Educating Engineers About Sustainable Energy: An Overview of the Issues

Carrie Sonneborn

Murdoch University
Perth

A B S T R A C T

The decisions and activities of engineers are often intimately connected with the choice of energy systems and their far reaching effects on society and the environment. Yet there is little or no explicit 'sustainable energy education'—that is, education about the role that the production and use energy plays in modern society, including the related technical aspects—in most undergraduate engineering courses.

The significance of energy to modern society, the culture of engineering, and the future outlook for sustainable energy education are explored from a historical perspective in the context of environmentalism, feminism and industrialism. The current status of sustainable energy education theory and practice in Australia is outlined. Drawing on interviews with key practitioners possible approaches to sustainable energy education in engineering are discussed. Current courses and resources for sustainable energy education for engineers are summarised.

It is impossible to get away from (the energy problem). It is impossible to overemphasise its centrality. It might be that energy is for the mechanical world what consciousness is for the human world. If energy fails, everything fails.
(Schumacher 1973)

Using energy probably causes more environmental damage, one way or another, than any other peaceful human activity (except perhaps reproduction).
(Cairncross 1991)

Energy is a prerequisite for a modern standard of living. The demand for energy by developing nations continues to escalate as overseas aid become increasingly energy-related. Meanwhile the production and use of energy is acknowledged as a major cause of environmental damage such as air pollution, acid rain, deforestation, climate change.

The decisions and activities of engineers are often intimately connected with the choice of energy systems and their far reaching effects on society and the environment. Yet there is little or no explicit 'sustainable energy education'—that is, education about the role that the production and use energy plays in modern society, including the related technical aspects—in most undergraduate engineering courses.

Sustainable energy education focuses on the environmental impacts of energy production and consumption and on the technical means, such as renewable energy, demand management and energy efficiency, of reducing these impacts. This paper explores the current status of sustainable energy education theory, practice and resources in Australia. The significance of energy to modern society, the culture of engineering, and the future outlook are also discussed.

Environmental education perspectives on engineering education

The image of engineering which engineering schools convey is of a field of endeavour that is overwhelmingly concerned with numbers and mathematical analysis. If one studies the course content of most Australian engineering degree courses, one finds an obsession with the technical, the mathematical and the scientific and an almost complete neglect of the social, political and environmental issues (not to mention the managerial and industrial relation aspects) that shape engineering practice in the real world. Where such issues creep into the courses they are usually treated as secondary and even unimportant considerations.
(Beder 1989)

Engineering fields are all under some level of environmental regulation. Within engineering education, specialised environmental engineering degree programs are now available and there is growing acknowledgement of the need to teach the basics of environmental topics to all engineering students. Given that the undergraduate curriculum of traditional engineering disciplines is full to overflowing most students will not find the time to do additional 'environmental' subjects unless they see the relevance to their future career. Some incentive, either from indsutry or teachers, is needed (Dorweiler & Yakhou 1998).

A symposium—Environmental Issues in Engineering Education: Greening Engineering Graduates—held at the University of NSW acknowledged that engineering graduates needed skills which were not being provided by traditional engineering courses. Publicity information for the symposium (UNSW 1993) declared that:

Prominent among these skills is an ability to practice engineering in a manner that is sensitive to

https://doi.org/10.1017/S0814062600001567 Published online by Cambridge University Press

the environment and aware of the tools being developed by many discipline areas—economics, law, management etc.—for environmental management. Equally important is an appreciation of the socio-political environment within which engineering is undertaken.

Environmental education has often been seen as the preserve of biologists, geologists and other 'Earth' scientists. There has been confusion as to how environmental principles relate to other disciplines and/or whether environmental education ought to be a discipline in its own right. Environmental education theory differentiates strongly between: education about the environment—or teaching environmental facts and concepts; education through the environment—via experiential learning in nature; and education for the environment—actively engaging students in the resolution of environmental problems (Fien 1993).

It is education for the environment which is seen by many environmental education theorists, such as Stevenson, and Huckle (cited in Fien 1993), as the most effective way to make a genuine contribution to environmental well-being since it combines social critique with political and practical action. A recent project aimed at engineering students, the Green Fridge Quest (Sonneborn 1994), is an example of providing engineering students with an applied experience of integrating environmental and social principles with technical solutions, that is an experience of 'engineering education for the environment'.

There is no doubt that one reason that young people—and particularly women (Carter & Kirkup 1990)—are 'turned off' science and engineering as fields of study is that they perceive these endeavours in some contexts to be responsible for many of the social and environment ills the planet and it peoples currently suffer.

Theoretical perspectives

Three theoretical perspectives are briefly considered below as being particularly pertinent to a discussion of the practice of engineering education. They are: environmentalism, because of the obvious impacts that engineering practice and products have on natural environments; industrialism, because of engineering's traditional links to industry; and feminism, because of the notable lack of women engineers.

Environmentalism

We are the priests of material development, of the work which enables other men to enjoy the fruits of the great sources of power in Nature and the power of mind over matter. We are the priests of the new epoch, without superstitions. (George. S. Morison, speech to the American Society of Civil Engineers in 1895, given in Layton 1986)

Once lauded as the harbingers of sought-after modern conveniences and comfort, in recent years engineers and engineering have come to be seen as contributing to degradation of environments and to its parent—unsustainable development. Yet historical precedents exist for engineering having enormously beneficial effects on society. For example, civil engineering and town planning played major roles in improving public health via the provision of basic sanitation services including running water, sewer systems and rubbish collection. Indeed, it has been argued that these innovations had more to do with eliminating highly contagious disease such as tuberculosis than the discovery of a vaccine cure by medical science. But the role of engineers is rarely acknowledged. Given the centrality of energy to modern society, engineers have an important role in creating a sustainable future. In the process the profession could reclaim its positive image.

Discussion of environmental orientations often distinguishes between the anthropocentric—humans as rulers or stewards of nature, and the eco-centric—humans as dependent on and in partnership with nature, the major difference being the extent to which, and the reasons for which, the non-human world is valued.

'a perspective of anthropocentric and techno-centric optimism'

When engineering education addresses environmental issues it is often done from a perspective of anthropocentric and techno-centric optimism. As a discipline that developed around providing practical technical solutions for the needs of society, this is not at all surprising. Even 'renewable energy courses', which are now available in TAFEs and Universities, must ultimately focus on the technical aspects of the topic. The real question, however, is "Can engineering education fully embrace and integrate environmental concerns in ways which achieve technical solutions to social problems and minimise environmental impacts?"

In recent years there has been growing awareness by engineers of environmental issues and the profession's role in addressing them. In 1992 the Institution of Engineers Australia (IEAust) developed an environmental policy for engineers. In 1996 the IEAust released its Review of Engineering Education (Institute of Engineers Australia 1996). It recommended:

no less than a culture change in engineering education which must be more outward looking with the capability to produce graduates to lead the engineering profession in its involvement with the great social, economic, environmental and cultural challenges of our time.

But energy issues remain largely unaddressed. A vision of a sustainable energy future needs to be developed on the part of engineers and their educators as well as society and industry.

https://doi.org/10.1017/S0814062600001567 Published online by Cambridge University Press

Industrialism

'the bearers of truth, prosperity, liberation, security and material comfort'

The industrialism typical of developed societies that are structured around investment in the means of production and reliance on an urban, centralised work force is based on a belief in science and technology as the bearers of truth, prosperity, liberation, security and material comfort.

Industrial societies, whether capitalist, communist, or fascist, are based on the 'work ethic' as the "most glowingly magical cult of industrialism (not in the sense of creative production, but in the sense of putting your nose to the grindstone in paid labour)" (Horne 1986). In contrast with industrial societies, pre-industrial and feudal societies worked to provide food, shelter, entertainment, and ceremonial needs. Such societies were guided by an economic principle of use, not gain. The mercantile class, the predecessors of industrial capitalists, characterised peasants as lazy because they did not work beyond producing what they needed to live.

In many ways engineering both created, and was created by, the Industrial Revolution, at the beginning of which the mining of fossil fuels in vast quantities began. Engineering as a profession was made possible by the growth of large corporations. In 1816 the engineering profession scarcely existed in America but between 1880–1920 increased by almost 2 000%. (Layton 1986). Engineering is by far the largest of the new professions to have emerged from that period (Gerstl 1969).

The engineer is thus the original 'organisation *man*' with most engineers today working for very large bureaucracies—they are not independent self-employed professionals in the sense that are doctors or lawyers. The essence of the engineer's dilemma lies in bureaucracies, not their host ideologies of capitalism or any other 'ism', and in the conflict between an assumed professional independence and ethics and bureaucratic loyalty. Furthermore, studies have shown that those who choose engineering as a profession are less likely than most to have an interest in social structure or the complexities of social relations. Engineering education does little to increase students awareness of these phenomena (Hacker 1990). Engineers are unlikely to become revolutionaries because engineering is rarely separated from those bastions of industrialism, large corporations and government bureaucracies.

Feminism

Many feminists, as well as environmentalists, have perceived a connection between the exploitation of women and the exploitation of '*Mother* Nature', noting parallels between the 'rape' of the 'virgin' land and the abuse of women. Consequently the women's movement of the 1970's focused attention on nature as an exploited female presence (Merchant 1980).

The roots of engineering can be traced to its conception as a solely military activity of the first patriarchal city-states such as the Roman Empire. The term 'civil' engineering was coined only in the eighteenth century to distinguish it from the more typically military pursuits of engineers. The first engineering schools, such as West Point in the USA, were military academies. Hacker (1990) has suggested that the military roots of engineering are an overriding aspect of the engineering culture which many people, particularly women, find so alienating and threatening.

According to Carter and Kirkup (1990), what distinguishes engineering from other masculine professions is the 'machismo' myth which surrounds it and the aura of masculinity with which it associated. Indeed, women engineers are a rarity. Engineering education as it now exists attracts students with stereotypically masculine traits: a high concern for order and certainty; little interest in humanities and social sciences; an 'action' orientation—wanting to see things 'working'; little interest in people; and moderately high interest in opportunities for self-expression and attainment of money and prestige (Gerstl 1969), orientations found to be true of both male and female engineering students. A picture of engineers, whether male or female, as fairly conservative and professionally identified individuals clearly emerges.

Some views about the current energy education of Australian engineers

'Sustainable energy education' is an obvious and important nexus between environmental education and engineering training. There is now a fair body of research and interest in environmental issues in engineering education, but little material which refers specifically to energy education. Therefore, in order to gain something of an 'insider perspective' in early 1995 I interviewed five engineers—four male and one female—working in some aspect of energy/engineering education. To gain an insight into whether they perceived any progress in the status of sustainable energy education for engineers in Australia, the same people were interviewed again in early 1998. Their responses are summarised below.

The current status of energy education

The interviewees expressed the opinion that energy education:

- should be a fundamental part of engineering education and ongoing training because "energy is a fundamental part of decision making of virtually all engineering these days [and] to quality of life".
- is virtually absent from general engineering education. "Engineers might get some input regarding energy issues as it related to their particular specialisation but

https://doi.org/10.1017/S0814062600001567 Published online by Cambridge University Press

the social, political and environmental context were rarely addressed".

- such as it is, ignores 'demand side' issues—energy conservation and efficiency—as non-technical and therefore not engineering tasks. In 1998 demand side issues were getting even less educational resources as the federal government had cut funds for energy efficiency education and training. The commercialisation of the electricity industry over the past three years is another factor
- has high inherent interest amongst engineering students.

Educational aims of energy education

The interviewees proposed that the overall aims of energy education in engineering should be that students—and practising engineers—attain appropriate levels of:

- awareness of the significance of energy to society, environment and engineering activities, that is 'energy education in context'
- ability to critically appraise how energy is currently used and produced, and to develop alternatives
- understanding of 'demand' and 'supply' issues as complementary elements of the energy 'equation'.

Barriers to energy education

In general, the major barriers cited to energy education in engineering training were:

- the lack of appreciation of energy issues on the part of educators and industry. Academics were seen to lack expertise in energy issues, particularly on non-technical issues such as demand management, social and environmental impacts, and political perspectives. This was considered the major deterrent to energy issues being included in context in engineering courses. By 1998 it was suggested that role of engineering in sustainable development was acknowledged by the IEAust, which was leading tertiary institutions in this regard.
- the influence of established fossil fuel based industries on the construction of tertiary engineering curricula. It was noted that 'big industry' provided traineeships to students and was regularly consulted by IEAust on curriculum development. The smaller renewable energy industry was not well consulted by IEAust and often did not have the resources to provide significant student placement opportunities
- an inappropriately high focus on technical content in curricula—at the expense of social, environmental and management issues. "You don't need a couple of years training in differential calculus to do the job! Even if you wanted to go into research, it would be much better to get across the principle of production engineering with concrete examples than the abstractions of differential calculus."

Possible approaches to energy education

Approaches to energy education in engineering training proposed by interviewees included:

- integrating energy education across engineering curricula. "A single one off 'context course' will never be successful in demonstrating to engineers the inextricable links between one subject and another. Energy, and the implications of energy, have to be built into all the places it shows up"
- developing a highly practical, 'hands on' energy education experience for students
- the use of guest lecturers from industry and interest groups
- establishing traineeships in a variety of energy-related companies
- resourcing educators with teaching materials
- the incorporation by tertiary institutions of energy efficiency, renewable energy and the principles of sustainable development in their own buildings, grounds and operations as a living example to students.

Role of professional organisations

The role and influence of the IEAust in the development of sustainable energy education was seen as:

- significant as the IEAust's 1996 Review of Engineering Education "spells out ecological sustainability as being a fundamental basis on which engineering should be built, which is pretty strong stuff".
- important in achieving wide implementation across all aspects of engineering education. The IEAust accredits all engineering degree programs. It was noted that the IEAust receives input from major fossil fuel based industries on what should be taught in engineering. "I guess there is the danger that educators' [views] will have the tendency to be coloured by major players [in industry]".
- in need of broadening to include greater input from renewable energy and energy efficiency industries in decision making about curricula.
- one of provision of ongoing energy education for practising engineers.
- potentially one of producing and disseminating energy education teaching aids to educators.

In summary, the difference in interviewees response from the first to the second interview was minimal, suggesting that, as far as they could ascertain, progress was being made only slowly or in isolated instances. In some cases things were seen to be 'going backwards', for example the loss of federal funding for energy efficiency training in the industry sector. There was, however, some optimism expressed with regard to some of the development in tertiary education itself. These are discussed in the following section.

https://doi.org/10.1017/S0814062600001567 Published online by Cambridge University Press

Current resources in Australian renewable energy education

'positive signs'

There are positive signs that engineering educators and the profession and have begun to acknowledge engineering's key role in the protection of the Earth. Environmental Engineering degrees—many with a female enrolment of 50% or more—have been developed within several Australian universities while many engineering courses now include a required subject on 'Engineering and Society', a kind of catchall for the impacts of technology; this subject normally includes some coverage of environmental impacts. At the University of Technology Sydney a major redesign of the engineering curriculum has resulted in a Bachelor of Engineering course (Civil, Electrical, Mechanical) whose "aim is to educate students for practice as professional engineers in a world in which environmental sustainability is under profound threat" (Faculty of Engineering 1996). Further, the Bachelor of Engineering course aims to "contribute positively toward the students' personal development as socially and environmentally aware citizens". While not specifically focusing on energy education, the truly pioneering aspect of all this is that teaching sustainability and developing students environmental awareness has been stated as an aim of a traditional Bachelor of Engineering degree—as opposed to an Environmental Engineering degree.

Positive examples of 'Renewable Energy Education' at the tertiary level also now exist. For example, within the Systems Engineering degree offered at the Australian National University a final year elective can be taken on 'Energy Systems' which focuses on renewable energy systems engineering. In addition, a recent major contribution to renewable energy education in Australia is the education program of the Australian Co-operative Research Centre for Renewable Energy (ACRE). ACRE is developing renewable energy education programs for primary school, high school, undergraduate, postgraduate and on into continuing professional development (ACRE 1998).

At the TAFE level, a 'Certificate IV in Renewable Energy Technology' course is now offered by seven institutions around the country. The most notable of these is the Brisbane Institute of TAFE which has a Renewable Energy Centre whose physical design plays a key role in student learning in an interactive environment. The Centre has been designed to demonstrate a highly energy efficient home whose electricity demand is easily met by a 1.2-kilowatt array of solar photovoltaic panels. This is all part of the Centre's philosophy which stresses that tertiary education institutions as a whole, as well as engineering faculties, can be examples of sustainability in practice as well as in their curriculum design (Berrill 1998).

A few educational institutions are responding. For example, in early 1998 Murdoch University in Perth became the first university in Australia to endorse the National Union of Students 'Sustainable Universities Charter'. Several other Universities have followed. The Charter commits universities to operating their own facilities in keeping with the principles of sustainability, including energy efficiency, waste reduction, recycling and ethical investment.

While no comprehensive Australian guide to engineering and technical training in renewable energy yet exists, the Australian & New Zealand Solar Energy Society is currently compiling a compendium of renewable energy and energy efficiency training courses in Australia and New Zealand. Until this is available, interested readers could refer to Linke's 1998 article in *Renew*, the magazine of the Alternative Technology Association. A regularly updated list is also available on the ATA web site http:/www.ata.org.au/

Conclusions

Given the historical and cultural back drop of Western societies, and the engineering profession as part of them, it is not surprising that 'sustainable energy education' is not yet commonly available through most engineering courses. Engineering curricula have been embedded in assumptions which bound the engineering profession as a whole—acceptance of intensive energy use and fossil fuel based energy production, and of engineering's symbiotic relationship with 'big industry', and a utilitarian view of the natural world.

'it could be that a shift within society—not just engineering education—will be needed'

But there are signs of change. More 'sustainable energy' courses are now available than there were three years ago. Some TAFEs, universities and individual departments are integrating sustainable practices into their own operations. The IEAust has demonstrated its awareness of sustainable development issues, both as a responsibility and as an opportunity for the engineering profession.

Ultimately it could be that a shift within society—not just engineering education—will be needed. What role can individual engineers hope to play in securing a sustainable energy future in light of the fact that technology, after all, may be just 'tinkering' with respect to the 'real problems' which include the following:

- population and consumption
- that as employees of 'big industry' individual engineers have little influence
- that technical skills are only a fraction of what engineers need to know to be effective 'change agents'
- that most engineering education is not providing students with the non-technical skills and awareness related to their future profession.

https://doi.org/10.1017/S0814062600001567 Published online by Cambridge University Press

There is a clear need for engineering educators and professionals—together with tertiary and environmental educators in general—to continue to promote, develop and implement more effective models of 'sustainable energy education'.

I began this paper with a quote from Schumacher. I think it appropriate to end with another:

> *Science and engineering produce 'know-how'; but 'know-how' is nothing by itself: it is a means without an end, a mere potentiality, an unfinished sentence. 'Know-how' is no more culture than a piano is music. Can education help us to finish the sentence, to turn the potentiality into a reality to the benefit of [humankind]?* (Schumacher 1973)

This paper is adapted from ISTP, Murdoch University Occasional Paper No 3/98 'Educating Engineers About Sustainable Energy—An Overview of the Issues'.

References

ACRE (1998): contact Associate Professor Phil Jennings via telephone 08 9360 2274; fax 08 9310 1711; email—jennings@fizzy.murdoch.edu.au; website—http://www.phys.murdoch.edu.au/acre/

Beder, S 1989, 'Towards a more representative engineering education', *International Journal of Applied Engineering Education*, vol. 5, no. 2, pp. 173–182.

Berrill, T 1998, 'Engineering education for sustain-ability', *Solar Progress*, vol. 19, no. 2, pp. 14–16.

Cairncross, F. 1991, *Costing the Earth*, Harvard Business School Press, Boston.

Carter, R. & Kirkup, G. 1990, *Women in Engineering: A Good Place to Be?* Macmillan, London.

Dorweiler, V. & Yakhou, M. (1998) 'Environmental education for the non-environmental engineering student: an imperative for the next generation of engineers', *Journal of Environmental Education*, vol. 29, no. 4, pp. 52–58.

Faculty of Engineering 1996, *UTS Faculty of Engineering Bachelor of Education Framework Document V 1.4*, University of Technology, Sydney.

Fien, J. 1993, *Education for the Environment: Critical Curriculum Theorising and Environmental Education*, Deakin University Press, Geelong, Victoria.

Gerstl, R. 1969, *Profession without Community: Engineers in American Society*, Random House, New York.

Hacker, S. 1990, *"Doing it the Hard Way": Investigations of Gender and Technology*, Unwin Hyman, Boston.

Horne, D. 1986, *The Public Culture: The Triumph of Industrialism*, Pluto Press, London.

Institute of Engineers Australia 1996, *Changing the Culture: Engineering Education into the Future*, Institute of Engineers Australia, Canberra.

Layton, E. T. 1986, *The Revolt of the Engineers: Social Responsibility and the American Engineering Profession*, John Hopkins University Press, Baltimore.

Linke, M. 1998, 'Renewable energy education and training guide', *Renew*, vol. 62, pp. 46–51.

Merchant, C. 1980, *The Death of Nature: Women, Ecology and the Scientific Revolution*, Harper & Row, San Francisco.

Schumacher, E. F. 1973, *Small is Beautiful: Economics as if People Mattered*, Harper & Row, New York.

Sonneborn, C. 1994, 'The Green Fridge Quest: tertiary environmental education for ESD', *Australian Journal of Environmental Education*, vol. 10, pp. 47–58.

University of NSW 1993, 'Environmental issues in engineering education: Greening engineering graduates', conference publicity brochure, UNSW, Sydney.

Carrie Sonneborn is Research Fellow in sustainable energy policy and markets for the Institute for Science and Technology Policy at Murdoch University in Perth, Western Australia, a position funded by the Australian Cooperative Research Centre for Renewable Energy (ACRE) Ltd. Her research focuses on the impacts of electricity industry restructuring, emissions trading, government policy and industry progress towards the development of renewable energy markets and exports in Australia. Formerly the Executive Director of the Sustainable Energy Industries Council of Australia (SEICA), she has also worked for the Australian Conservation Foundation on greenhouse, ozone depletion, and environmental education issues, and has consulted and published on sustainable energy policy and market development.

https://doi.org/10.1017/S0814062600001567 Published online by Cambridge University Press