DO THE BIG SUSTAINABILITY CHALLENGES LIE IN THE ECONOMIC AND SOCIAL DOMAINS AND DOES ENGINEERING EDUCATION NEED TO ENGAGE MORE WITH THESE?

John J. Fitzpatrick
Process & Chemical Engineering, School of Engineering, University College Cork, Ireland
j.fitzpatrick@ucc.ie

Abstract: Engineering education is mainly a technical education. However, in the context of the sustainability of the human species, it could be argued that graduate engineers entering the workplace and applying their technical education may be only accelerating humanity towards unsustainability and societal collapse. The rationale being that engineering graduates mainly enter industry and the private sector which is dominated by the neo-classical economic paradigm and short term pursuit of economic growth and profit to the detriment of the sustainability of natural systems that are underpinning the survival and flourishing of humanity. The author has been teaching engineering students for nearly 19 years in technical subjects and later on in sustainability and environmental protection. Over the last few years, he has had the niggling feeling that he, and other engineering educators, are complicit in the formation of engineers that may only accelerate humanity towards unsustainability. They mean well and truly believe that they are doing good for society. There may be good in the short term, but it is unsustainable and ultimately bad for society in the longer term.

This paper briefly explores the impact of engineering on environmental sustainability in the current dominant neo-classical economic paradigm. It questions if engineering educators are producing engineers that are accelerating humanity along an unsustainable path. Even though technology and engineering are important drivers in trying to move humanity towards an environmentally sustainable paradigm, the paper constantly tries to suggest that maybe the most important levers and challenges lie in the economic and social domains. Short case-studies of energy efficiency, the experience of the industrialist Ray Anderson and the authors own reflection of teaching chemical engineering students are used to highlight this. Engineering / technological innovation is not enough and is often used and counteracted by the rebound effect and the current dominant neo-classical economic paradigm. The paper discusses what engineering educators can do to produce sustainability informed engineers who are able to engage with the economic and social dimensions of sustainability. Some suggestions for engaging engineering students with the economic and social dimensions of environmental sustainability are provided. Engineers must somehow find ways, not just to influence technological levers (which are very important) but also to influence economic and social levers so that changes in economic and social behaviours can complement and facilitate technological change in moving humanity to an environmentally sustainable paradigm.

1 INTRODUCTION

Ehrenfeld (2013) describes sustainability as "the possibility that humans and other life will flourish on the Earth forever". At one level, sustainability may be considered as an easy concept to grasp but at another level it can be considered as being extremely complex. For example, the renowned Brundtland definition (WCED, 1987) "meeting the needs of the present generation without compromising the ability of future generations to meet their own needs" is relatively easy to grasp. It is all about meeting the needs of people and being able to continuously do this over time. It starts to become more complicated, and indeed highly normative, when you try to explore what the statement means in more detail. There are many factors that influence sustainability, which makes the whole area very complex. There are a number of conceptual models relating to sustainability and most of these incorporate the inter-relationship between the three domains of environmental, economic and social (Byrne & Fitzpatrick, 2009). It could be argued that environmental sustainability is the foundation to sustainability in the sense that humanity needs the environment to provide the natural resources and to deal with its wastes continuously over time for humanity to sustain itself and prosper. Many realise that humanity currently is on an environmentally unsustainable path, with natural resources being gradually used up and harmful emissions building up in the natural environmental, such that nature is becoming less and less able to support large numbers of people (McKibben, 2011; Meadows et al., 2005; Randers, 2012).

Engineering, by its nature, is a technical discipline and has the potential to provide technological solutions to try and move humanity back towards an environmentally sustainable paradigm. However, it could be argued that technology is not enough and in the current dominant neo-classical socio-economic paradigm technology is only moving humanity faster along an unsustainable path. Sure, technology has an important role to play in moving towards a sustainable future, however the major challenges to moving to a sustainable future may lie in the economic and social domains (Barry, 2012; Gilding, 2011; Jackson, 2009; Heinberg, 2011; McKibben, 2007) and that engineers need to engage with and influence these domains (Byrne & Fitzpatrick, 2009). This paper explores this theme and the need for engineering educators to engage with this and produce sustainability informed engineers and hopefully this education may influence their career decisions in trying to move humanity towards a sustainable path.

2 EFFECT OF ENGINEERING ON ENVIRONMENTAL UNSUSTAINABILITY WITHIN THE CURRENT NEO-CLASSICAL ECONOMIC PARADIGM

Within the current dominant neo-classical economic paradigm, engineering and technology are only accelerating humanity further along an unsustainable path; just look at the numbers for CO_{2eq} concentrations in the earth's atmosphere, they continue to increase. Within this paradigm of the relentless desire for economic growth and consumption, engineering and technology are accelerating unsustainable throughputs of materials and consumption of energy (Meadows et al., 2005). The late Ray Anderson, founder of Interface Inc. was a pioneer in applying sustainability concepts in his business; he was an industrial engineer and very successful business man and strongly believed in the market and making a profit. In his book (Anderson, 2009), he realised that our current market, which he referred to as "Market 1.0", is on an unsustainable path. Market 1.0 was spawned out of the industrial revolution and made sense in the past and brought prosperity when the global economy was small in comparison to nature. However now and in the future, it really doesn't make sense in the longer run, because of the constraints of nature that will eventually lead to the collapse of Market 1.0 [due to limits to natural resources and pollution sinks]. Consequently, he believed that there is a need for "Market 2.0", not a totally new system, just a modified version of Market 1.0, which recognises the inherent problems in Market 1.0, in particular with the natural environment.

Engineers spend much effort in improving resource efficiencies, which is important in a sustainable paradigm in terms of trying to maximise functionality per unit of natural resource. However in the neo-classical economic paradigm, economic growth and the 'rebound effect' have been much stronger than improvements in natural resource productivity, and as a result energy consumption, greenhouse gas emissions, water and minerals extraction and land conversion has grown despite laudable efforts to

improve natural resource productivity (von Weizsäcker et al, 2009). Consequently, human existence is becoming more environmentally unsustainable rather than less.

The teaching of improvements in energy efficiency and how to consume less energy to produce a good or service is commonly an important component of most engineering education programmes. This is considered as good for the environment, as improving energy efficiency should reduce energy demand which will reduce CO_2 emissions and environmental impact. Figure 1 illustrates how energy efficiency and energy consumption have evolved in the USA over time from 1970 to 2007. Energy efficiency has been improving over time with a continuous reduction in the amount of energy consumed per unit of GDP. This appears like something good and something engineering educators should be teaching their engineering students and should result in a reduction in energy consumption and environmental impact globally. However, the rebound effect coupled with economic growth produced increased consumption in the neo-classical economic system, which counteracted energy efficiency gains and caused the opposite effect, whereby energy consumption in the USA actually increased rather than decreased along with the resultant environmental impact. This is an economic / social effect which is using the technological improvement and counteracting it, and making humanity more unsustainable rather than less. Consequently, there are important levers in the economic and social domains that must be leveraged if humanity is to reduce energy consumption and the environmental unsustainability associated with it. Engineers need to engage with this and try to influence these domains or else their technological solutions may be counteracted and actually move humanity faster along an unsustainable path. Considering the trends in Figure 1, one could be factitious and argue that it might be better to teach engineering students how to use energy more in-efficiently so that this would result in less energy consumption and environmental impact.

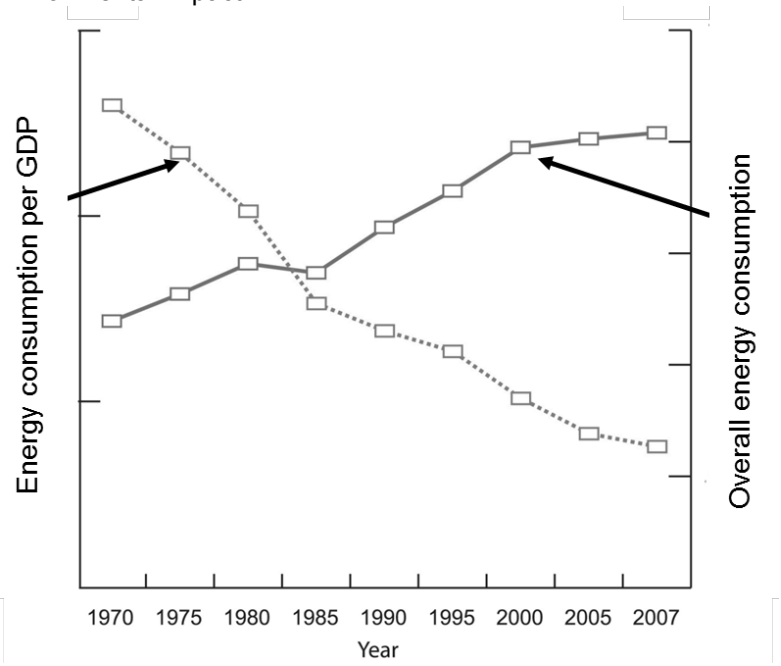

Figure 1: Evolution of energy efficiency and energy consumption in the USA (adapted from von Weizsäcker et al., 2009)

Considering the above, it may appear that teaching energy efficiency in the context of non-fossil fuel energy, such as in a renewable energy paradigm is of key importance. The logic being that increasing energy efficiency will reduce the land and infrastructure requirement required to deliver a given amount of energy, which are critical barriers in the delivery of renewable energy. However, economic growth will counteract this also because the technological improvement will lead to higher GDP which will require even more renewable energy which will require more land and infrastructure.

3 ARE ENGINEERING EDUCATORS PRODUCING "EDUCATED BARBARIANS"?

Maybe engineering educators are producing "educated barbarians", that is, engineering students who graduate, become engineers and enter the work place dominated by the current neo-classical economic paradigm and end up using their education / skills to accelerate humanity faster down an unsustainable path rather than moving towards a sustainable path. Engineering educators are effectively facilitating this, even though they truly believe that they are doing good for society. There may be good in the short term, but it is unsustainable and potentially bad for humanity in the long term.

Ray Anderson (Anderson, 2009) states that "our top universities have been very good at turning out professionals equipped with skills appropriate to the first industrial revolution, but not to the new one" He states that "while there has been a tremendous surge of interest in sustainability within academia, the courses that many teach offer no sustainable solutions for the world their graduates will find. They are still part of the problem." He continues by stating that "Change comes slowly in academia, and so the harmful effects of obsolete curricula tend to persist. The decision that leaders in academia are going to have to make consciously is either pass on and perpetuate an old outmoded, and destructive body of knowledge, ensuring that it will remain (and cause more harm) for another generation or two or three or wake up to the responsibility and the satisfaction of challenging the status quo in their curriculum."

4 WHAT CAN ENGINEERING EDUCATORS DO?

The socio-economic paradigm needs to be modified to provide a framework within which facilitates and incentivises engineers to deliver technological improvements to people's well-being that are sustainable. In other words, there not just short term improvements to the ultimate detriment of the future. Engineering educators need to embrace with concepts in these modified or alternative socio-economic paradigms and engage their students. This is not easy for most engineering educators, it is difficult, complex and potentially subjective which engineers don't typically like; it is typically outside their discipline and comfort zone. Engineering students need to appreciate that moving towards an environmentally sustainable paradigm is not just about technological solutions. Major and possibly even more important levers to change exist in the economic and social domains and that engineers need to engage with these. Furthermore, engineering educators need to engage their students with the economic and social levers that have potential for moving humanity away from its current unsustainable path.

An example of such an effort in engagement is to provide a case-study of Ray Anderson and his experience using his book (Anderson, 2009) and this is summarised in this paragraph. He was an industrial engineer, business man and a big believer in the market economy. He strongly believed that it has many real positives in efficiently generating wealth for the good of humanity, but Market 1.0 is simply unsustainable. Humanity needs to "find ways to create wealth sustainably through efficient use of resources, renewable energy, and closed-loop manufacturing processes that use recycled waste as raw materials". Thus, modification to Market 1.0 is required to produce Market 2.0 that can sustainably generate profit and wealth. He believed that "modern commerce is riddled with economic distortions. Some of these distortions manifest themselves in perverse incentives, financial rewards that actually encourage us to the wrong things, such as subsidies to oil companies to support more production of that to which we are already addicted. You don't do that to an addict." In a simple sense, the transition to Market 2.0 firstly involves recognising the unsustainabilities and developing a willingness to tackle them head on over time (a bit like the first step an addict must take!). Then, legally and economically discourage activities that are causing big unsustainabilities, such as taxing carbon emissions and pollution (or even better, carbon consumption taxation, i.e. a tax on products that is directly related to their life cycle GHG emissions). Furthermore, incentivising "good" activities, such as some forms of recycling (that make sense from a life cycle perspective) or the phasing out of dangerous chemicals. None of the above is easy. In fact, it is potentially very complex and difficult. However, actions need to be tried out to try and move us to an environmentally sustainable future. We need to learn as we go, as some measures may work very well, while others may not work as expected and may need to be scraped or modified. Ray believed that it is industry and not government that will practically move us towards a sustainable path

because industry has the capabilities to do this in practice. Industry must change and use its "muscle" to innovate and develop technological changes and new approaches and deploy its resources to move us towards a sustainable paradigm. However, Ray believed that this does NOT mean that governments (globally) do not have a key role to play. Yes, they do! Their job is to devise smart laws and use economic instruments wisely that penalise "bad behaviours" and encourage / incentivise "good behaviours". Government is like the rule-maker and referee in the market game. They kind of steer the market in a certain direction (that of sustainability), but it is industry and the market that does the implementation in practice and efficiently picks winners and losers to effectively move us towards a sustainable paradigm. Likewise for Interface – they could be a much less environmentally unsustainable company if they existed within Market 2.0. Ray believed that our current environmentally unsustainable path could represent a major down-turn for humanity, even a collapse, however he was a total optimist and believed that if humanity was willing to change direction that it would represent a huge market opportunity to create sustainable wealth, and that the market would embrace the challenge if only it could be pointed in the right direction.

5 AUTHOR'S JOURNEY AND REFLECTION

I, as the author of this paper, have been teaching chemical engineering students for over 19 years in mainly technical subjects. About 10 years ago, I started teaching a module in environmental protection followed by a half a module in sustainability 5 years ago. These modules focused mainly on management and technical aspects from a process industry perspective, including waste minimisation, energy management, life cycle assessment, carbon footprinting, cleaner product and process technology, cleaner energy, waste treatment and disposal. There are also lectures dealing with legislation and corporate environmental sustainability, where we look at moving towards environmental sustainability from a corporate perspective.

Over the last few years, I have had the niggling feeling that the big challenges to moving humanity towards an environmental sustainable paradigm lie in the economic and social domains (from reading many books including those cited in this paper). This is not to say that the technological innovation and challenges are not important; yes they are but the critical levers to moving humanity towards a sustainable paradigm may exist in the economic and social domains. I also had the niggling feeling that I am complicit in producing "educated barbarians". Consequently, I have and am in the process of trying to weave social and in particular economic aspects into my module content. This is in ways interesting but it is uncomfortable as I know I am way outside my comfort zone, its potentially very subjective and open for criticism, but I feel it needs to be done and I do inform my students of the subjective nature of some of the material I present. Some of the initiatives that I have taken to embed an economic and social dimension include:

- Economic and social dimension to global energy and climate change: I teach a section on global energy and climate change. In addition to looking at some technical aspects, such as renewables and energy efficiency, I tried to explore reasons from an economic and social dimension for why there's been no significant move away from the burning of fossil fuels, even though the potential for disastrous climate change has been well documented for over 20 years.
- Environmental / sustainability debates: As part of continuous assessment, I hold a number of student debates on topics of environmental / sustainability interest that are somewhat controversial, such as "The world will face major food and water crisis that will reduce the global population by billions" and "Wind energy is the way forward for generating electrical energy in Ireland". The students are divided up into teams where one team prepares and debates the pros side of the topic and the other the cons. The students are encouraged to investigate the topic from a broad perspective, which includes economic and social issues in addition to scientific and technical.
- Case study on the late Ray Anderson and Interface: I recently included this case-study, that I highlighted above, where we consider "Market 2.0" in more detail and I recommend the students to read his book.
- Final year research projects: Every year I offer a number of student projects that focus on environmental sustainability and some of these incorporate a consideration of economic and social aspects. For example, the "lecturer carbon footprint" project which, in addition to evaluating the

carbon footprints of 2 lecturers, the student investigated the social and economic barriers that inhibited the lecturers from making significant reductions in their carbon footprints.

Other initiatives that I am considering are:

- Introducing a section on ecological economics: I personally believe that economics and the social values that underpin it have a major role to play in moving humanity to a sustainable future. Money "talks" and is a huge motivator, thus this section will further engage students with the relationship between economics, social values, industry and environmental sustainability in particular. Dietz and O'Neill (2013) have recently authored an appropriate book that could underpin this section, entitled "Enough is Enough – Building a Sustainable Economy in a World of Finite Resources". Books like this have the potential to engage engineering students with economic and social levers that may have potential for moving humanity away from its current unsustainable path.
- Directly "encouraging" final year students to reflect on the sustainability education that they have received when it comes to their future careers, the types of employment they select and the organisations they choose to work for.

6 CONCLUSIONS

Engineering is a technological discipline by its nature and is very important in moving humanity towards a sustainable paradigm. However, focussing on technology alone is simply not enough. Other levers to change, such as in the economic and social domains are just or even more important. Engineers and engineering educators need to recognise and embrace this. Graduating engineers entering "Market 1.0" and applying their education and talent may do some good in the short-term but ultimately may be just moving humanity faster towards collapse. Engineers must somehow find ways, not just to influence technological levers (which are very important) but also to influence economic and social levers so that changes in economic and social behaviours can complement and facilitate technological change in moving humanity to an environmentally sustainable paradigm. None of this is easy; in fact it is very difficult. Moving into the future and in the context of sustainability, embracing the socio-economic dimension of engineering is becoming a very important aspect of the job of engineering educators. Through engaging their students with this aspect of their education, they can always hope that some of them will embrace this, have influence somewhere and become change leaders, and maybe even emulate engineers like Ray Anderson.

References

Anderson, R.C. (2009). *Confessions of a Radical Industrialist – How Interface Proved that you can Build a Successful Business without Destroying the Planet*. Random House Business Books, London, UK.

Barry, J. (2012) *The Politics of Actually Existing Unsustainability: Human Flourishing in a Climate Changed, Carbon Constrained World*. Oxford: Oxford University Press.

Byrne, E.P. and Fitzpatrick, J.J. (2009). Chemical engineering in an unsustainable world: Obligations and opportunities. *Education for Chemical Engineers*, 4, 51-67.

Dietz, R. and O'Neill, D. (2013). *Enough is Enough – Building a Sustainable Economy in a World of Finite Resources.* Earthscan, Oxford, UK.

Ehrenfeld, J.R. and Hoffman, A.J. (2013) *Flourishing: A Frank Conversation about Sustainability*. Stanford University Press.

Gilding, P. (2011). *The Great Disruption*. Bloomsbury, London, UK.

Heinberg, R. (2011). *The End of Growth.* Clairview Books, West Sussex, UK

Jackson, T. (2009). *Prosperity without Growth Economics for a Finite Planet,* Earthscan.

McKibben, B. (2007). *Deep Economy: Economics as if the World Mattered*. Oneworld Publications, Oxford, UK.

McKibben, B. (2011). *Eaarth: Making a Life on a Tough New Planet*. St. Martin's Griffin, USA.

Meadows, D., Randers, J. and Meadows, D. (2005). *Limits to Growth: The 30-Year Update*. Earthscan, Oxford, UK.

Randers, J. (2012). *2052 – A Global Forecast for the Next Forty Years.* Chelsea Green Publishing, Vermont, USA.

von Weizsäcker, E., Hargroves, K., Smith, M. H., Desha, C. and Stasinopoulos, P. (2009). *Factor Five – Transforming the Global Economy through 80% Improvements in Resource Productivity.* Earthscan, London, UK.

WCED [World Commission on Environment and Development] (1987). *Our Common Future*, Oxford, University Press, Oxford.