Integrating the many dimensions of sustainability: energy systems

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It is possible to move to a sustainable future but it will require fundamental changes to our values and national social institutions. We must recognise that we share a common future with the entire human family and the other species with which we share the planet. An integrated approach to sustainability assessment requires considering resource limits, ecological impacts, social effects, economic dimensions and the impacts on other countries. The principles are illustrated by a case study of the prospects of hydrogen fuel cells being used to power land transport vehicles.

Introduction
The case for hydrogen fuel cells on three foundations: depletion of petroleum reserves, global climate change and the need for a secure, equitable world. So I can make a powerful case for serious investigation of hydrogen futures. There are, however, some serious issues that we have to confront if those futures are to eventuate.

Resources
About seventy years ago, King Hubbert used statistical data on US oil discoveries and associated production to predict that US oil output would peak about 1970. It did, leading to a change in the relationship between petroleum producing nations [OPEC] and those, which use oil. The 1970s oil "shocks" dispelled the myth of infinite resources, causing significant policy changes in many northern hemisphere countries. Hubbert's techniques was being used in the 1970s to estimate that world oil production would peak about 2010, plus or minus ten years. That is still the best estimate: there are optimists who think the peak might be as far away as 2020, while there are pessimists who think it happened in the year 2000! Whoever is right, there can be no escaping the fundamental geological truth that we are using petroleum much faster than it was produced naturally, so it will not be plentiful for much longer. Some analysts think the struggle for the remaining oil is already under way. Prof. Gretchen Daily, of Stanford University, made the obvious point when she asked a forum in Sydney last year to reflect on how differently the US administration would regard Iraq if it only had 10 per cent of the world's broccoli.

Military and other geo-political issues aside, most decision-makers are still in denial about the approach of the peak in world oil production and the consequent need to change our transport systems, which are still based on the presumption that fuel will continue to be plentiful and cheap. While fuel prices in Australia are much higher than in North America, they are much lower than in Europe. In fact, Australians pay more per litre for beer, cask wine, milk, orange juice or even bottled water than they do for motor spirit! Cheap fuel leads to profligate use, with many urban commuters driving long distances as the sole occupant of large and inefficient cars. The situation is being worsened by the current fad of buying large four-wheel-drive vehicles to cope with the uneven terrain of suburban streets. A recent survey in Australia found that the dominant reason for buying these urban assault vehicles is that drivers no longer feel safe on the road in sedans, given how many large four-wheel-drive vehicles are on the road! So we are witnessing an urban arms race, leading to vehicles which are heavy and extremely inefficient.

Alternatives to petroleum
There are alternatives to oil as a transport fuel, but most of them pose problems. In the short term, it is relatively easy to envisage natural gas being used. LPG is already the fuel for most taxis in Australian cities, while Brisbane City Council decided a few years ago to move its bus fleet from diesel to compressed natural gas. The problem is that gas is also a finite resource. While the known reserves of gas are much greater than the reserves of oil, using gas

for all transport purposes would roughly quadruple demand, so the change would only buy a decade or two of breathing space. Many see gas as a bridge to a sustainable future, taking advantage of that breathing space. That possibility leads to a questioning of the current enthusiasm to export gas. If all the large projects currently under discussion were to materialise, Australian gas exports would increase from the present 7 million tonnes a year to about 40 by 2020. The sale of the gas would produce short-term economic benefits, but it may be doing future generations a disservice by selling a resource they might need.

A second group of fuel alternative contains those that can be produced sustainably from plant material. Australia has produced ethanol from sugar since the 1930s, while Brazil and the USA also produce large quantities from sugar and maize respectively. There are three problems with ethanol. The collection and processing of crops like sugar requires significant amounts of transport fuel, so the energy benefits are small – or, in the view of some analysts, possibly negative. The second problem is that growing sugar leads to other environmental problems; in Australia, pollution of the waters around the Great Barrier Reef are a consequence. The third problem is the ethical dilemma of whether it is appropriate to use food-growing land to produce transport fuel in a world where millions go hungry. The scale of the potential contribution is also limited; converting Australia's total sugar production to ethanol would meet about 10 per cent of transport fuel needs. Methanol looks promising because a 1979 CSIRO study found that pyrolysis of rapidly-growing trees could produce all of Australia's transport fuel, but only if it were possible to use an area about the same as that now devoted to all agricultural purposes. So plant-based alcohols may be a useful supplement of petroleum fuels, but they are unlikely to be produced on a scale sufficient to be a replacement.

From time to time, other hydrocarbon resources such as oil shale and tar sands are promoted as the solution to the problem of transport fuels. There is no doubt that it is technically possible to produce synthetic fuels from these sources. A site at Glen Davis, not far west of Sydney, produced oil from shale when I was young. The problem with oil from shale and tar sands is the economics, but the economic issue is actually a manifestation of a deeper and more fundamental obstacle. The recent history of oil shale is a cautionary tale. In the early 1970s, when the price of oil was less than US$2 a barrel, the entrepreneurs with shale oil concessions said that the product would be economically viable if the price were ever to reach $5. When it did, the break-even point had drifted up to seven or eight dollars a barrel. It is not necessary to go through all the intervening steps; a current price over US$50 a barrel has not been enough to make oil production from shale viable. There is a fundamental explanation. Oil shale is a low-grade resource, typically containing about 100 kilograms of oil equivalent per tonne of rock. It takes large amounts of energy to dig up the rock, crush it and process it to obtain the hydrocarbons. Energy analysis by Gerald Leach twenty-five years ago suggested that the energy used to process typical shale deposits is about the same as the energy content of the product. So, in energy terms, the process is effectively paying one lot of men to dig a hole and another lot to fill it up. However high the price of oil goes, the economics will always be dubious. Glen Davis was an unusually rich deposit, yielding about 350 kilograms of product per tonne and proving profitable. Many shale deposits are very large, with huge amounts of potential hydrocarbons, but the low grade of the resource makes the economics questionable. There would also be serious environmental problems if we were ever to process shale on the scale needed to make an impact on fuel needs.

So the case for hydrogen as a fuel is essentially that it appears the only realistic solution to the problem of a world dependent on plentiful transport fuels as the peak of world oil production leads to scarcity and higher prices for petroleum products.

Global climate change and other environmental issues

The second reason for supporting hydrogen is to reduce the environmental impact of transport. Petroleum fuels are largely responsible for poor air quality in urban areas, with the

emission of particulate matter and the contribution to “photochemical smog” having tangible direct health effects. The burning of petroleum fuels is also a major contributor to global climate change. While the natural range of carbon dioxide levels in the atmosphere have varied between about 180 and 280 parts per million for the last half million years, the figure is now about 380. This is a direct result of burning huge amounts of coal, oil and gas since the Industrial Revolution. The Earth is now about 0.6 degrees warmer than it was a hundred years ago, with consequent changes to rainfall patterns, plant growth, distribution of animal species, sea levels and the frequency of severe events like storms, floods and droughts. Perth is a city facing severe water problems as a direct result of climate change. Where the average run-off to the city’s water supply reservoirs for the first 75 years of last century was about 370 Megalitres, the average figure since 1998 is 115. The WA State government is planning a de-salination plant and tapping a deeper aquifer to meet the city’s needs. All the projections suggest the situation will get much worse. The UN’s advisory body, the Inter-governmental Panel on Climate Change, gave in its Third Assessment Report a range of possible future outcomes, depending on the pattern of future fuel use and taking account of uncertainties in the science. The worrying “bottom line” is that the most optimistic future, based on a rapid phasing out of fossil fuels and the best interpretation of the scientific uncertainty, still involves a further 1.5 degrees increase in average global temperature, with associated changes in other outcomes influenced by temperature. That is why the governments of most industrial nations have agreed to begin a process to reducing emissions of carbon dioxide. The first step is the Kyoto Protocol, still unfortunately being obstructed by short-sighted politicians in the USA and Australia, but now likely to be ratified and enter into legal force early next year. Some nations are looking well beyond the first timid steps in the Kyoto agreement; for example, the UK recently adopted a target of reducing its carbon dioxide emissions by 60 per cent by the year 2050. Even if petroleum reserves were unlimited, climate change would be requiring us to look seriously at ways of reducing its use for unnecessary purposes. Future generations will find it difficult to believe that we drove alone in a commuter vehicle, and will probably be startled to learn that we actually fuelled vehicles and raced them around a track just to see which was the fastest.

The International Geosphere-Biosphere Project recently released a major report on its decade-long scientific study. *Global Change and the Earth System, A Planet Under Pressure*, was published by Springer-Verlag this year. It points out that global change is more than just changes in the climate. It is real, is happening now and in many ways is accelerating as the multiple interacting effects of human activity cascade through the natural systems of the Earth. In addition to carbon dioxide levels, several other parameters of the Earth system are now well outside the natural variation observed over the last half million years or more. We also know that the dynamics of the natural systems of the Earth are characterised by critical thresholds and abrupt changes when those thresholds are exceeded. So, the report warns, it is entirely feasible that human activity “could inadvertently trigger changes with catastrophic consequences”. The analysis leads to an obvious conclusion: “Dramatic increases in energy efficiency, decarbonisation and the development and utilisation of new sustainable energy technologies, such as a hydrogen-based energy system, are needed”.

So the second leg of the case for hydrogen is the need to move away from the energy sources that are changing the global climate and threatening our future.

Social issues

The third leg is the need to move toward a more equitable world if we want a sustainable future. I don’t believe that entrepreneurs in the OECD countries can be secure doing property deals on mobile telephones as they speed around in large cars in a world where the majority of humans have never ridden in a car, never made a phone call and never owned property. The division between the “haves” and the “have-nots” is widening all the time. In 1980, the richest 20 per cent of the world had 70 per cent of the wealth and the poorest 20 per cent had 2.3 per cent: a ratio of about 30:1. By 1995, the ration was 60:1 and today it is 75:1. That

trend cannot lead to a secure future. The dominance of US media has also made many people in the poorest countries acutely aware of the relative material comfort of the wealthy nations. An increasingly inequitable world is very likely to be an increasingly insecure world, with literally millions of people from poor countries risking their lives to make their way to north America, western Europe or the relatively affluent countries of the Pacific Rim: Japan, Australia and New Zealand. It is possible to imagine social and political solutions to basic needs; for example, the UN Development Program has estimated that the entire developing world could be given adequate nutrition, clean drinking water, reasonable shelter, basic education and health care for about 5 per cent of the global military budget! But there is no prospect even in principle of extending to the developing world the sort of access to transport energy we take for granted. It has been estimated that if the entire world used oil at the rate of Australians and it could be pumped out fast enough, the entire global reserves would be exhausted in about a year. So the only prospect of more equitable access to energy, arguably a pre-requisite for a secure and peaceful future, involves the development of energy technologies based on plentiful resources. That makes a compelling case for promotion of hydrogen futures.

Problems of widespread use of hydrogen

The wise US journalist H.L. Mencken was quoted as saying that every complex question always has a simple answer, but it is always wrong! It is never possible to change only one thing in a complex system, because other changes always follow. Though there is a compelling case for seriously considering hydrogen fuel cells as a future transport energy source, it is also important to be aware of the outstanding issues.

There are some technical problems still to be solved before we can be confident of having reliable energy systems based on local conversion of hydrogen using fuel cells. The papers presented at the recent Hydrogen and Fuel Cell Futures conference in Perth make it possible to be very optimistic that these problems are soluble. In general, we can be reasonably confident that problems that are **purely technical** can be solved if sufficient resources are devoted to the task.

The technical issues overlap with the economic questions. Both technically and economically, the most attractive way to produce large amounts of hydrogen is to use fossil fuels like coal or natural gas as the feedstock. But serious analysis suggests that the natural gas – hydrogen – fuel cell approach is approximately greenhouse neutral, while starting from coal significantly worsens the greenhouse impact of transport. If we want the hydrogen economy to reduce our impact on the atmosphere, we will need to produce hydrogen by using renewable electricity to split water. Turning solar or wind energy into hydrogen is a way of storing those intermittent sources, so it has obvious appeal. The problem is that the present technologies make hydrogen from renewable electricity economically unattractive. So the prospect of hydrogen fuel cell futures eventually being based on clean renewable energy hinges on development of less expensive ways of harnessing those energy forms. There are promising studies under way of geothermal energy from hot dry rocks, of wave energy and of new generations of the established technologies like solar cells and wind turbines. At this time, however, it seems likely that these “clean” alternatives will mean much more expensive transport energy. While transport energy is almost certain to become more expensive as increasing demand in the USA and China chases a fixed or declining supply, in the real world of politics there are few leaders willing to risk the voter backlash of deliberately increasing transport costs.

The third issue is the environmental impact of large-scale hydrogen production. As I have already discussed, the hydrogen route may not solve the problem of climate change. Producing solar cells, or wind turbines, or any other renewable energy devices on the scale needed to supply enough hydrogen for the global transport task will have environmental impacts. A more serious issue is the uncertain impact on atmospheric chemistry of large-scale use and inevitable release of hydrogen. As the lightest molecule, hydrogen is notoriously

difficult to contain. A study by a group of researchers at CalTech, published in the journal *Science* in 2003, calculated that a future global hydrogen economy could result in 60 to 120 million tonnes of hydrogen being lost each year into the global atmosphere. We just don't know what the impact would be. An optimistic view would hope that it would just react with oxygen to form water and return to the oceans, or that it would be absorbed in ways that don't cause unforeseen problems, but we cannot be certain. So we should be doing the research now. Nobel Laureate Paul Crutzen has pointed out that we were just lucky that CFCs were based on chlorine rather than bromine, and so thinned the ozone layer rather than destroying it entirely! Some researchers have also pointed out that the lightness of hydrogen makes it likely that significant amounts would drift into the stratosphere and possibly even be lost from the Earth system. They argue that taking water from the oceans to transfer hydrogen into the atmosphere might, in time, lead to reductions in sea level. It could be argued that this might be desirable in the short term, given the problems of rising sea level caused by global warming, but we would obviously have to be very confident about our sums if we were to consider this as a conscious strategy! The serious point is, once again, that this is an issue that should be studied. Before we embrace the hydrogen economy, we need to have done enough research to be confident we are not getting out of the climate change frying pan into some unknown environmental fire.

The fourth issue is the social and political impact of working toward a hydrogen future. The time, intellectual effort and other resources expended on one area of research and development inevitably reduces the capacity to work in other fields. Some well-intentioned people see the nub of the transport problem not as oil and the internal combustion engine, but the inefficiency of the average vehicle. They have a point that cannot easily be dismissed. Imagine giving a group of engineering students the task of designing a transport vehicle to carry a fragile payload, typically between 50 and 100 kilograms. If they produced a design that weighed more than a tonne, you would almost certainly recommend they review their career options, possibly steering them toward a future for which numeracy would not be important. It is easy to imagine a vehicle like the Amory Lovins hyper-car, weighing about 250 kilograms instead of five times as much and as a direct result using only one-fifth the fuel. Making such vehicles the norm would make the limited oil reserves last five times as long and dramatically reduce emissions. Others go back one step further and see mobility as a response to poor urban design. Again, these people have a point. The reason we move into cities is to access the wider range of services that are available there. We don't move to cities so we can spend hours travelling to access those services. So a fundamental priority should be improved urban design, making the services people want easily accessible, rather than accepting the inadequacy of current design and flattening increasing fractions of our cities to allow people to drive by themselves for hours in pursuit of the services that are now inaccessible. Finally, it could be argued that the technical task of expanding hydrogen fuel cell transport to the entire human population is so huge that embracing this approach will do nothing to bridge the gap between the mobile and the immobile

I concede the relevance of these criticisms. We should, of course, encourage improved urban design and smaller, more efficient vehicles. But these measures have long time lines. Much of the structure of the cities of 2030 is already in place. Most of the vehicle fleet of 2015 is already on the roads. So we need to be pursuing cleaner energy systems as well as trying to develop better vehicles and putting greater effort into urban planning. While the prospect of extending hydrogen transport to the entire human population seems daunting, it is in principle possible if there is the political will, whereas there is no prospect even in principle of universal access to oil-based transport. There are also, of course, resource issues. Before we could embark on a programme to produce millions of hydrogen fuel cell vehicles, we would need to be confident that the materials needed are actually available! Like the other problems I have discussed, these issues should not deter us from working on hydrogen fuel cell futures; they simply provide the wider context within which we should be doing that work.

Conclusion: the case for sustainable futures

I have no doubt that we should be working toward sustainable futures. That is a moral imperative. It is indefensible to be developing futures that we know cannot be sustained, producing inevitable problems for future generations. As the second report in the UNEP series on the Global Environmental Outlook said, our present approach is not sustainable, so doing nothing is no longer an option. A sustainable future will be one in which we are not depleting the resources future generations will need, are not doing serious damage to natural systems and are moving toward an equitable and secure world. So, market-led wealth generation and government-guided technological change has to be supplemented by a values shift towards a new global vision marked by equity and marked by durability.

I believe we should be looking at strategic goals, like stabilising the population and eliminating hunger. That doesn't require technical advances, it simply requires a more equitable distribution of the two kilograms of food per person per day we now produce, rather than a market approach in which those who cannot afford food go hungry, while land which formerly grew cheap food for subsistence living in Africa is now increasingly being used to grow flowers to be air-freighted to rich consumers in the developed world. We should also be aiming at a dematerialisation of society. Some European nations have now adopted the goals suggested by the Wuppertal Institute of reducing energy use to a quarter of the present level and reducing material use to 10 per cent of the present level; they see those as realistic targets. But above all else, we need a values shift, perhaps away from *Homo sapiens*, which is gendered and a link back to our past, towards what my partner Patricia Kelly calls, based on Pentti Malaska's idea, *Globo sapiens*. The idea of being wise citizens of the planet recognises that we share it with all other species and that we hold it in trust for all future generations. That means that we need to see the economy as a *means* to service human needs rather than end in itself, and that we should be committed to *genuine* globalisation rather than the current fad of simply reducing the constraints on corporations. We also need to improve our social institutions and processes for making difficult decisions. It will only be possible to take difficult decisions if there is an open and transparent process, involving the community and allowing time to work through the costs and benefits of alternatives. Changing one thing in a complex system always produces other changes, so no change is ever universally beneficial; there are always losers as well as winners. In a fair world, those who lose out from a change that benefits the community as a whole should be compensated by the rest of the community. We accepted that principle when we decided that those using Sydney airport should pay a noise levy to compensate those under the flight path. It is an approach that should be considered more generally.

We have to see that growth in itself is not a solution. The Brundtland Commission pointed out 15 years ago that the two main causes of environmental degradation are extreme poverty in the poor countries and unsustainable levels of consumption in the rich countries. Growth can in principle do something about the first problem; but growth is both in principle and in practice making the second problem worse, and will continue to do so unless we embrace a different sort of growth which is oriented towards human need rather than human greed.

The fundamental problem is still that that most decision-makers are operating under what could be called the pig-headed model of the world, in which the world is seen like the head of a pig, with the economy a large shape like the face, while society and environment are minor protuberances like the ears. For those who still have that primitive world-view, it actually makes sense to say that the economy is supreme and the minor problems of society and environment can be handled as long as the economy is thriving. The only intellectually defensible model is one that accepts that **the economy is a part of society**; it is a very important part, to be sure, but only a part, because we expect from our society a range of services which are not part of the economy, like a sense of place, like a cultural identity, security, companionship and love. Our societies are totally enclosed within natural ecological systems on which we depend for breathable air, drinkable water, adequate nutrition, a sense of

cultural identity, spiritual sustenance and so on. We tend to behave as though we are not part of natural systems. We should each remember that every molecule of our bodies was once part of the natural systems of this planet, and indeed every one of those molecules will, in time, once again be part of the natural systems of this planet.

We need to accept that our social and economic planning should be within an ecological framework, that we do need planning and conscious decision-making, rather than trusting the magic of the market which cannot, even in principle, represent the interests of other species and future generations. So we need new social institutions, we need new technologies to meet our needs, but above all else we need values for a sustainable future based on the principle of *Globo sapiens* and continuous adaptive management based on social learning.

I suspect even the intelligent and thoughtful participants in this process may see that proposal as utopian. It is, but we should always remember that *all* of the significant social reforms through human history have been seen at the time as utopian. Two hundred years ago it was utopian to be advocating a world without slavery, and the abolitionists were told they were unrealistic because no economy could function without slave labour. A hundred years ago it was utopian to be urging votes for women, and those who did so were openly persecuted. Closer to our present time, twenty years ago it was still utopian to be dreaming of Berlin without the wall, or South Africa without apartheid, or laptop computers, or mobile phones, or for that matter, good coffee and civilised licensing laws in Queensland! In fact, practically all features of modern life were once utopian visions; we have them because visionaries of previous days were *not* content with the world in which they lived, but worked systematically for a better world. In those terms, just as those who thought long term and who had a moral conscience felt obliged two hundred years ago to be working to end the slave trade, I believe those of us who are thinking of future generations have a moral responsibility to be working for a sustainable future. That requires an integrated assessment rather than simplistic analyses based solely on technical and economic aspects of the problem.

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