Energy issues for a biosensitive society

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Introduction

Energy provided naturally at no economic cost, by thermonuclear reactions in the sun, by gravitational forces near the core and mantle and by radioactive decay of uranium and thorium in the crust, sustains life on this Earth. But Earth's population is rapidly rising to levels too high for its resources to support and the very existence of the human race is under challenge. The variability of the sun's emission together with changes to the earth's orbital parameters has resulted in huge shifts in climate and hence in the biosphere over past aeons. During the rise of the human species these shifts have produced many destructive periods which have threatened survival but the adjustment of behaviour to live through those challenges has assisted the development of speech, thought and with them, our culture and society.

Competition for natural resources and the innate drive within the human psyche for the individual to want a "fair" share of those resources was a driver for advancement when the population was largely sustainable. The choice of a particular energy resource was determined by availability, abundance and technology. Coal and later oil became the obvious choices to replace wood and made possible the industrial revolution, the capitalist culture and the rise of consumerism. While a few people foresaw that mankind's striving for growth and wealth may not be sustainable, the governing paradigm did not allow for the huge increase in the demand for energy, the environmental costs or the eventual depletion of resources. The need to sustain a viable population well into the future, requires society to recognise that each member must live within certain energy and resource limits consistent with the availability of those resources on this planet.

Energy criteria

The essential characteristics of the new bio-sensitive society will determine the criteria which any energy option must satisfy for sustaining that society through the various natural events which will affect its existence in regional areas and ensure the health and well being of the global community. The criteria listed below, necessary for achieving and sustaining a bio-sensitive society presume the characteristics in the PAN paper "Our place in Nature".

1. No harmful pressures on the ecosystems of the biosphere through the influence of pollutants of all types.

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2. Sufficient resources to sustain the population in a manner that allows adequate food, health, and shelter for all.
3. Maintenance of all fields of education, creativity and research.
4. Support for technological enterprises and development consistent with maintaining the ideals of the society.
5. Maintenance of local and global communications systems, to ensure the free exchange of ideas.
6. Maintenance of a sustainable local and global transport system that allows free interchange of personnel and ideas within and between nations.

These criteria imply a static global population at a level at which every individual has a sufficient share of resources to maintain a satisfying lifestyle. Each person will have to consume less energy in such a situation than the majority consume in the present consumer-capitalist society.

The current view amongst the governing few that technology can maintain a growing global society in the style enjoyed by the rich and developed nations, predicates that the resources required for its sustainability will far exceed those available on Earth. The present rise in oil prices reflects the fact that the 'peak' in oil production is here now or only a decade away. It is the most important, and the first, of the fossil fuels to reach production levels that threaten widespread economic and political disruption in the future unless drastic measures are taken to provide alternative solutions.

The bio-sensitive society then appears to mirror many of the attributes considered by Ted Trainer in his "simpler way" [1],

> *"a society based on non-affluent but adequate living standards, high levels of self-sufficiency, in small scale localised economies with little trade and no growth, to basically co-operative and participatory communities, to an economy that's not driven by market forces and profit, and most difficult of all, a society that's not motivated by competition, individualism, and acquisitiveness. Many have argued that this general vision is the only way out of the mess we're in."*

This may well be an unachievable ideal, particularly when one considers that even within a bio-sensitive society there will still be a distribution of personal character traits with the more disruptive elements of all types at the two extremes. These will have demands and behaviours counter to the ideal peaceful existence of the majority. The narrower that distribution the better but the possibility of extreme elements attempting to disrupt energy sources and distribution systems requires that they be distributed and robust against attack. However the above 'simpler way small scale' societies cannot exist in isolation from their neighbours. A high degree of interaction will be essential between these groups to satisfy their transport, education, health and cultural needs. Unless these societies are close enough to avoid large scale energy requirements for that interaction to proceed, then the concept[1] becomes questionable.

Fred Pearce[2], shows that very large cities achieve economies of scale despite the serious impacts they are presently having on the environment. Certainly in energy terms the distribution of energy to a large population is far more efficient in a large metropolis than to a similar sized population scattered in small-localised urban communities. However the provision of that energy via large centralised power stations and all-encompassing

grids covering many large cities is not the most efficient, whatever the type of generation employed. The production of energy from all available local sources (a high degree of distributed and co-generation) feeding through local grids or pipelines to users, ensures greater efficiency and equity. Also communication, health, educational, cultural, manufacturing and technological facilities can be provided to large conurbations at much lower energy cost than to large groupings of separated small communities.

Pearce points out that the most significant technology that mitigates against maintaining both a large metropolis and alternatively, distributed small villages, as bio-sensitive societies is the motor vehicle and its associated road infrastructure. Significant also are the energy costs of food and goods transport within and between nations via sea and particularly air. For the metropolis, provision of adequate food and water supplies from local sources, disposal of waste of all types, and inefficient transport, together with the "heat island' effects, are serious problems requiring solution before a megacity can achieve the advantages of a closely knit coherent and bio-sensitive society . On the other hand if those problems can be solved while maintaining the bio-sensitive criteria then the megacity does offer economies of scale that can minimise the energy needs compared to Trainer's localised small villages. In the present context therefore a megacity will consist of a very large and high-density population with an overall design that minimises its energy requirements while maintaining a satisfying lifestyle consistent with the themes of this paper.

Technology has provided spectacular growth for the more privileged sectors of society over the last 100 years, but at huge energy and environmental costs. However the enemy has not been technology *per se*, but its misuse in the scramble for wealth and economic growth. Research and development with their application through technology in all areas will be essential to the global societies' overall needs and to perhaps changing the present dysfunctional megacities into viable communities for the future.

Energy Options

A major factor in the success of any future society will be the ability to supply the majority if not all, of its total needs from local and sustainable sources. Recycling of all wastes and materials will be essential while the sources of overall energy requirements must be greenhouse-gas neutral. This latter condition assumes that the global greenhouse gas concentrations are contained at a level consistent with a stable climate influenced only by natural events. It also assumes that greenhouse gas emissions are still possible but balanced by sequestration techniques that do not cause other environmental problems. In this balance it will be essential to take into account the lifetimes that the various gases take to circulate through the atmosphere. For example a sudden large emission which spikes the global carbon dioxide concentration can take 100 years to decay back to normal levels.

The energy sources available locally to all communities are solar, wind, methane (from anaerobic human and animal waste digestion), and plant biomass. A secondary source is local geothermal energy via geothermal heat pumps (GHP) which use electricity to pump heat between the surrounding ground some 100 metres or so deep and the local buildings. They are more efficient than air conditioners and generally transfer an amount of heat energy some three times the operational energy. Other sources depend on the particular locality of the city, e.g run-of-river hydro, tidal and or wave.

Large infrastructure high power sources such as hydro, geothermal and hot rock facilities are source localised and require high power grids for delivery. Their usefulness depends on their locality to major centres and to any adverse environmental effects. Local environmental impacts of dam construction followed by water management issues with hydro are well known and may not be consistent with the overall requirements of a bio-sensitive society. Nuclear fission and fusion both fit into the large infrastructure category and are considered further below.

Solar, both small thermal, photovoltaic and to a lesser extent wind may be sourced from roof tops for heat and power. Electricity generated can be interconnected through the local grid. Small wind turbines of a few kilowatts each are being touted as suitable for roof tops within present urban areas. However annual efficiency factors are not encouraging when compared to those obtainable from a wind farm of the same overall rated power. Also, as with roof-top and other surfaces suitable for pv solar, there will be a trade off between the need for high density housing to reduce the energy requirements for transport while maintaining the over all power needs of the population. It is likely therefore that roof-top systems will need to be supplemented with local wind and solar farms. The latter comprise large solar thermal plants of types consistent with the locality and/or photovoltaic systems depending on efficiencies and also on the local environment. Biological photosystems using various applications of photosynthesis under research at present, may also be a factor in future energy options. Siting of the city will also change the mix of viable renewable options and introduce others such as less solar, more wind, wave and tide, more biomass etc.

However solar, wind, wave and tidal systems cannot achieve their full potential to become major sources for domestic, school and office power without the ability to store energy and so smooth out their variability. The principal options at present are hydrogen with fuel cells, ammonia, various redox battery systems presently under development, for example zinc oxide, vanadium and vanadium bromide. The latter offer kW to MW electrical storage capability with application to transport as well as stand alone systems. Hydrogen can be produced directly from water by electrolysis and the fuel cell reverses the process with the usual loss due to efficiency and entropy production. Hydrogen in this case is a 'carrier' for solar power. The practical difficulties of storing hydrogen in a manner and volume that ensures its rapid recovery and in useful quantities are major handicaps to its present wide-spread use but are under such intense research and development that solutions may well be found in the near future. If solar and wind power with storage can cover residential, school and office needs then hydrogen production from methane may provide a source for some transport requirements, but may not be the best option for the megacity (see below).

Presently hydrogen is mainly produced in large quantities from mined natural gas (methane CH_4) with good yields due to the high number of hydrogen atoms per molecule. The alcohols, such as methanol and ethanol also provide a source and are being used in small fuel cells under development for powering devices such as music players and laptop computers. A steam reforming two-step process in methane produces hydrogen and finally carbon dioxide, and is otherwise "clean" provided the original methane has no impurities. All biological wastes from the megacity could be decomposed to produce methane that may then be used either for hydrogen production, or as a direct fuel source for co-generation of heat and power. The end product of course is CO_2, but

the other alternative, namely aerobic decomposition of the waste, which may seem to be more friendly to the environment, produces the same amount of CO_2 per kilogram of waste. Both also produce fertiliser for use with food production so it is far more efficient from the energy standpoint to go anaerobic and fully use methane either as a direct fuel or for hydrogen production. This is a case of necessary production of a greenhouse gas. However methane itself is some twenty one times more potent than carbon dioxide as a direct greenhouse gas. Consequently it is far better to use it as an energy source and sequester the equivalent carbon dioxide by biomass planting.

An essential requirement for any society will be oil, even if not used for transport. Oil is essential for lubricants, as a feedstock for chemicals, plastics, and a wide variety of products in use every day. Without direct fossil supplies, oil can be produced from biomass, various wastes, and coal. Germany developed the Fischer-Tropsch process during the second world war and it is being used and further developed in South Africa. However the process for coal uses a finite fossil resource, produces a number of impurities already present in coal and of course, carbon dioxide. If the transport requirements for oil can be minimised then renewable sources may be sufficient to sustain society's needs. A major difficulty will be the maintenance of a viable air transport system, at present heavily reliant on cheap oil. Hydrogen as an aircraft fuel may be possible well into the future but to become viable requires major advances in storage and technology beyond those required for land transport. Air transport will therefore become a major problem unless an alternative non-polluting fuel can be found. Even if sufficient oil from renewable sources can provide a basic service, the problems of carbon emissions will remain. Ocean transport will need to become highly efficient by vessels increasing in size. Diesel engines can be made more efficient and clean but to maintain sufficient supply from renewable resources remains a problem together with emissions. Small nuclear reactors could easily solve the ocean energy problem but the waste disposal then becomes an environmental problem not consistent with the criteria.

It is possible that local solar, wind, small geothermal and methane with co-generation will satisfy the megacity's basic residential, school, health, commercial and cultural needs provided energy efficiency is paramount. However there is a question concerning the power requirements for a robust industrial and manufacturing sector, which may also include food production. At present a 'base load' or an unchanging quantity of power is provided by power generating technologies for all societies and this base is supplemented by a fluctuating peak as demand changes. A bio-sensitive society will certainly reduce its overall power load compared to today's developed societies, and one can expect that the local renewable sources will cover all peak loads and substantially lower the base load requirements. However a certain base load would seem necessary to ensure the entire power needs are met. Intra- and inter-city transport requirements (see below) imply also that high capacity power sources for those systems will be required.

The large infrastructure high power sources become necessary to satisfy a base load, and with questions concerning new large hydro schemes, hot rock geothermal sources come into consideration. Being locality specific, one might argue that large industrial and manufacturing complexes may well coexist. This may be feasible if the power source is reasonably close to the megacity, if not transport issues would favour location of the industries close to the city and transport of the power via the grid. Nuclear power and 'clean coal' are considered answers to our present emission problems but both present dilemmas to the bio-sensitive society. Both are finite fossil resources and both have

environmental problems. Coal can never be 'clean' even if carbon sequestration into underground 'safe' reservoirs becomes feasible. Coal contains a large number of metallic impurities and radioactive elements such as uranium and thorium. While the quantity of these impurities varies with the particular coal deposits, the process of turning that coal into useful heat or oil concentrates them into the ash and fly ash. The carbon dioxide and sulphur oxides can be removed and sequestered or used, but the remaining ash has much higher concentrations of impurities and needs disposal. To date most has been used as a filler for bricks, concrete and included in road fill material. Likewise while nuclear fission is in wide spread use and is a mature technology with recent high safety standards, it is a fossil source and waste storage remains a major problem at present. Future technology will broaden the fuel sources and may solve waste problems but it is unlikely that coal or nuclear fission will be considered options for the bio-sensitive society. Nuclear fusion does not have any of the environmental impacts of fission and it is presently at a stage where the international Tokomak experimental reactor (ITER) should be operational by 2017. It is designed to produce more power than it consumes, but to go from an experimental device to a commercially viable generator, will take many more years of development. It is therefore an option but one which is still too far into the future to predict what its final role might be.

In the megacity the 'heat island' effect will need addressing. The options appear to involve minimising roads and to assist with cooling, having residences interspersed with 'breeze corridors' of treed parks, recreation areas etc. and areas for intense food production. This in turn puts stress on the types of intracity transport. Advanced internet style communications including voice, image and script may assist in allowing many employment tasks to be home based, or within walk or cycling distances, and so minimise the necessity for "travel to work" except for very specific work areas involving hospitals, museums, research centres, etc where concentrated facilities are necessary for the efficient delivery of services. Privately owned vehicles are inefficient and power hungry whatever the energy source. It would seem therefore that private vehicle ownership would be unlikely and where transport is necessary, public electric light rail or similar vehicles interconnecting centres would be available at population centres. These may vary in capacity, be entirely automatically controlled and be either on call for specific journeys or immediately available for small groups over well-defined routes. They would need to draw no power while idle. While the necessity for transport between megacities would be minimised there would still be a need for the transfer of specific foods and manufactured items and to provide transport for vacations and family visits. An automated electric rail, highly controlled to ensure efficient operation, could again satisfy these. These transport issues again point to the need for a large infrastructure high power source.

Conclusions

The definition of a bio-sensitive society and the limitations that imposes on the criteria for its energy options restrict those to renewable sources of all types using as much distributive and co-generation as possible and supplemented by high power facilities from hot rock geothermal sources. Nuclear fusion may be a "far into the future" possible high power energy option. Efficiency in the use of energy in all sectors will be paramount to the success of the society as will comprehensive recycling. Energy for transport will prove a major issue and will be the driver determining the design of cities and their interconnection in all aspects. Ships and particularly aircraft present real problems in

finding a non-polluting and safe energy source, which can satisfy the demands of modern travel. Renewable oil supplies may be insufficient while still presenting emission issue

References;

1. "What is our biggest problem?" Ockham's Razor, Radio National Sunday 27 November 2005, and see http://socialwork.arts.unsw.edu.au/tsw/.
2. "Ecopolis Now" and "Master Plan" , Fred Pearce, New Scientist 17 June 2006.

[Further Reading list to be added]