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The Very Basics of Sustainability - an Alternative Viewpoint

Jim McGovern
Dublin Institute of Technology, jim.mcgovern@dit.ie

THE VERY BASICS OF SUSTAINABILITY—AN ALTERNATIVE VIEWPOINT

Jim McGovern[1]

1. School of Mechanical and Transport Engineering, Dublin Institute of Technology, Ireland; email: jim.mcgovern@dit.ie.

ABSTRACT

This paper examines the context and meaning of the term 'sustainability', the factors that determine and govern climate on Earth, the population of the Earth and its trends and influencers, the requirements for sustaining life and the options that are available to humankind. Some viewpoints are presented that are alternative to 'conventional alternative' thinking. The author advocates keeping an open mind on all available options, including the use of oil, gas, coal, tar sands, carbon capture and sequestration, nuclear power etc., as well as the technologies that are more widely considered 'green' and also argues that humankind needs to face up to the population size that the Earth can sustain and the desired sustainable distribution of wealth.

Keywords: Sustainability, Earth Climate, Sustainable Energy, Environmental Protection

1. INTRODUCTION

There is a fair degree of scientific consensus that the known, vast universe started with a bang perhaps fourteen-and-a-half billion years ago (14,500,000,000). Our solar system was formed perhaps four-and-a-half billion years ago and nothing, so far, has been sustained in the sense of remaining unchanged or fixed. To over-simplify the situation, the universe was unbelievably hot and unbelievably compact very shortly after the Big Bang, but has been expanding and cooling down ever since. We are passengers on a not uncommon type of planet orbiting a not uncommon type of star in a not uncommon type of galaxy in the vast universe. The very atoms like iron, silicon and oxygen that make up our world are the products of cataclysmic galactic events and multiple transformations. Everything is relative in the Cosmos and our relatively young planet has gone through continuous change and many cycles. There have been collisions of huge meteorites with our Earth. There have been ice ages and hot periods. In the very distant past there were natural nuclear reactors on or near the surface of the Earth. Neither the first nuclear reactors nor, perhaps, the first nuclear bomb that detonated on the Earth were man-made. The magnetic polarity of the Earth has inverted in the past and may undergo inversions in the future.

Our Earth is delicately balanced in many ways. One of these is the fact that it has its own daughter stabiliser, the Moon. Going back more than ten thousand years it is very hard to find evidence of an organised human society on the Earth. It is really only in the last few hundred years that humankind has been able to exert a significant influence on the Earth, in the sense of influencing such things as the weather or the appearance of the planet when viewed from afar.

2. THE EARTH'S CLIMATE

2.1 The Position of the Earth

Even though the core of the Earth is probably as hot as the surface of the Sun, at about 5,800 K, the rate of heat transfer per unit area from within the Earth to the surface is negligible on average because the outer mantle and crust are good thermal insulators.

The Earth appears to be cooling down very slowly, although there is some thermal energy generation within owing to processes such as radioactive decay, friction, viscous flow and electric currents. Geothermal energy, where accessible, is real and volcanoes, tsunamis and earthquakes are very serious issues that challenge engineers and humankind, but none of these are of much climatic significance. As a convenient simplification let's take it that the internal goings-on of the Earth do not affect climate.

The Earth is a ball that receives energy as radiation from the Sun (almost exclusively) and radiates energy to outer space. On average over millions of years and even over much shorter periods, like hours, the rate at which energy is received by the Earth as a whole equals (to a close approximation) the rate at which energy is lost.

Energy comes in a straight line from the Sun to the Earth. Half of the Earth is permanently in receipt of this energy. The Earth intercepts the solar energy in much the same way as a disc having the same diameter as the Earth would if it were at right angles to the rays of solar energy and at the same distance from the Sun. For each square metre of the disc 1.370 kJ of energy are intercepted per second.

Energy leaves the Earth by radiation to outer space, which is at a temperature of 2.725 K. As the surface area of a sphere is exactly four times the surface area of a disc having the same diameter, the area that radiates energy to outer space is four times the projected area that intercepts solar energy.

A very basic model treats the receiving hemisphere and the emitting sphere as grey bodies for which the emissivity and absorptivity are assumed to be the same. In fact, from this simple model we can deduce that the temperature of the Earth as a whole would be 278.8 K. The actual value assumed for both the emissivity and absorptivity does not influence this result, once the same value is used for both. The actual mean temperature of the Earth's surface is about 287 K, so this very simple model is not far off in explaining one of the main parameters of the Earth's climate: the mean surface temperature.

With a more elaborate form of the same type of model we can calculate the average surface temperature for each latitudinal band of the Earth's surface (ignoring the tilt of the Earth's axis, for simplification). These temperatures can be taken as the predicted mean daily temperatures of the Earth, if it had no atmosphere. They vary from about 108 K near the poles to 296 K near the Equator. On this basis the model predicts a mean (area-weighted) surface temperature of about 275.7 K. Although this is a little further from the actual mean temperature of the Earth's surface than the previous estimate, it is in fact quite a good estimate of what the mean daily temperature on the surface of the Earth would be if the Earth did not have an atmosphere. To a very large extent, the average climate of the Earth, characterised principally by the average surface temperature, is determined by the distance of the Earth from the Sun and the fact that the Earth spins so that all parts are exposed to the Sun's rays on a daily basis (again ignoring the tilt of the Earth's axis).

2.2 The Topography of the Earth

The Earth's mantle and crust is not in a state of stasis. However, changes in the topography of the Earth occur very slowly—over millions of years. If the Earth's surface were considerably less textured and profiled than it actually is then the entire globe would be covered with a layer of water. In fact, at present about three quarters of the surface of the Earth is covered with water (liquid and solid) at sea level.

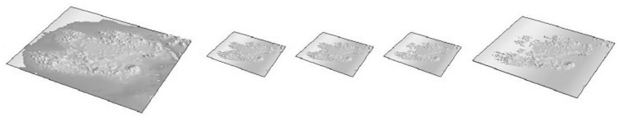

Figure 1. Possible sea levels for Ireland: past, present and perhaps future (only light grey with a sheen is water). From left to right: last ice age −122 m; now 0 m; 125,000 years ago +5.5 m; 3 million years ago +50 m; with ice caps melted +68 m.

If water accumulates near the poles as ice then the average level of the oceans drops and if ice near the poles melts the average level of the oceans rises. Both types of change have occurred in the past and are likely to occur in the future [1]. In an ice age, with more of the Earth's water as ice at medium to high latitudes, sea levels would be lower and there would be more land area and less ocean area—though at medium to high latitudes much of the land would be covered by glaciers. In a warm age, water levels would be higher, but there would still be a lot of dry land even if all of the ice near the poles had melted, Figure 1. It seems likely that life on Earth, including human life, could continue through cycles of glaciation and deglaciation.

2.3 The Oceans as Moderators

The oceans have a moderating effect on the Earth's climate. Compared to land, ocean water is capable of very considerable movement: convection currents redistribute energy between the warmer and colder latitudes. The manner in which this occurs is also influenced by the Earth's topography and by the fact that Coriolis forces are at play. Water substance is rather special in the way the density of the liquid and solid phases varies with temperature. The density is a maximum at around 4°C or 277 K and the phase at this temperature is liquid. There is a tendency for this temperature to exist at the bottom of the deep ocean, because water that is warmer or colder is displaced upwards by any water that is at this temperature. The density is a minimum for ice (solid-phase water) at a temperature of 0°C. Ice is therefore buoyant and floats at the surface wherever it exists in the oceans or in seas, lakes or rivers. Floating ice has high reflectivity and serves as an insulating layer (without convection) for the water below.

Of course water substance also has a vapour phase. The vapour pressure is very low at temperatures of around 0°C or below, but reaches about 0.1 atmospheres at 50°C. Water has a latent heat of evaporation of about 2,468 kJ/kg. If there were no atmosphere other than water vapour there would be considerable transport of energy as latent heat from the warmer latitudes to the cooler latitudes and indeed from the shaded side of the Earth to the illuminated side.

2.4 The Greenhouse Effect

Atmospheric gases like oxygen and nitrogen are transparent to the Sun's radiation and also to radiation from the Earth's surface back to space. However, water vapour is a greenhouse gas, which means that it is transparent to incoming, generally shortwave, solar radiation but is capable of absorbing part of the long-wave radiation from the Earth and re-emitting it both upwards towards space and downwards towards the Earth. The atmosphere is therefore heated more than it would otherwise be if it did not contain water vapour. Water vapour is the major greenhouse gas in the Earth's atmosphere. If there were no water vapour present in the Earth's atmosphere and all other constituents were present in the same amounts as at present then the mean temperature at the surface of the Earth would be lower than it currently is.

At the mean temperature of the surface of the Earth, 287 K, the volume fraction of water vapour in saturated atmospheric air is about 1.58%. In contrast to this the volume fraction of carbon dioxide in air is about 0.0389%. There is a certain inconsistency in the way in which greenhouse gases are classified by comparing their global warming potential to carbon dioxide, without reference to the fact that water vapour is by far the most significant greenhouse gas [2].

Returning to the very basic analysis referred to in §2.1, where the average surface temperature of the Earth in the absence of an atmosphere was estimated to be about 275.7 K, in contrast to the actual value of about 287 K, the main cause of the difference between the two is the presence of the atmosphere and, more specifically, the warming effect known as the greenhouse effect. Therefore, as a very rough estimation, the greenhouse effect is responsible for the average temperature of the surface of the Earth being about 11 K higher than it would be if there were no atmosphere. It is the view of this author that a lot of work still needs to be done in developing models of climate that fully explain and quantify the greenhouse effect and its parameters. Carbon dioxide and carbon have been vilified, perhaps unfairly. Green plants need to absorb as well as emit carbon dioxide—it is part of their natural cycle. In common with other living beings, humans produce and breathe out both water vapour and carbon dioxide. Both substances are entirely natural, but, of the two, water vapour is by far the greatest contributor to the greenhouse effect. Has anyone ever suggested a hydrogen tax (analogous to a carbon tax) or a reduction in water vapour emissions?

As the two most significant greenhouse gases, water and carbon dioxide have their own individual absorption and emission spectra that are specific to certain wavelengths of radiation. This adds complexity to the process of quantifying the greenhouse effect due to a particular greenhouse gas. For example, if all of the solar radiation within a narrow band of wavelengths is already being fully absorbed by water vapour or carbon dioxide then an increase in the concentration of the greenhouse gas will not cause any further greenhouse gas effect through absorption of radiation in that particular band. If the concentration of greenhouse gases is doubled it does not follow that the greenhouse gas effect will be doubled.

2.5 Clouds

Clouds can contain water substance in the vapour, liquid and solid phases. Clouds are visible and block direct sunlight because they contain small particles of water substance in the liquid or solid phases. These small particles are nucleated on their formation from water vapour by tiny particles of dust or aerosols or electric charges. Clouds reflect, absorb and partially transmit solar radiation as well as radiation emitted from the Earth's surface. They re-emit radiation upwards towards space and downwards towards the Earth's surface. When clouds are present, they reduce the direct radiation received at the surface of the Earth by day and reduce the direct radiation from the surface of the Earth to outer space by day and by night. They can store and release energy as latent heat and of course they can transport energy and water as they move over the surface of the Earth. Clouds created by human activity on the Earth must influence global warming somewhat and there is a need for deeper understanding of how human activity has influenced the quantity, distribution and nature of global cloud cover.

2.6 The Thinness of the Biosphere

A major aspect of sustainability insofar as it relates to humans, animals and plants is that the biosphere is extremely thin in relation to the size of the Earth. The average depth of the oceans is about 3.41 km, but if the Earth were a smooth sphere covered entirely by ocean the average depth would be about 2.62 km. Roughly speaking, the thickness of the atmosphere could be regarded as being of the same order, but with an average density well below the value of about 1.2 kg/m^3 that air has at sea level. For comparison, water has a density of about 1,000 kg/m^3. If the atmosphere were compressed so that it had the same density as water it would have a thickness of only 10 metres, which would represent only 0.00016% of the Earth's radius. In fact, even this tiny percentage understates the relative size of the atmosphere that sustains life on Earth, because the average density of the Earth is about 5.5 times the density of water. This thin atmosphere is a resource that is shared without geographical boundaries. Whether humans are rich or poor they can survive for only minutes if deprived of the oxygen that they take from the atmosphere. Perhaps the human right to breathe clean air needs to be better enshrined.

Besides redistributing energy over the Earth, redistributing and purifying water, providing oxygen, being a source and sink of carbon dioxide that sustains living organisms and conferring on the Earth the additional warmth of the greenhouse effect, the atmosphere provides effective shielding from harmful radiation and from debris from outer space. Although density is extremely low in the upper levels of the atmosphere (the stratosphere), important effects for sustaining life occur there. Especially because of its relative finiteness, the atmosphere can be damaged relatively easily by human activity. The oceans and the accessible outer layer of the Earth's crust are considerably more substantial, but their relative finiteness needs to be appreciated too.

3. THE EARTH'S POPULATION

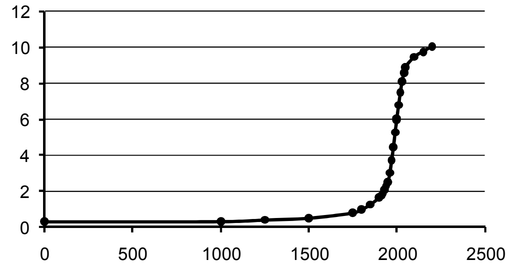

Figure 2. World population (in billions) over 2000 years, with projection to 2200 [3].

There has been some recent excitement at the discovery of a primate fossil (a possible early link in the human evolutionary chain) from about 47 million years ago, but it is difficult to find evidence of human-level activity dating back more than about 40,000 years. Like any finite habitat, the Earth can sustain only a finite population. Over the last century, or a little more, advances in sanitation, agriculture, medicine, communications and technology generally have enabled exceptional rates of human population growth (Figure 2) that clearly could not be sustained for long on the planet Earth. With these types of growth rates, turning down home-heating thermostats by a few degrees, by those who have home heating thermostats, or cycling to work rather than taking the car, by those who have bicycles and cars, to *save* energy will not delay the inevitable levelling-off, or potential subsequent decrease, of the population for very long.

4. HUMANKIND'S OPTIONS

There are many options open to humankind. It is unfortunate that some of these options have come to be labelled *green* or *sustainable*, while others have been condemned or rejected by many for reasons that are linked to bad experiences rather than to a logical process of assessment.

4.1 Population

On a scale of perhaps a thousand years it is not obvious that there will need to be any particular limit on the growth in the number of human beings, but if the population is constrained to remain on the planet Earth and to live off its finite resources the size of the population will inevitably evolve in that context. War, famine, diseases, natural disasters, enforced fertility control, societal norms and economic pressure are all mechanisms whereby population size limitation currently occurs. If certain sectors of the Earth's population, such as countries or associations of countries, control their growth while other sectors do not, pressure on resources may nonetheless be felt eventually by all sectors.

4.2 Energy

Energy is not running out. Energy is conserved as a principle of nature. The very term 'global warming' implies an excess of energy over requirements. The Earth occupies only the tiniest fraction of the solid angle that surrounds the Sun, which means that there is plenty of solar energy that passes by the Earth. While reserves of natural gas and oil are being depleted rapidly, the reality is that the resources available, including for example coal, tar sands and oil shales are such that energy needs could be met for a long time to come, although global warming and pollution of the shared atmosphere are serious issues that have to be addressed. Some options, such as open mining of tar sands, are not pretty [4]. Some options require discommoding or displacing existing residents or spoiling scenes of great natural beauty. In principle, pollutants can be retained or captured for recycling rather than emitted and carbon dioxide can be sequestered. In principle, production of radioactive waste in nuclear power plants can be minimised and radioactive waste can be stored safely. Wind power, wave power, tidal power, biofuels, solar energy, energy-use efficiency enhancement measures and various forms of energy storage can all be used, but, here too the usable resources have limitations and there are negative consequences that have to be countered. Nuclear power, through fission, is in principle sustainable for a long period of time. Controlled nuclear power through fusion will eventually become available and in principle will be sustainable for a much longer period into the future.

4.3 Recycling Resources

Recycling resources effectively and keeping the planet Earth organised are two of the major challenges because, while mass and energy are inherently conserved, a type of entropy death can be envisaged where natural substances that were once concentrated become scattered and mixed within the environment in such a way that they can no longer efficiently be retrieved. How will we get back the deposited tin on all the tin cans ever made?

4.4 The Regulatory Problem

Figure 3. Suds on the River Liffey in Newbridge, Ireland. Photo: J. McGovern

Figure 3 shows small amounts of suds floating on the River Liffey at Newbridge in Ireland. At the time of writing and for more than six months, existing regulatory policies and procedures had failed to deal with this environmental pollution. This is a microcosm of the regulatory issue with regard to the Earth as a whole. It has been reported that in the United Kingdom radioactive substances seeped into the ground under the Bradwell nuclear power station in Essex for twenty six years up to 2004 [7]. It has been reported that the nuclear power plant at Tricastin in France lost 75 kg of untreated liquid uranium into local rivers in July 2008 [8]. In the three examples mentioned, the responsible regulatory authorities were relatively local and, it would seem, were not answerable to adequate higher regulatory authorities that could have ensured the necessary levels of diligence in maintaining appropriate standards. It should not be assumed that the exploitation of so-called *alternative* or *green* energy sources is any less in need of proper diligence and regulation. Energy in a concentrated form is always dangerous and meeting the needs of what is now, relatively speaking, a very concentrated population on the

Earth requires very strong regulation. In particular, all who are partners in the shared environmental resource are entitled to be represented and to have their interests defended.

4.5 Challenges

In relation to population, energy, recycling of resources and regulation there are no easy answers, but the technical challenges involved are all capable of being met. The International Federation of Red Cross and Red Crescent Societies [5] and Oxfam International [6] have recently pointed out that natural disasters, ostensibly linked to climate change, are increasing and that, in consequence, large and growing numbers of human beings are suffering or dying. According to Oxfam about 250 million people are affected by natural disasters, on average, in a year. This is not sustainability; rather it is suggestive of growth in human misery for, perhaps, the majority of the human population while the minority retains dominant control over resources. It may well be that the pace of climate change is being affected by mankind's activities, but the human misery that has been referred to is more a reflection of lack of human solidarity and the failure to recognise that the Earth's biosphere is a shared resource to which all human beings are equally entitled.

The real challenge is not the technical one, but the social and societal one. The challenge is to find a mechanism for respected and just regulation to ensure that some sectors of the human population do not use the shared resources of the biosphere in a way that disadvantages others and to ensure that all humans are held responsible for what they use and how they use it.

4.6 The World Economy

In recent times it appears that, even in affluent and well organised societies, blameless individuals have suffered the consequences of financial dishonesty and inappropriate economic risk taking. Moreover, the very rule books of the free-market appear to have been torn up by their authors, as certain players were deemed so important that they could not themselves be subject to the checks and balances of the free-market. Finance and the economy are nothing more than a mechanism that regulates or facilitates the orderly allocation and use of resources, while encouraging work for the benefit of society, innovation, creativity and sharing of responsibility. The great tragedy is that the world economy is segmented and disjointed and seems to operate on a win-lose basis, rather than win-win. A technical re-design seems called-for, but is humankind smart enough?

5. CONCLUSION

In the homeland of the author, green is a predominant colour. However, in the author's view the term green is not a suitable label to attach to technologies for moving humankind along its path of change. The author has not found a definition of sustainability with which he feels comfortable, but in this article has attempted to set out its very basics nonetheless.

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