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Climate Change, Contemporary Society and Engineering Practice: A Sustainability Journey

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Abstract: Climate change, Contemporary Society and engineers share an indivisible pathway towards sustainability through the means of technology. Climate change and sustainability are now new domains that require a better understanding by engineers. Ten years ago sustainability was a development for the future however the absence of climate certainty in contemporary society has raised sustainability awareness to the forefront of societal debate. While sustainability in theory is defined as the capacity to maintain a certain process or state indefinitely. However the literal meaning of "indefinitely" in sustainability definition poses a set of intriguing questions, is indefinite human survival a plausible proposition in a finite world. For this reason efforts in the fight against climate change are becoming a global effort, since it requires global cooperation and greater scientific consensus to reduce carbon emissions and consequently the planet's energy footprint. We recognize that Sustainability ought to be economically viable, ecologically sound and sensitive; socially responsible and culturally appropriate. Surrounded by this realm of thinking all these mentioned definitions are equal measures that fail to address the importance of "technology" as a subject in the climate change and sustainability debate. Since this generation had inherited the historical legacy of nonrenewable energy technologies. The term "technology" in this context implies any technical system that can result in and/or be well described in terms of a process by which humans modify nature to meet their needs and wants. This paper seeks to investigate the underlying philosophical frames and the nature of the issues of sustainability present to engineers. It explores the notion of "Sustainability" and "technology "in engineering practice. Further, we argue that in order to establish a clear, measurable, actionable, and universally accessible working definition of sustainable engineering practices. climate change and technology life cycle need to be inclusive to sustainability.

Keywords: Climate Change, Applied Sciences, Technology, Energy Efficiency

GLOBAL WARMING AND climate change are of greater concern today as it is more widely realised that the planet Earth does not provide an infinite capacity for absorbing human industrialization in the 21st century. However industrial and economic growth are needed whether a sceptic or, advocate of climate change. On the other hand whether a sceptic or, advocate of climate change, industrial and economic growth are both needed today. Not so much for ourselves here in the Western world. that the rapidly growing other half of the world population is entitled to their share of wealth and happiness (Venselaar 2003). The recent World Bank,*World Development Report 2010:* Development and Climate Change outlines significant damage to developing countries from climate change, with up to 80 per cent of all costs associated with global warming borne by poorer countries. Similarly at the close of the 40th Pacific Islands Forum in Cairns. The Australian prime minister Mr. Kevin Rudd said dealing with climate change is more than just a matter of urgency for many Pacific island nations, it is an issue of national survival. It was (Montgomery

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2007) that described in his book Dirt: The Erosion of Civilizations, how soil erosion led fall of civilisations from Mesopotamia to Rome, hence from poor irrigation common engineering tasks lead to the fall of ancient civilisations? The significance of engineering technologies role in the climate change debate is colossal, sustainability cannot be addressed separately to engineering efficiency. Who would suspect that a chemical compound as common and seemingly innocuous as carbon dioxide would generate such gales of contention? this example of engineering technology is Carbon Dioxide CO_2 being one of the main contributors in the human induced global warming, that is accelerated by the burning of fossil fuels and deforestation, i.e. the more we burn the more greenhouse gases are produced. Hence as a system natural variation for the planet is incapable to recover from its own loses. The above mentioned challenges define the concept of sustainability. Which is generally acknowledged as the results of a balance among the three aspects of sustainable development: economic, environmental, and societal (Martins et al. 2007). This paper is divided into two sections. The first gives a brief overview of the contextual background sustainability discussion in engineering, the second discuses the linkages between technology, engineering and climate change.

1.0 Engineering and Technology

In the words of Goldman (1991), engineering, as an element of technology as a social process, is actually changing the world. Technology is the process by which humans modify nature to meet their needs and wants (NAE 2007). Engineering has been central to the great economic growth that has characterised the rise of industrial capitalism and as we move into a knowledge-based economy it remains a fundamental element (Institution of Engineers Australia 1997). Engineers are applications people, typically engineers apply science to create solutions. Engineers, are creators of technology (Christ 2002), through the application of scientific principles design and construction essentially defines engineering. Similarly “technology” is has strong links to economics and growth models. The importance of the engineering sciences and technology in driving sustainable economic and social development and addressing basic needs and the reduction of poverty was emphasised at the World Conference on Science in 1999, the World Engineers’ Convention in 2000, the Johannesburg World Summit on Sustainable Development in 2002, WEC 2004 titled Engineers Shape the Sustainable Future and relate particularly to the UN Millennium Development Goals. Finally Technologies ‘evolve’ to solve the problems as perceived by various relevant social groups hence contemporary society, Science and technology are inseparable. This validate by the Social Construction of Technology (SCOT) Studies, (Berger and Luckmann 1967; MacKenzie and Wajcman 1985; Beniger 1986; Bijker et al. 1987; MacKenzie and Wajcman 1999; Klein and Kleinman 2002; Webster 2002; Dafoe 2005).

2.0 Society and Technology

Society is becoming even more dependent on engineering and technology (Chisholm 2003). Technology is essential to the human condition. Our human species is now totally dependent upon it. Without technology, we would not be able to sustain the present human population on this planet. Moreover, without technology, the human population could never even have grown to anything near its current level. Therefore Technology is intertwined with society’s progress, similarly the critique of technology root of sustainability originated in 1960’s and

1970's (Bell and Morse 1999) this theory was advanced by (Schumacher 1973) however Kidd (1992) suggested the roots of sustainability in a broad sense has originated from six separate strains but we do not intend to describe each of these, except for technology. The reason is that information technology lies at the root of productivity and economic growth (Sterne 2000). Economic developments in the first decade of the 21st century emphasize the essence of information technology and digital society in the expansion of knowledge (Lowenstein 2004; Lowenstein 2005; Hasna 2009). However a digital society implies dependence on networked ICT's, with more people using the internet, cell phones, digital video, digital music, and PC's etc.. Therefore a digital society implies reliance on electricity in supporting 21st century socioeconomic development (Baer et al. 2002). But electricity as by tradition poses reliance on finite natural resources. Engineers have long benefited from a seemingly limitless supply of natural resources from which to draw, including sources and sinks for society's wastes(Ouda,2008).

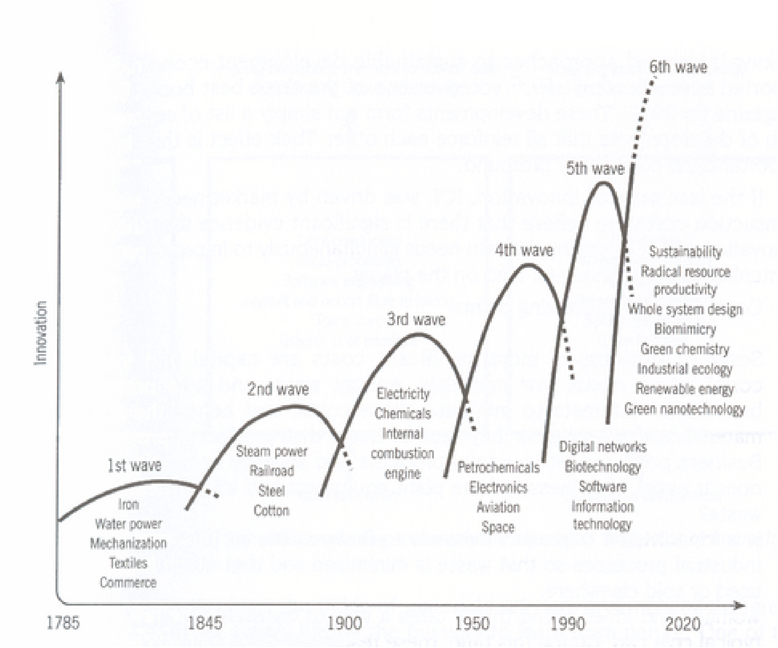

Figure 1: Waves of Innovation (Hargroves and Smith 2005)

3.0 Engineers and Technology

What is exactly an engineer? from the Renaissance on, engineers have often insisted on the necessity to ground their practice on science (Picon,2004). Engineering formalized knowledge relates to engineering practice and science. this science is formalized by relations of mathematics, mechanics, physics and chemistry. Technology is essential to the human condition. Our human species is now totally dependent upon it. Without technology, we would not be able to sustain the present human population on this planet (Merkel 2000). With impending and burgeoning societal issues affecting both developed and emerging nations such as India and China, the global engineering community has a responsibility and an opportunity to truly make a difference and contribute (Mishra, 2009).

The fundamental role of engineers and technology in the economic and politic arena has direct relationship with the perception of our natural resources, for instance the world largest economy the United States, has deliberated on the issues through the white house as follows, Science helps us to understand the origins, characteristics and consequences of global problems. Finding solutions to these problems, and elucidating the complex chains of cause and effect through which they may be linked, requires a coordinated effort by natural and social scientists, engineers, and policy-makers. During the so-called modern era of the last 400 years, Western civilisation has flourished in virtually all areas. The Renaissance ushered in an era of philosophical, institutional, social, technological, and economic development unparalleled in human history (Hector, 2008). Today science remains to play an increasing role in the expansion of contemporary Society. Engineers must remain true to the fundamental principles of objectivity and impartiality. Since transforming scientific breakthroughs into new technologies can have a profound impact on the ecosystem, but wise stewardship of these technologies is essential to the well-being of the greater humanity. The economic development experienced by the developed nations in the past 50 years raises interesting questions whether the so called “western system” is sustainable in the long-term, particularly as industrialisation extends to the emerging economies or the other rest of the world population. One challenge for engineers in sustainability is to use technology in a harmony to advance productivity with long-term viability. For example, technology helped bring about the Green Revolution, which resulted in increased agricultural productivity worldwide (White House 1995). But at the same time, poorly designed irrigation systems led to soil degradation in some areas. In the decades ahead, technology will be called upon to feed a growing world population, with minimum impact on the integrity of soil, water, forests, and other resources (Wasserman-Goodman 1996).Sustainability assessment tools are one of the ways available to engineers to relate to the needs and aspirations of the broader community in providing a sustainable future for humanity.

3.2 Critique of Sustainability Measurement Tools

What direction should the engineering profession be driving towards? A number of methods were presented in literature, primarily through Educating engineers on over consumption, this was suggested by Swearengena and Woodhouseb, (2003), furthermore A central issue for engineers in the context of sustainable practices in engineering would be the plethora of definitions and measurement tools of the concept of sustainability. A review of current practices had been conducted by (Hasna, 2009). A number of notable works had critiqued the limitations of these tools. Sustainability assessments should be objectives-led, rather than merely being a baseline assessment.

Hurley et al.,(2008) Articulated limitations of tools use to include the following

1. Lack of available data on the day prevented proper consideration of options; even using assumed data, the process is too time consuming to fit into ordinary work schedules.
2. Public engagement (for evaluation of social criteria) is difficult without incentives, funding and training.

3. Criteria weighting is subjective and depends on the spatial and temporal scale of the problem.
4. Criteria definitions are seen by some to be vague and overlapping.
5. Criteria evaluations focus on negative rather than positive aspects of different water management options.
6. Some criteria are actually vetoes, with boundaries having been previously set at policy level.
7. Decisions are made based on what users think should denote importance, not what they think actually does.
8. The overtly quantitative

Jha and Murthy (2006) found serious problems in respect to ESI methodology. These involve (i) intercorrelation amongst variables – cause and effect; (ii) use of equal weights – ignoring PCA (for a brief overview of PCA see Chapter 4); (iii) ignoring outliers – truncation; (iv) correlation with other variables; (v) ambiguity of the index (changing the sign); and (vi) relevance index (implicit weights). We now briefly discuss these problems.

According to (Pediaditi et al., 2006) most tools that do exist focus on building performance and environmental issues either during construction or in the future land use and thus fail to consider the site holistically across its lifecycle and to evaluate the wider implications and socio-economic effects of a development. In addition there are no tools capable of assessing the sustainability of a redevelopment project throughout its life-cycle (meaning from its conception and design to construction and its operation) (Pediaditi et al., 2005).

Smythe and Isber (2003) found need for additional guidance and training in the analysis of cumulative and indirect effects and for more specific guidance on the appropriate level of analysis reviewed the implementation of The National Environmental Policy Act (NEPA) in the USA which required federal agencies to integrate environmental values into their decision making processes by considering the environmental impacts of their proposed actions and reasonable alternatives to those actions.

4.0 Challenges for Engineers: Adapting to the Inevitable?

With so many voices weighing in on climate change debate, the emerging questions centre on what climate change really means to engineers? (Mastromatteo 2009) Engineering is a key discipline for the resolution of many of the problems of sustainability and it is argued here that to identify some principles of 21st-century sustainable engineering practice is of great importance(Hector, 2008). Engineers as the problem solvers provide for scarcity of resorces needed for human survival, i.e energy assurance, acute water challenges, food production, housing, sanitation and waste management, energy efficiencies, decarbonization, engineers are being invited to strut their hour on the global warming stage. Engineers have much to contribute, all decisions making, solutions and innovation needs to include engineers needs to include an engineering perspective, given that engineers are the makers of technology and technology is directly related to climate change.

Let us examine the engineers role and professional existence in society, we live in a world captured; uprooted and transformed by the titanic economic and techno-scientific process (Hobsbawm 1994). According to picon (2004) Engineering has a relatively specific type of ambition, an ambition extending far beyond the simple desire to gain or maintain one’s social status and power. This ambition might account for the recurring links between engineering conceptions and utopia from the Renaissance to the present. Strangely enough, the figure of the engineer has been often associated with utopian dreams, from the fantastic machines of 16th- and 17th-century utopian narratives to the technocratic streak of many 20th-century fictions. From the 19th century on, engineers have been furthermore associated to many utopian movements. Emerging economies the like of china, India and Brazil are redefining the climate change argument. Hence with this in mind OECD Engineers are well poised to deal with the challenges of climate change and emission trading schemes. Similarly Engineers in developing nations need to be conscious as not make or repeat of the same mistakes born by outbursts of industrialization to their OECD counterpart. In a global historical context, (Cohen 1995) suggested four periods of evolution in human population growth, the first related to development of local agriculture (8000 BC), the second related to global agriculture (AD 1750), the third related to public health (1950) and the fourth related to fertility (1970). But it is information technology that defines this special period. But according to (Crump 2001; DeGregori 2003; King 2005; Restivo 2005; Kehl 2008) whether the focus is technology, the economy, or society at large, it is widely accepted that technology will have profound effects on natural resources. According to (Hargroves and Smith 2005) technology develops as a response to a perceived problem, need, or desire, the waves shown in Figure 1 illustrate the progression of technology along with the time, simultaneously with the maturing civil society. Development is often described in terms of the successive advances in technology. For example, the steam age, the industrial age, and the information technology age all refer to different historical periods. We now live in a world that is highly reliant upon technology for food, employment and economic prosperity. Very often several solutions are available to address a given situation. Being able to select the most appropriate technology initially can reduce the potentially disastrous social, economic and environmental impacts that an inappropriate choice may have in the longer term.

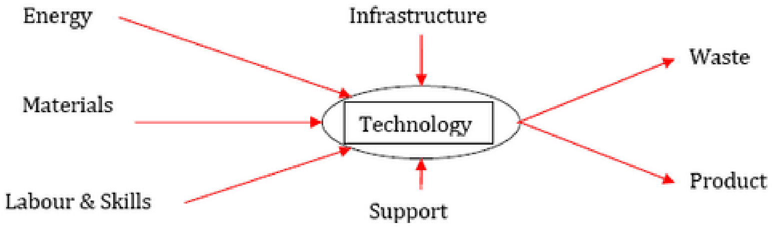

Figure 2: Components of a Technological System Source (Hay and Noonan 2002)

The major sources of environmental pressures normally associated with the different components of a technology are listed in Figure 2 not limited to material, energy, transport, CO2 emissions and solid emissions The main pathways by which a technology interacts with its surroundings can normally be divided into the following categories; the material, labour and energy resources used by the technology, the wastes and hazardous products released into the environment, and the impacts of the supporting infrastructure and services. Whilst the environmental consequences of a technology will vary with both the characteristics of the pressures, all the components listed in Figure 2 relate directly to climate change, and sustainability. Hence, technology operating in different locations may have very different environmental impacts relates directly to sustainability. Technologies that improve energy efficiency and green energy from renewable sources in all its different forms are a reality, solar power, wind power, wave power, geothermal power and tidal power. The cost of carbon capture and storage must be accounted for in engineering to remain true to sustainability ideals.

Therefore it is astounding why technology would not remain a major criterion in sustainability assessments. Fuchs and Lorek (2000) identified technology as an important determinant of Sustainability. In addition (Van der Wal and Noorman 1998) found that technology influences energy consumption, (Dürrenberger and Nikola 1999) found that technology is an important source of reduction potentials for energy consumption. Ferguson et al. (1997) examined the relations between total energy consumption and wealth creation and between electricity generation and wealth creation and recommended that the benefits of electricity generation are at last of the same order of magnitude as economic development itself. The relationship between energy consumption and the gross national product (GNP) of countries has become such a commonly understood concept that figures in US dollars per tonne of oil equivalent (toe) are quoted as world development indicators by the United Nations (UN) 1994. Pacey (1983) tackled the idea that technological design seems to be divorced from the context of the use of products. He gives examples of big dams feeding leaking pipes and electricity generating stations pumping heat into the atmosphere when electricity is mainly used for heating, as examples of halfway technology. Today most major car companies are taking steps to lighten their vehicles while improving their quality, to improve the efficiency of existing types of engine while reducing their unwanted exhaust emissions. This is perhaps what (Alexander 1964) would describe as forms that badly fit their context; Fitness is the relation of mutual acceptability between domains. In a problem of design we want to satisfy mutual demands which the two make on one another. We want to put the context and the form into effortless contact or frictionless coexistence. The importance of technology is recognised in the literature. At a macro level, technology has been described as the major engine of economic growth (Dunning 1988). At micro level, technology has given firms the power to circumvent scarce factors via new products and processes (Porter 1990). According to (Freeman 1974) sociologists like Marcuse and novelist such as Simone de Beauvoir see technology as a means of human enslavement and destruction while Adam Smith and Karl Marx see it primarily as a liberating force. This is exceptionally attractive especially because it was written in the early part of the industrial revolution. The interaction of the technology with the environment as described by (Balkema et al. 2002) where the demands of the end user is translated into functional criteria that must be fulfilled by the technology. In accordance with (Hasna 2008) we acknowledge the importance of financial criterion observed under Triple bottom line (TBL) to assess for climate change and sustainability assessments (Rapport 1997; Wall 1997; Safley 1998; Saida et al. 2006); however on the other hand literature is limited with clarity on the relationship between climate change, sustainability and technology. Hasna (2009) refers to technology as sphere of influence to climate change. All too often, climate change is seen as an adverse effect of technology or technology failure that occurred as a consequence of events that have not been identified and planned for in advance. As we move away from the age of industrialization to the age of knowledged. We beg to question whether climate change was avoidable, i.e. If had the risks of technology were been highlighted at the start of the age of industrialization would current end result have varied of climate change exist today? Hence, sustainability in the age of knowledge is a process which tells of a development of all aspects of human life affecting sustenance. It means resolving the conflict between the various competing goals, and involves the simultaneous pursuit of economic prosperity, environmental quality and social equity famously known as three dimensions (triple bottom line) with is the resultant vector being technology, hence it is a continually evolving process; the ‘journey’ (the process of achieving sustainability) is of course vitally important, but only as a means of getting to the destination (the desired future state). However,the ‘destination’ of sustainability is not a fixed place in the normal sense that we understand destination. Instead, it is a set of wishful characteristics of a future system.

4.1 Managing CO_2 Emissions — Today Not Tomorrow

According to Molina et al 2009 (1995 Nobel laureate in chemistry) rapid cuts to greenhouse gases other than CO_2 would slow down dangerous climate change and buy us time to bring down CO_2 emissions.

World Development Report 2010, development and Climate Change, says that advanced countries, which produced most of the greenhouse gas emissions of the past, must act to shape our climate future. As engineers conversing on sustainability, it is important to keep it aligned with the physical laws that govern our universe; to facilitate a comprehensive discussion a note worthy to mention the two dominating philosophies revolving around what “sustainability” really means? Cornucopian theory states that there are few intractable natural limits to growth and believes the world can provide practically limitless abundance of natural resources. Opposing to that is the Malthusian school of thought predicts population would outrun food supply and resources, In another context second law of thermodynamics governs the conversion of energy from one form to another, $dU = dW + dQ = dW + TdS$

Where dU, the change in the internal energy of a system is equal to the sum of the reversible work done on it dW and the heat irreversibly exchanged with the environment $dQ = TdS$ (which is associated with a change in the entropy of the system). Hence from the Second Law of increasing entropy or unidirectional flow of thermal energy, no machine that is 100% efficient. Consequently if we consider entropy in terms of thermodynamic efficiency, which is the ratio of the amount of work done by a system compared to the amount of heat generated by, doing that work, $dS \geq 0$, on that basis the thesis puts forward a premise of balance and moderation. This work has attempted to address how sustainability philosophy, or culture in engineering might drive development towards net positive outcomes, rather than the current focus on minimizing negative impacts on the environment and society”.

5.0 Conclusion

How can you drive forward the concept of sustainable development? Social responsibility, transparency needs to replace profit driven values. In order properly to address sustainability in engineering, engineers must work inside their institutional boundaries but outside the boundaries of their professional knowledge, to cause integration between different professional domains. Danger of present repeating the past mistakes. We need agreed language and principles to engage in transparent dialogue. Engineers are not separated from society and engineers have a greater moral obligation to stop climate change. Engineers are capable of producing radically different process changes in the context of severe limits on the consumption of primary physical resources. However, all engineered solution will always be limited by the same physical principals that govern our universe therefore limitations will exist within sustainable development. The facts are that most people driving the motion lack scientific training to gain an understanding of the essence of the problem. We need an engineering perspective. Hence, it is surprising that most of the climate change discussions are dominated by non engineers and scientist. For instance I recently attended a conference on with a specific theme on environment, where I was the only engineer voicing an engineering perspective to sustainability, furthermore most of the policies that were tabled had little scientific or engineering point of view. Most of the papers presented were hypothetical that lacked any sense of realism, i.e. one presentation suggested genetically modifying carnivores to stop them eating herbivores, tigers verses gazelles. The title and the content of some environmental conferences were incongruous with reality. In fact In all intents and purposes the facts remain those kinds of conferences and gathering do contribute to climate change "environmental footprint" i.e. transportation, disposable plastic cups and paper printing usage, yielding little benefit to society. So how can engineers and consequently engineering practices play any significant positive role in climate change and sustainability? The engineering profession can make significant contribution towards the global aspiration of sustainability by recognising that the future cannot be a continuation of the past in response to climate change. Since the development of technology provides innovation and economic success, as a concluding remark a question is posed what are the risks in focusing too strongly on climate change innovation for its own ends and in not adequately applying technology efficiency to meet the needs of an expanding population which is expecting a higher quality of life. Hence we argue that society is driven by growth, growth is determined by successive technology. Thus technological change compliments societal change and hence a subset of climate change and in due course sustainability. Therefore we propose the inclusion of an engineer's perspective on sustainable engineering perspective in any future sustainability feasibility assessment discussions for austerity.

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A.M. Hasna was awarded a PhD in Manufacturing Engineering from Swinburne University of Technology in 2002, Graduate Certificate in Higher Education Deakin University, Graduate Certificate in Management, Swinburne University of Technology, and Bachelor of Engineering Chemical RMIT University. He has experience in process engineering, held senior positions in the chemical and process industry, mainly waste water treatment, water flocculation systems in the mining industry, plantation timber molding, fuel cell power generation for air independent propulsion, and sacrificial corrosion protection for the green river project, paperboard manufacturing, and developed a microwave corrugator with Visy Industries. Previously a senior lecturer Department of Sustainability, Central Queensland University.

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