course, only a little of this could ever be harvested. But the potential is so huge, and the means of harvesting so varied, that a solar future can be the only sane way forward.

There are several features about this:

First, the ecological: the sun shines anyway, wind and waves flow anyway. However much it is used, the energy that flows from the sun to the planet remains a continuous income, whether we use them or not. Use makes no difference and use consumes nothing. Ambient energy, as it is best called, is a resource that cannot be depleted. The term "renewable energy" is a misnomer; it is actually continuous. Renewable resources, like soil and timber, can be depleted if mis-used; they are

renew-able but not necessarily renewed. Ambient energy cannot be depleted; it finishes as waste heat anyway.

Second, because ambient energy is distributed over the globe, it tends to promote rather than prevent democratic development. It would end the destructive dynamics of the fossilized global economy and create a viable, varied and human-scale dynamics of development. Everyone can have a wind turbine or solar panel. But of course, in our existing economy of concentration of power, there is still a pressure to concentrate, as we see now with the development of wind power in the UK, but not in Denmark.

Thirdly, as we have seen so often, and now again, the fossil economy leads to wars. It is the resource dependence on fuels that are concentrated in few parts of the world, that have provoked dramatic conflicts and which have compelled the 'globalisation' of economic activities. Global access to solar power is an essential precursor to peace.

To develop towards a solar economy, we need first to evaluate just where we stand and where we want to go. That means using something other than money as a measure. Second, to find political and economic ways to get there.

Ways to find out

I will look briefly at three ways to judge whether our activities of civilisation are within the capacity of the planet.

First: An FoE study in Holland, together with the Wupperthal Institute in Germany, analysed for crowded Holland, how much of their use of resources came from other places – what was the space that the Dutch were actually using? Hence the concept of Environmental Space.

Second: "The Ecological Footprint measures what we consume of nature. It shows how much productive land and water we occupy to produce all the resources we consume and to take in all the waste we make. The average American uses 30 acres to support his or her current lifestyle. Nature provides an average of 5 acres of bioproductive space for every person in the world."

These approaches are both static snapshots; they may influence how you live; they do not test the future consequences of changes in policies.

Third: A dynamic method of resource accounting developed by Jane King and Malcolm Slesser, partly here in CHE. It uses energy instead of money as the accounting measure and models every activity of our society in energy terms. One can test, over any number of years, what policies for development would be physically impossible. For instance, that so much effort and energy must go into the solar and wind projects, that less industrial output is available for living and investment. Everything we do, every product, is assessed by the energy it takes to create it – its 'embodied' energy.

Fourth: All these and other ways of accounting our lives, all ultimately based on energy, must also be judged for how they can satisfy human needs - Fundamental needs. Even here, methods for assessment are available, worked out by Maslow and by Manfred Max-Neef. They provide guides that help you make your choices, and Manfred's distinguished fundamental needs from the satisfiers that fulfill those needs. Except to mention this here, I will not go into it until the last talk.

By a combination of such approaches, we could match our true needs to the limits of growth.

Ways to manage the next steps.

1. Global warming and Kyoto insignificance. If the Kyoto agreement were ratified and acted upon, it would make very little difference to the output of greenhouse gases. Very much greater reductions are needed. The Kyoto agreement has at present but one purpose: to create the international political framework to be able to move forward. Ultimately, that means understanding what the issues are really about, and especially that a change is needed anyway for the global economy.

There are some brilliant ideas. Aubrey Mayer and colleagues, who set up the GCI for the purpose, invented one. It was the idea that a long term gradual change could be agreed, step by step, towards overall reductions, the contraction, and concurrent convergence between the rich and poor countries. The rich have to reduce much more than the poor. In this way, fairness is achieved for all and seen to be fair, so all can agree.

2. Fiscal changes. I cannot describe here all the small financial adjustments that have been considered and are being made, to stimulate conservation of energy and harnessing of ambient energy. But at least, taxes must speak the truth and at present they do not. The different European countries promote non-fossil energy differently. Denmark

stimulated its wind power program with quite minor tax and planning incentives. Thereby it set up the world's most active wind power industry, and boosted the national economy – a lesson, for all of us and especially for G W Bush. In the UK, our electricity has a non-fossil fuel charge, most of which goes to the nuclear industry. But there are complex arrangements for buying and selling renewable power, which in a small way, are stimulating the industry. However, the failure of the transport fuel levy shows how difficult it is to move on. As George Monbiot pointed out, farmers who were among the strongest protesters actually would have much to gain from higher fuel costs, to stimulate local food marketing and limit foreign competition.

Perhaps one of the boldest suggestions is a complete reversal of our tax system, from taxing labour to taxing fuels. It would be a way to start from scratch and invent a taxation system that matches the true economy. Unitax would tax energy and not people. Thoroughly worked calculations show that fuel costs would rise up to 4 fold, labour would be cheaper. Enough revenue could be made to couple to a universal state income to distribute wealth more equitably and make up for the increase heating bills. The result would be much greater incentives to invest in ambient energies.

3. Technical changes. Design of anything must start from the ecological basis. No design starts from nothing; there is always some context, some background. And the environmental, let alone ecological, is almost always neglected. The ways in which we build cities, houses, organise transport, manufacture, provides services, grow our food, can all be made ecologically sound, which means that "our doings must fit into nature's patterns", as Brundtland said.

That means that every new housing project should be designed around the concept of zero emission buildings – they give off no pollution and no waste; the only output may be spare energy to sell.
There have been lots of pilot projects; innovative housing, sewage treatment, solar photovoltaics, and so on, have been shown to work. The UK government's plan for 4 million new houses cannot proceed, unless they are ecologically designed. Every roof should be solar.

4. And the last word for agriculture. Farming and the inputs to it, like tractors and fertilisers, consume some 3 to 4% of all fossil fuel. The extra, fossil, energy input into farming in industrial countries is getting close to the solar input. Land use is said, by the Scottish Executive reports, to emit about a third of all greenhouse gas emissions. This is absurd – green land

should if anything be absorbing carbon. As it is not, even if the figures are wrong as they probably are, it means that the soil is degrading. We are here in Scotland as guilty as anywhere of spending the capital of land quality. If land were properly managed, organic matter would be stable or increasing, forests storing long term capital and carbon, and agriculture managed, like organic farming attempts to, for long-term sustainability. Farming could become one of the positive attributes of our activities, in renewing the natural capital of the biosphere.

All these things are possible. Why don't we do them?

So, you sit in the Council Chamber, taking a collective decision on whether to build, say, the Gyle shopping centre. You know as a reasonably green person, that it is a crazy project and will cost hugely in external costs as well as environmental costs. Yet you can only consider, and talk, on the margin. The big issues cannot be tackled, until the whole community has changed.