Environmental Sustainability Education for Engineers - some reflections and a suggested checklist of essential concepts

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ABSTRACT.
The intention of this paper is to equip future engineers with essential background knowledge in environmental sustainability. This will hopefully enable and motive future engineers to become more proactive in solving environmental sustainability problems. A strong requirement now exists to strengthen sustainability engineering curricula, as delivery upon this newly emerged topic is probably less consistent than in other more established areas of engineering. This review/position paper constitutes a condensation of the most pertinent concepts, but for purposes of brevity, only contains a skeleton (gist meaning) behind these concepts. The suggested checklist is merely that, and for reasons of space, is not intended to encompass a fully referenced and rigorous definition of each topic. The checklist is not meant to cover all environmental engineering topics. Importantly, the teaching philosophy behind the purely factual material alluded to, is to allow students (and staff) to formulate their own opinions and beliefs regarding specific environmental sustainability issues. This list as presented is suggested as a minimum for delivery on environmental sustainability related courses. It is hoped that this paper will stimulate discussion across universities, government, professional bodies and industry, and thereby enhance quality and uniformity in the delivery of engineering education in this important new area. It is important to note that statements and opinions expressed in this paper are those of the authors alone, and certainly do not apply in particular to any University in Australia, or the world.

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Introduction

This paper some presents suggestions for making more consistent across universities, engineering course material on the topic of environmental sustainability. One of the main problems faced by engineering educators is that the meaning of the word sustainability has continually changed and evolved over the years (Lau, 2010). It is not surprising therefore that perceptions of environmental sustainability amongst academic staff, let alone students, tends to vary somewhat. To many, sustainability is all about conservation biology, and to others it may be recycling, use of green technologies or conscientious and wise natural resource management. To many economists, sustainability means 'sustainable-economic-growth' and is at odds with what is meant by environmental sustainability. The nature and magnitude of these variations would require an extensive study to fully validate. As a matter of fact, a project along these lines has recently been commenced at USQ, under an Australian Learning and Teaching Council (ALTC) funded research program. The precise range of topics delivered in Environmental Engineering courses around Australia is being mapped, and this will be reported upon at a future occasion.

In the interests of speed, action to improve possible inconsistency in education delivery should possibly arrive ahead of full problem definition. Specific recommended material provided here is intended to serve as stimulation for discussion amongst deliverers of Sustainable Engineering Science. It is hoped that this will assist in the formation of globally uniform curricula that can be agreed upon and developed through conventional Delphi style processes.

A problem discussed in this paper is resistance within institutions to invoke change – quote 'academia changes slowly, with the average innovation requiring 26 years to be implemented by the median institution' (Stiver 2010, Getz et al 1997). In support of this, during the late 1970s / early 80s some notable earth scientists refused to fully accept the theory of plate tectonics, first introduced in the 1960s. As years progress, new theories are gradually accepted by the majority. New ideas are seldom announced early on as true by conservative institutions, but gradually and often surreptitiously slide into acceptance. There are few now who continue to dispute plate tectonics, or the negative health effects of cigarette smoking, for example.

Rowe (2007) states "right now, sustainability is treated as an add-on, as another item on an already full plate". Perhaps in Mechanical, Civil, and Electrical and Chemical engineering disciplines, in the interests of time it is possible that sustainable or 'green' aspects of each discipline can be successfully added as footnotes. But for the newly emerged discipline of Environmental Engineering, it is recommended here that the subject of sustainability should be treated as 'fundamental to its core'. It is this branch of engineering that should fully take on the task of delivering the message of sustainability to young engineers.

To ensure sufficient motive for young engineers to really practice their engineering sustainably, do they really do need to believe that CO_2 induced climate change is real ? That question will intentionally remain unanswered in this paper – like the theory of evolution in the past century - it is after all the great question of our day. But for students to consider this properly, it could be argued that all engineering students should have at least an elementary understanding of basic earth science concepts, including some basic paleoclimatology. Rather than being poorly delivered or omitted entirely, these topics in particular should receive equal importance to the other topics normally included in standard Environmental Engineering curricula.

Adams et al (2010) states “you gotta work on the right things rather than trying to make the wrong things less bad”. The case scenario which immediately comes to mind is the rapid acceleration in the natural gas exploitation in Australia and elsewhere in the world. This is made acceptable to the public based on a heavily marketed perception that gas is ‘clean energy’ rather than ‘cleaner energy’ as compared to coal. Without a strong background training in sustainability science, some engineers may well be lulled into a false sense of security. By designing some green widget or ecofriendly technology, they may actually be of the opinion that they have done something significant to combat climate change. Placing non-incandescent light globes in one’s house, for example, should certainly not alleviate the burden of guilt one should have regarding the planned continual increase of fossil fuel burning as our primary energy source.

From the standpoint of an Environmental Engineer, with initial training in Earth Sciences, coverage in basic earth science concepts is certainly not strong enough in current engineering curricula. This position paper will assist educators towards a more consistent and uniform model of what higher engineering education should now be delivering in terms of the precise subject matter on this most important topic. It will also comment on other important areas of environmental sustainability engineering, including ecological, social and economic aspects.

Sustainability topics.

Topic areas traditionally taught in environmental engineering courses usually include soil, water, waste and recycling, hazard and risk management, contaminated land, transport and energy. Notably, air quality is frequently omitted. It is paradoxical that the main issue of debate raging presently, namely CO2 induced climate change, is fundamentally an air pollution problem. All areas listed above are at least alluded to in the following suggested checklist of essential concepts in sustainability engineering. The list is certainly not meant to cover the full range of topics that should appear under an environmental engineering course, as the number of entries would be in the thousands. Entries are included here because of their direct relevance to the meaning of sustainability as defined in this paper, best defined by example under glossary entry number 10.

1. Climate Change - Scientists have in many ways completed their task. In a very well coordinated and organised group, their work over the past twenty years has demonstrated that humans have added about 500 billion tonnes of carbon to the atmosphere since pre-industrial levels, which caused the earth to warm by about one degree (IPCC 2007). Assuming a 'business-as-usual'scenario out to 2050, another 500 billion tonnes is due to be added, which will generate a further 2 to 3 degrees of further warming. Earth in 2050 will then have expended about half its fossil fuel reserves. If the remainder is combusted also, global warming could be 4 to 6 degrees or higher, which would be higher than at any time in the last several million years. Another important impact is ocean acidity, which is now higher than it has been during the past 40 million years, but there may be other causes of this other than purely CO2, namely pesticide and nutrient release.

2. *Consequences of Climate Change* - So far, the effects of only one degree of warming appear to include widespread melting of mountain ice, increased ocean acidity and increased frequency of flood, fire, drought and heat wave events (IPCC 2007). It appears that one in one hundred year events may now have become one in twenty year events. If we as humans make the sensible decision to limit warming to absolutely no more than +2 degrees from pre-industrial levels, we really have to commit <u>now</u> to steadily reducing the consumption of fossils fuels to zero by 2050. The technology already exists for solar and wind to provide utility scale electricity, and for all ground based transport to be electrically powered. Aircraft can be powered with agriculturally produced biofuels which are (optimistically) carbon neutral. The economic price to pay for carbon free power and transport will be limited to an approximate doubling of the existing cost of these items – really a very small price to pay if we are going to protect the earth. But in the 20 years since the Rio Convention we have seen very little action towards actively reducing fossil fuel consumption, which is 12 billion tonnes oil equivalent now and is expected to rise to 17 billion by 2030 (Vigotti and Frankl, 2009). The reason for this is that politicians and governments are driven by harsh economic reality and the desire to pay off their immediate bills, putting off environmental concerns. It is human nature for people and countries to compete against one another in this sense.

3. Environmental movement – initiated by Rachael Carson's book 'Silent Spring in 1962 (Carson, 1962) which documented DDT bioconcentration in the world's ecosystems. The need for a world environmental movement was recognised by the public with World Earth Day in 1970, and formally recognised by world governments at the Rio de Janiero Earth Summit in 1992 (UNCED 1992).

4. Definitions of sustainability - modern concept of sustainable development which originated during the 1980s – the 1970s fossil fuel shortage is mentioned as the main driving force. Mention of the famous publication "Limits to Growth" by the "Club of Rome (Meadows et al 1972). Further information is available from the United Nations Environmental Program (UNEP 2002) and also the World Wildlife Fund (WWF).

5. Brundtland Report - the 1987 World Commission on Environment and Development (WCED) 'Brundtland Report' (Bruntland, 1987) is provided as a satisfactory definition of sustainability ie. 'meeting the needs of the present generation, without compromising the needs of future generations'. The question should be raised here about how much present generations care about future generations, with it being obvious that present generations do not care overly much about the present generation !

6. Current human population **-** by the year 2000 the world's population exceeded 6 billion people. Brief mention here of Malthus's early population theory (Malthus, 1798). World population now approaches 7 billion and is expected to exceed 8 billion by the year 2025 [14]. The world is starting to show signs of severe stress as a result of this population pressure.

7. Social economic inequity - approximately 40 percent of the world's population continue to suffer from serious food and water shortages and manage to exist on less than $2 per day amounting to 5 percent of global income. (Bongaarts, 1995). Eighty percent of people live on less than $10 a day. The wealthiest ten percent of the world's population own approximately 75% of the world's wealth, and the wealthiest two percent own approximately 50%.

8. Environmental degradation - humans are starting to run out of fresh water and soil to grow food. According to UNEP, approximately one half of the world's rivers are seriously depleted and polluted, one third of the world's soil is now classed as degraded as a result of human activities, and one quarter of all wildlife is threatened. The rate of extinction of species, primarily due to habitat removal, is greater now than it has ever been in the geological past.

9. Insatiable humans - few humans are concerned with the needs of future generations, or indeed the needs of the present generation. We now understand that human needs are insatiable. We exploit the world's resources as fast as we possibly can to maximise the wealth of ourselves and perhaps our immediate families.

10. Newfoundland Northern Cod industry – this should be presented as possibly one of the best case examples illustrating concept of sustainability (WRI 2005). Small boats produced a sustainable catch of around 250,000 tonnes per year until about 1950. Then with the arrival of large trawlers from all over the world, catch of northern cod increased to a peak of 800,000 tons by 1968 prior to the first major collapse. By 1978 the yield was 140,000 tonnes, and in hindsight this which is probably where it should have been capped to enable stock recovery. Unfortunately, by the mid-1980s huge Canadian trawlers were still landing more than 250,000 tonnes of northern cod annually, destroying habitat, spawning grounds and destabilizing the ecosystem generally. Despite protests from Newfoundland's small-scale inshore fishermen, the Canadian government delayed action in reducing quotas, and by the mid 1990s the resource had gone completely. The Newfoundland Cod industry might still be thriving today if authorities had taken a more proactive and 'precautionary' approach. In this case an overly 'permissive' approach led to complete and permanent collapse of the resource.

11. Human population growth - with the recession of ice and dawn of agriculture 10,000 years ago, human population grew steadily from less than one million to about 300 million by the 1st century AD (estimates only). Kept constant for hundreds of years by frequent plagues, population suddenly started to grow significantly after the 18th century. With steady advances in agriculture, human population reached roughly one billion at the beginning of the 19th century. In the middle of the 20th century, advances in supply of fresh water and medicine (antibiotics) saw rapid decrease in infant mortality which saw a temporary rapid increase (above 2 percent) in population growth rate. World population is expected to hit 7 billion during the next few years.

12. Fresh water resources - only 3% of the world's water is fresh and two thirds of that is frozen. Of the remaining 1% most is groundwater too deep for human consumption. Only a tiny fraction is therefore accessible for human use. This is the water that we find in lakes, rivers, reservoirs or in accessible groundwater basins or aquifers. Of the nearly 7 billion people alive today, more than a billion do not have adequate access to safe water (UNFAO 2009). By 2050, the world's population could rise to 10 billion. Demand for water, mainly for irrigated agriculture, is expected to be intense. By 2050, three out of four people around the globe may be affected by water scarcity (UN 2006).

13. Irrigation - the greatest consumer of water is irrigated agriculture, which accounts for some 70% of total water withdrawals worldwide – but this generates 40% of total agricultural output. Global irrigated land has increased approximately linearly (2% per annum) since 1960, and accounts for approximately 20% of total cultivated land. Defined as the ratio of withdrawal to availability, water stress is greatest in Asia which accommodates more than half of the world's population. Asia's consumption of fresh water is less than 10 cubic meters per person per day. In the developed world, water consumption per capita is more than an order of magnitude greater than that. In Asia there were only a few dozen large dams prior to 1950, now there are several thousand.

14. Agricultural intensification - through mechanisation, chemical advancements in the form of pesticides and fertilizers, and appropriation of increasingly more land for agriculture, the world experienced a four-fold increase in agricultural production since 1950. From 1960 to 1980, plant breeding programmes were able to deliver a five-fold increase in wheat production in Mexico, and a three-fold increase in grain production many other poverty stricken areas of the world including India and Pakistan (Borlaug, 1994, 1997). China is now the largest agricultural producer (>US $ 500 billion) followed by Europe, India, US, Brazil and Japan. Australia is ranked as the 10th largest producer at US 40 billion.

15. Land shortage - humans are now already using approximately 50 million km^2 or one third of the land surface of the earth for agricultural production. Another one third of land area consists of forestry and woodland, and the remainder supports little or no vegetation. The rate of growth of agricultural production will inevitably start to slow as fertile areas on earth become more difficult to find. Areas found for additional food production are already becoming increasingly marginal in terms of soil quality and erosion potential.

16. Energy - the present world oil consumption is 85 million barrels of oil per day, or about 8.5 million tonnes. According to the International Energy Authority (IEA, 2009), this provides approximately one quarter of the world's total primary energy demand of about 12 Btoe (12 billion tonnes oil equivalent per year). This is roughly equal to 500 exajoules (500×1018 J/yr) or 16 trillion watts (16×1012 J/s). More than eighty percent of this energy demand is currently provided by fossil fuel (coal, oil and gas) resulting in approximately 9 billion tonnes (9 gigatonnes or 9 Pg) of carbon entering the atmosphere every year (IPCC, 2007). Coal emits approximately 25 tonnes of carbon per Terajoule (TJ), oil 20 tonnes/TJ and natural gas about 15 tonnes/TJ. The other 20 percent of the worlds energy demand is provided by biomass, nuclear and hydroelectricity. Currently less than one percent is provided by other renewable energy forms such as solar, wind and geothermal (Philibert, 2004).

17. Rising world energy demand – the current 12 billion tonnes oil equivalent is predicted to rise steadily to 17 Btoe by the year 2030, an average growth rate of 1.5 percent [IEA, 2009]. This is just in excess of current world population growth of 1.3%. The prediction by the International Energy Agency is that over the next 20 years there is likely to be <u>no</u> significant reduction in the growth of consumption of fossil fuels (oil, coal and gas) for stationary energy purposes (electrical power) and transport (gasoline).

18. Carbon flux to atmosphere – according to the Intergovernmental Panel on Climate Change (IPCC, 2007) the total annual anthropogenic (caused by humans) flux of carbon to the atmosphere is about 8 billion tonnes per year (MtCO2-e/yr or GtC/yr). About one billion tonnes is from agriculture and deforestation, and about another billion tonnes is from industry and cement production. The remainder (6 GtC/yr) is produced by fossil fuel burning for stationary energy production and transport. The increase in the carbon in the atmosphere is about 40% of this or 3.5 GtC/yr. The oceans absorb about 2 GtC/yr and vegetation and soils around 1.5 GtC. A further 1 GtC is thought to be in soil water and is eventually carried by rivers to the ocean.

19. Australia's total GHG emissions - from the year 2000 to 2008, these rose from about 500 to 550 MtCO2-e/yr, which is about 7% of the world total. This is despite the fact that we have only 0.3% of the world's population. Australia produces about 400 million tonnes of coal per year (about 6% of total world production) and is the largest exporter of coal at 230 million tonnes per year (Petrie 2005, ABARE 2010). (This section to be made specific to university's country).

20. Green house gases - the main greenhouse gases (GHG) include carbon dioxide (primarily from the combustion of fossils fuels for energy) methane (from livestock) and nitrous oxide (from soil cultivation) and halocarbons (from industry). GHG traps extra heat in the atmosphere by absorbing infrared radiation energy which would otherwise leave the earth. It should be noted that the cooling effects of atmospheric aerosols (eg. sulfur dioxide) roughly balance the warming effects of methane, nitrous oxide, halocarbons and tropospheric ozone, leaving the net warming as roughly equivalent to that from CO2 alone.

21. Radiative forcing - according to IPCC (2006), the extra net radiative forcing due to the presence of GHG is approximately 1.5 Watts per square metre. According to some scientists this has contributed to a global mean surface temperature to rise by nearly 1 degree centigrade since the year 1900.

22. Global Ice Retreat - there are many physical signs of signs of recent global temperature rise including the notable retreat of mountain ice all over the world, Greenland, Alaska and the Arctic (NCAR, 2011). In assessing global temperature change, earth scientists study ice data, because ice has the effect of integrating temperature on the decade timescale

23. Paleoclimate – ice data must be but expressed properly against the context of the geological history of the earth. The earth is presently in the 'Quarternary Ice Age' which commenced approximately two million years (2Ma) ago and coincided with acceleration in the development of early humans. With ice covering much of Northern Europe during about seven cool glacial periods, early humans were able to out-compete other species because they were more adaptable. Over the past half million years or so, ice core records indicate that atmospheric carbon dioxide levels have alternated from lows during cold glacial periods of around 180ppm, to highs of around 280ppm during warmer interstadial (or interglacial) periods (Petit, 1999). We have 390ppm today. As a matter of interest, during the extremely cold glacial periods (eg. cold peaks at ~17 and ~135Ma), global mean sea level was approximately 100m lower than today. During the warmer interglacial periods (eg. warm peaks at 125, 240 and 330Ma), sea level was 5-10m higher than today. Prior to the Quarternary period it was generally much warmer on earth, with no ice ages (apart from a long one during the Carbonifereous and a short one at the Ordivician/Silurian boundary), and sea level was on average about 100m higher than today. Quarternary glacial cycles have had a periodicity of around 80, 000 to 120,000 years, and are driven by natural variations in the earth's orbit called Milankovic cycles. Initial disturbances, once started, can be accelerated by 'amplification feedback loops' caused mainly by the ice albedo effect.

24. Ocean acidity - since oceans absorb CO2, ocean acidity is now worryingly higher now than it has been in the past 40 million years (NOAA, 2011) although there may be other sources of acid to the ocean (eg, fertilizers, acid sulfate release).

25. *Ozone depletion* - Despite legislation put in place to address the issue (Montreal protocol 1987), depletion of the atmospheric ozone layer which protects life from damaging UV radiation from the sun, is now also at record levels (NASA, 2006).

26. Changes in hydrological cycle - climatic warming observed over several decades has been linked to changes in the hydrological cycle such as increased atmospheric water vapour content, cloud cover, more variable rainfall, substantial melting of continental and sea ice, and changes in soil moisture and runoff. Over the past 100 years precipitation has mostly increased over land in high northern latitudes, whilst decreases have occurred from 10°S to 30°N since 1975, with a doubling in the area of land classified as very dry (Bates et al 2008). There have been significant decreases in water storage in mountain glaciers and Northern Hemisphere snow cover. Up until recently, statistical proof of the 'anthopogenic contribution' towards climate change has remained rather elusive. However, some solid data linking human activities to intensification of extreme precipitation events in the northern hemisphere is now starting to emerge [Pal et al 2004, Min et al 2011,]. Expected impacts of climate change (IPCC, 2007) are :-

i) further melting of global ice (particularly Greenland and Alaska),
ii) changed ecological habitats (wetlands, reefs, mountains, species extinction)

iii) 1m – 5m rise in sea level (0.5-1.5m prediction in early IPCC reports)
iv) significant warming of upper ocean (300m) and lower atmosphere
v) increased acidity of the oceans, changed ocean currents
vi) significantly hotter, drier mid continental conditions eg. Australia
vii) increased frequency of drought, fire and flood events eg. Australia
ix) possibly more intense coastal hurricanes / inland tornados eg. US

27. Precautionary Principle - we know we have had periods both warmer than now and colder than now in our past and these have been entirely due to natural variations. But the point to be made here is that concentrations of atmospheric CO2 have now exceeded 380ppm and are a full 100ppm higher than they have ever been over the past 800,000 years. It would be advisable therefore for humans to err on the side of caution, deploy the Precautionary Principle and start doing something about rising CO2 levels. According to the majority of scientists, the significant role of humans in this, is now believed to be 'unequivocal'. In just 100 years humans have driven atmospheric CO2 levels from 280ppm to 390ppm, about 100ppm higher than pre-industrial levels and what they should normally, be for the top of a warm interglacial period. Scientists are not exactly sure what the precise effects of a continuing rise in CO_2 will have on climate, but there is a significant risk it will lead to continued significant warming of the earth. One realistic target which has been suggested by some scientists is that we define 450ppm as the absolute maximum limit for atmospheric CO2 in the future, because that would limit further temperature rise to only a further 1-2 degrees above current levels. Governments are therefore advised to put in place policy which observes the 'Precautionary Principle' ie. even if we do not have to have complete proof of the link between GHG emissions and global warming, we should act now to reduce them in any case.

28. Environmental Leglislation - the most significant Environmental Conference ever to have taken place was undoubtedly the United Nations Conference on Environmental Development which took place in Rio de Janeiro in 1992 (UNCED 1992). Known as the Rio Declaration or Rio Earth Summit, 180 countries agreed an environmental plan of action known as Agenda 21. Apart from the Kyoto Protocol which in 1998 set targets on CO2 emissions, nothing significant really happened though over the next decade. In September 2002 another conference took place in Johannesburg (UNEP 2002) which set more goals including an intention to halve world poverty by 2015 – a goal which certainly was very unrealistic. Despite increasing prosperity of the middle classes in China and India, the total number of people living in poverty continues to increase, as world population continues to increase.

29. Environmental Assessment - up until the middle of the 20th century, in a tradition continuing on from the industrial revolution, the primary consideration of engineers was how to maximise profit from industrial production, with little or no regard paid to the environment. This situation has now changed, and Environmental Impact Assessment, or EIA, is a process now very relevant to the day to day business of Spatial Scientists and Engineers. The main priority areas to receive attention according to Agenda 21 include :- i) Atmosphere (air pollution) ii) Oceans (eg. oil spills, acidification, algae, oxygen) iii)

Fresh water (eg. river flow management, irrigation) iv) Agriculture (soil management, reduced till, erosion) v) Wind based erosion (desertification and dust) vi) Deforestation, biodiversity and habitat loss vii) Mining (eg. health of remote communities) viii) Construction (eg. acid sulfate soils).

29. Benchmarking - with the start of the environmental movement in the 1960s, and it can be argued the story of the pesticide DDT (Carson, 1962), increasing attention has been paid by scientists and engineers to identifying, recording and cataloguing environmental impacts. Now, mainly with satellites, environmental benchmarking is producing a large database of environmental data against which we can quantify environmental impacts.

31. EIA process - the EIA process in building and manufacturing contexts, commonly consists of six stages :- scoping, preliminary investigation, implementation, monitoring, evaluation and review (SPIMER). EIA reports relevant to specific developments generally contain sections on :- a) pollution of air, soil and water, b) carbon/water footprints, c) biodiversity/habitat loss, d) ancestral/cultural impacts, and e) aesthetic considerations.

32. Ecological footprint – this term was first used in the 1990s to describe the consumption rate of the world's ecological resources. It was estimated in 2006 that humanity's total ecological footprint was 1.4 'planet-earths' – ie. humanity uses ecological services 1.4 times as fast as Earth can renew them.

33. Global biocapacity - this is measured in global hectares is now also in common usage (Rees, 2006). In 2005 there were 13 billion hectares of biologically productive land and water available, and 6.5 billion people on the planet ie. an average of 2 global hectares per person. China uses about 2gha/person, the UK about 5 gha/person and the USA about 9 gha/person, but in most developing countries, it is far less than 1 gha/person.

34. Earth carrying capacity – this is another accepted way of describing a similar concept. The earth could sustain a population of only 1.6 billion if they were all American, 2.6 billion if European and about 7 billion if they all were Chinese, and 14 to 18 billion if they were from the poorest developing countries. In 1987, the year of the Bruntland report, the world population reached 5 billion, what many regard as the earth's carrying capacity. Current growth rate is now 1.3 percent annually, but this is enough to add approximately 1 billion people to the earth every 13 years. In 2010 we are now at 6.8 billion people, and consuming resources at the rate of about 1.5 'planet earth's'. The magnitude of future human population growth is debated a great deal and is certainly very difficult to predict accurately. It has been forecast by some population scientists that that projected limits on available soil and water to grow food must cause human population to level off at around 11-12 billion by 2150 [Bongarts 1995, Richter et al 2007).

35. Life Cycle Assessment and Waste Management **-** appropriate standards for the correct calculation of carbon footprint should be followed. LCA should follow from 'cradle-to-grave' and 'cradle-to-cradle' theories and practices regarding waste management. Use the example of the problem of ever growing car tyre mountains here. If this industry was to switch to providing a service, rather than a commodity, the incentive would be there to manufacture much longer lasting tyres. This concept could be applied equally across many areas of the present capitalist driven consumerism which dominates our lives today.

36. Environmental Engineering – Australian Standards – all engineers are duty bound by their professional institutions to 'life-long-learning' and 'keeping-up-to-date'. To do this they should regularly consult standards databases. In the environmental area, examples are AS/NZS ISO (2011) and HB203 (2006). Engineers should also regularly access leading 'knowledge sites' relating to their area, in this case examples include ALTC (2011) and AGIC (2011).

Discussion

We are now in the 21st century and the 'knowledge age', and have ready access to incredible satellite derived earth observations (eg. ocean chlorophyll animation kindly provided by NASA, 2010). However, rapid and positive action towards mitigating climate change is rather like going to the dentist – most people know they need to go, but they don't actually get around to it unless they feel direct personal pain. Most people also do not fit security devices to their homes or vehicles until after they are actually burgled. It is natural human behaviour to want to conserve the outlay of money on such items until the last possible moment. The threat of climate change on the environmental sustainability of the earth is no different to this. The negative effects on earth maybe observable and measurable by scientists, but direct effect on personal lives is rather hard to detect. The psychology of climate change denial has been written about by a number of authors, summarised in Newall amd Pitman (2010).

Democratic and political situations around the world reflect the selfishness of human nature – the majority of people vote for a politician which promises to benefit them directly, rather than the population as a whole. The public and politicians tend to ignore the bigger picture. Even in relatively prosperous times, economists are not satisfied unless they can maintain a three percent growth rate with low inflation, and yet billions can be immediately found to come to the aid of global financial crises. Improvement to the environment is always put off as a future problem to be solved, once we are 'out of the present economic situation'.

Many people still do not see the climate/environmental threat as real. The reason for this is that the effects are insidious rather than direct. With major diseases largely under control, the human population is thriving and continues to increase at a staggering rate of approximately one billion people every twelve years. One degree of warming has had little or no negative effect on the day to day lives of most people. In many parts of the world there is a 'bring-it-on' attitude. For example, there is every reason that warmer conditions in Alaska will assist in exploration help alleviate the USA's oil shortage. This attitude leads on to a significant degree of climate change scepticism also persisting amongst both student and professional engineers.

Engineers who are seen by their employers as having a production focus rather than an environmental focus, also tend to do better in their careers, unfortunately. If we are going to change this situation and attempt to engineer fossil fuel elimination by a certain date in the future, we need to train the current generation of young emerging engineers more thoroughly in the environmental sustainability area. We need engineers that are firmly committed to this important cause and belief.

Conclusion

It is now more than 40 years since World Earth Day marking public recognition of the environmental movement and nearly 20 years since the Rio Earth summit at which governments around the world promised to start doing something about sustainability. But the evidence from Copenhagen and Cancun is that next to nothing has yet been achieved. Governments seem to be stuck in policy paralysis and quite complacent to the fact that annual fossil fuel consumption is set to rise from 10 billion to 14 billion tonnes oil equivalent by 2030. Scientists have now completed their job in telling governments what they need to do and why they need to do it. It is now the role of engineers to inform governments how, when and where to take the necessary action. In the ‘what-why-how-when-where’ chain we seem to be stuck at the ‘how’ stage which is where engineers need to come to the fore.

Before 2000, understanding of the concept of sustainability, climate change and recognition of environmental engineering as a subject and profession in its own right was generally very poor. Quoting Bremer and Gonzalez (2010), ‘for a large number of people, sustainability is a fuzzy word that has something to do with environmental care, but has little meaning in real life’. The subject has also been described as ‘rather vague and of the interest of scientists rather than engineers’. Sustainability has often been described as ‘more suited to female rather than male’ engineering students, and sustainability courses have in some cases been designed with the interests of female and ethnic minority students specifically in mind (Oehlberg et al, 2010).

Amongst both higher education students and staff, there appears to exist a reasonably wide spectrum of opinion of what should be included in engineering courses on the topic of environmental sustainability. The spectrum of opinion amongst staff on climate change appears to range from ‘complete denial’ to ‘we’re all gonna die’. It is amongst this apparent chaos of opinion that clear guidelines are necessary regarding education of this now most important area.

Regarding climate change and the degree to which it is anthropogenic, the only thing we know for sure is that we don’t know, and that in situations where we don’t know, it is wise to use the precautionary principle and at least start doing something to mitigate risk. From a pollution reduction point of view, it is good that much research is now being conducted into energy efficient vehicles such as biofuel and hydrogen fuel cell powered vehicles. But once the Net Energy Value of these technologies is properly calculated (energy value of fuel divided by energy required to produce the fuel), it is unlikely that these technologies alone will have much impact upon reducing climate damage (Powers et al 2011).

Responsible for more than two thirds of the climate problem, coal burning for stationary electrical power is really the central issue, and needs to be tackled ahead of transport, agricultural or industrial technologies. The University of Melbourne Energy Research Institute have stated that conversion to solar power is possible in Australia within a 10 year timeframe, at a cost of $37 billion each year. (Wright and Heaps, 2010). At about 3% of Australian GDP, this is roughly what Australians spend each year on Christmas. Public share ownership schemes would certainly provide adequate finance of these 'solar cooperatives'. Over longer periods, one percent of world GDP (ie. one third of current military expenditure) would provide very effectively for solar thermal and offshore wind programs. This would be an economic burden initially - but has to be weighed against the cost of not making this investment.

In general, science students generally appear more committed to environmental causes than some engineers. But in their subsequent careers they are less likely to do anything to actually solve practical environmental problems. Both scientists and engineers tend to be focussed on definition, measurement and modelling of the problem, rather than doing anything to actually fix it. The challenge of providing real, practical and economic solutions to problems is however more likely to be left to engineers. This is why if we are going to achieve the goal for 2050 described in this paper, it is of paramount importance to provide sustainability and environmental training directly to engineers as well as scientists. Delivery of effective and uniform environmental sustainability education (Mihelcic et al 2003) to young qualifying engineers is therefore now of supreme importance. Environmental engineering should also be seen as equal in importance to the other engineering disciplines.

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