

Energy transformed: building capacity in the engineering profession in Australia

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1. Introduction

Global pressures of burgeoning population growth and consumption are threatening efforts to reduce negative environmental pressures associated with development such as atmospheric, land and water pollution. For example, the world's population is now growing at over 70 million per year or 1 billion per decade (Brown, 2007), increasing from 3.5 billion in 1970, to 5 billion in 1990, to 7 billion by 2010 (United Nations, 2002). In 1990 only 13 percent of the global population lived in cities, while in 2007 more than half did. More than 60 percent of the global population lives within 100 kilometers of the coastline (World Resources Institute, 2005) and nearly all of the population growth hereon is forecast to happen in developing countries (Postel, 1999). Future levels of stress on the global environment are therefore likely to increase if current trends are used for forecasting, which is particularly challenging as scientists are already observing significant signs of degradation and failure in environmental systems. For example, the Intergovernmental Panel on Climate Change *Fourth Assessment Report* (IPCC, 2007) provided an unequivocal link between climate change and current human activities, in particular: the burning of fossil fuels; deforestation and land clearing; the use of synthetic greenhouse gases; and decomposition of wastes from landfill. The UK *Stern Review* concluded that within our lifetime there is between a 77 to 99 percent chance (depending on the climate model used) of the global average temperature rising by more than 2 degrees Celsius (Stern, 2006), with a likely greenhouse gas concentration in the atmosphere of 550 parts per million (ppm) or more by around 2100.

Hence, the way in which the human race deals with energy over the next 30 years will determine the quality of life for generations to come. This includes increasing the level of non-fossil fuel energy generation, improving the efficiency with which energy is supplied (i.e. reducing supply losses, for example from the power station to the end user), and increasing the efficiency of the end user (i.e. reducing demand, for example improving the efficiency of machinery and appliances to perform, for example heating, cooling, and washing). However, the reality is that there are significant skills shortages - particularly within the engineering profession - to address these issues. As highlighted in a United Nations Environment Program report on working in a low-carbon world, '*... companies in the fledgling green economy are struggling to find workers with the skills needed to perform the work that needs to be done. Indeed, there are signs that shortages of skilled labor could put the brakes on*

green expansion...There is thus a need to put appropriate education and training arrangements in place' (United Nations Environment Programme, 2008).

In Australia for example, considering energy efficiency, according to a national study, 'Given the wide range of technical issues associated with energy efficiency, gaps in the skill sets of specialists such as engineers or trades people could prevent the uptake of these options across a range of sectors' (Garnaut, 2008). Modelling by the CSIRO has shown that 3 million Australians (of a population of just over 20 million), will need training or re-training in energy efficiency, green building technologies, sustainable energy and more sustainable agricultural systems to enable Australia to achieve the IPCC's recommended targets for greenhouse gas reductions (Hatfield-Dodds et al., 2008). Furthermore, surveys are highlighting that the state of knowledge, understanding and implementation of even basic environmental and energy management systems in the business sector is poor. For instance, a 2008 survey of 300 Australian business CEOs regarding operating in a carbon-constrained economy found that two-thirds (67 percent) of businesses were concerned or unsure about compliance obligations, and only a handful of businesses (less than 3 percent) had implemented a strategic response to climate change (Price Waterhouse Coopers, 2008). A 2007 survey of the Australian mining and metals sector also highlighted an alarmingly slow adoption of energy demand management practices, with nearly half (43 percent) of companies still not having implemented an official energy policy. In the same context, only 10 percent of companies responding to a 2007 national Australian Industry Group survey on climate change practices felt informed enough to manage the risks associated with climate-related impacts (Australian Industry Group, 2007). Australia's peak engineering professional body, the Institution of Engineers Australia, has also acknowledged that, 'The need to make changes in the way energy is used and supplied throughout the world represents the greatest challenge to engineers in moving toward sustainability' (Institution of Engineers Australia, undated).

Within this context, this chapter overviews the need to transform engineering education, to deliver graduates and capacity build professionals who can address such energy supply and demand challenges, highlighting the complexity of transforming such education systems. We begin by discussing the problem of a time lag dilemma facing education worldwide, whereby the timeframe for capacity building the profession is converging with the requirement for global action. We also briefly discuss related risks and benefits facing organizations in light of this dilemma. The chapter then focuses on requirements for capacity building the engineering profession, drawing on two research initiatives that we have previously led: a 2007 Australian survey of the state of energy efficiency education in engineering education, and a 2009 investigation into increasing the extent of energy efficiency content in curriculum. Finally, we discuss a peer reviewed, online and freely accessible resource that has been developed from this increased understanding, to assist with capacity building, focusing on sustainable energy solutions for climate change mitigation.

2. A time lag facing engineering education

With considerable advances over the last century, the effectiveness of the education system to deliver skilled professionals would appear to be self-evident. Yet signals now clearly suggest that the focus of much of higher education requires a significant update, with an

emerging time related imperative facing the engineering community. Despite an absence of discussion in the literature, anecdotal evidence from discussions with engineering educators suggests that a typical (or 'standard') process of curriculum renewal in the higher education sector may take 3-4 accreditation cycles (of approximately 5-year intervals) for engineering departments to fully integrate a substantial new set of knowledge and skills within all year levels of a degree as required; i.e. between 15-20 years.

Given that the average pathway to graduate from an engineering and built environment program is approximately 3-5 years, from enrolment to graduation, followed by 3-5 years of on-the-job graduate development, if HEIs take the typical approach over a 15-20 year period to fully renew such bachelor programs, this has the potential to result in a time lag of around 21-29 years - 2-3 decades - before students graduating from fully integrated programs will be in decision-making positions. Clearly this is well beyond the timeframes needed to address immediate climate change issues. For postgraduate students the time lag may be shorter as students may already be practising in their field and studies span just 1-2 years. However the time lag may still be in the order of 5-10 years depending on the curriculum renewal process, which still potentially results in a lack of capacity in the professional sector over the next decade to address urgent climate change and sustainable development issues.

Along with understanding that current education systems are yet to be prepared to rapidly develop knowledge and skills related to reducing environmental pressures, it is important to understand that it is logistically impossible for the education system to change 'overnight', as programs need to balance the current student demands and expectations with industry expectations for graduate attributes. Figure 1 highlights how the transition might occur, with a period of rapid curriculum renewal followed by continual program improvement which follows a regular improvement cycle of research, curriculum development, trial, evaluation and review.

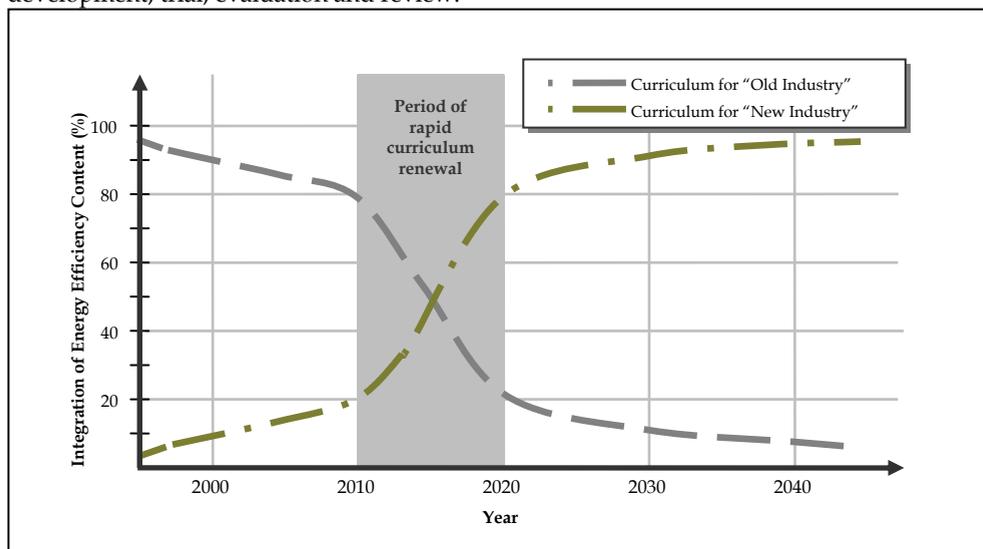


Fig. 1. An illustrative scenario for integrating energy efficiency knowledge and skills to match industry requirements over time

A key consideration in timing the transition, is the shift in focus from 'old industry' to 'new industry' curriculum, matching changing educational needs with the pace of emerging demand for such graduate attributes by employers. As part of the transition towards more sustainable infrastructure and societies, 'old industry' plant and equipment will require service and maintenance by professionals with 'old industry' knowledge and skills. However as with any major adjustment such as the information technology revolution, there needs to be a staged approach, where the balance of 'old' and 'new' needs to be carefully managed in relation to the emerging needs of society and employer demands. As the large amount of embedded infrastructure (for example buildings, power stations, electricity grids etc) needs to be managed, maintained and transitioned, this requires 'old industry' education. Hence the process to integrate 'new industry' knowledge and skills needs to be appropriately staged, as if it is too quick, this could be problematic as graduates may not have the skills that the employment market needs at the time that they graduate.

Hence, the timeframe for updating undergraduate engineering curriculum using standard methods may be too long to ensure that engineering professionals will be equipped with knowledge and skills that can address such immediate 21st Century challenges while still being able to maintain current systems. The extent of the time lag will depend on how quickly the new knowledge and skills are embedded into engineering curriculum, to the point where a student can begin studies in first year, and fully develop the new set of desired knowledge and skills (or 'graduate attributes') by the time they graduate.

This observed time lag dilemma facing engineering education has significant implications for society if the need for curriculum renewal is not addressed. Furthermore, there are implications for university engineering departments as they make decisions about the scale and pace of curriculum renewal as regulations and the market continue to change. Engineering departments may also be exposed to potential risks with regard to both student demand for the programs, and tightening accreditation requirements. However, departments need to be wary of keeping pace with graduate demand (i.e. not stepping too far in front) to ensure that their graduates remain employable and in demand throughout the process.

Drawing on the literature, Figure 2 presents an illustrative representation of the relationship between a department's commitment to engineering education for sustainable development and potential risk and reward implications. Risks include for example falling student numbers, increasing accreditation difficulties, poaching of key staff. Rewards include for example attracting the best students and staff, staying ahead of accreditation requirements, attracting research funding, securing key academic appointments and industry funding.

For the last 20 years, there has been relatively low risks and benefits from seeking to accelerate curriculum renewal in this area, evidenced by the relative lack of action on the whole in the sector apart from a small number of outstanding cases (Desha et al., 2009). However, recent market, regulatory and institutional shifts around environmental and sustainable development related issues, together with the significant shift in public opinion on these matters, and the increasing competition among higher education institutions, have caused the level of both the risks and the benefits to increase dramatically over the coming decades.

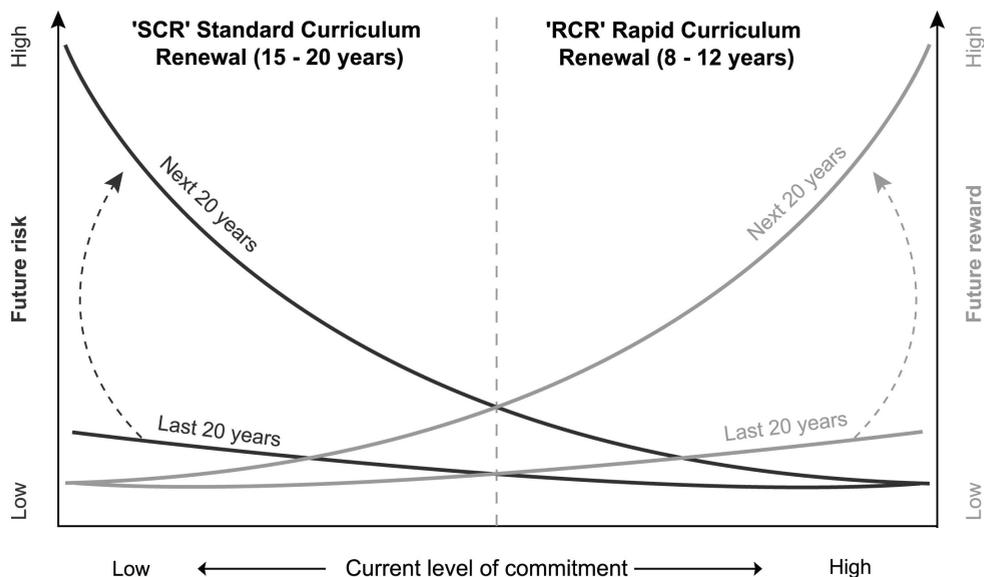


Fig. 2. A stylistic representation of risk and reward scenarios for curriculum renewal in the higher education sector

Source: (Desha & Hargroves, 2009a)

This situation presents significant cause for universities and engineering departments to rethink their strategies related to curriculum reform in order to minimize the risks and capture the rewards. In short, over the coming years, departments who do not transition their programs with topic areas such as energy efficiency are likely to find it increasingly difficult to operate. Furthermore, their traditional roles as providers of education for engineers may be challenged by private training providers who explore niche business opportunities in capacity building in these topic areas, along with engineering firms and government departments developing in-house capacity building programs that assume a base-line graduate capacity.

3. The state of energy efficiency education

In the face of such a time lag dilemma, the literature suggests that engineering educators need to undertake rapid curriculum renewal to update what is taught, within 2-3 accreditation cycles in undergraduate programs. Furthermore, rapid curriculum renewal in postgraduate engineering education also needs to occur; equipping practitioners and decision-makers with knowledge and skills surround energy efficiency. With this in mind, we now consider the state of engineering education for energy efficiency, for which a full account is provided by Desha et al. (2007). We also identify challenges and opportunities for energy efficiency education within universities, for which a full literature review is available online (Desha, Hargroves & Reeve, 2009) and a summary is provided by Desha and Hargroves (2009b).

3.1 Understanding the state of engineering education for energy efficiency

The sub-topic of energy efficiency is a prime example for a new area of practice that needs to be rapidly integrated into engineering courses, while also addressing a knowledge gap in a highly topical content area. However, there is an absence of literature documenting the state of affairs, to provide a robust platform on which to act. Hence, in 2007 the National Framework for Energy Efficiency (NFEE) funded researchers from Griffith University (The Natural Edge Project, TNEP) to undertake the first survey of energy efficiency education across all Australian universities teaching engineering education, which asked, 'What is the state of education for energy efficiency in Australian engineering education?' (Desha et al., 2007).

The subsequent research project used a paper-based questionnaire which was issued in hard copy and electronic format to the heads of department of all 32 Australian universities providing engineering undergraduate and/or post-graduate programs. It included an invitation to every Dean for completion by every lecturer teaching energy related material within engineering education. The project also included a student questionnaire, which was provided to all lecturers who received the lecturer questionnaire, to distribute and collect in one or more of their classes where energy related material were taught. The results of the two questionnaires were cross-checked for additional context and validity of interpretation through semi-structured telephone interviews with a subset of Australian academics who were experienced in engineering education for energy efficiency.

With excellent participation by 27 of the 32 universities teaching higher education (comprising 62 lecturers and 261 students), the survey identified that even though energy efficiency education was highly variable and *ad hoc*, there were a range of preferred options for improvement (Desha et al., 2007; Desha & Hargroves, 2009b). In summary, for more than half of the surveyed courses (55 percent), lecturers reported that their course could include more (in-depth) energy efficiency content, while most respondents (74 percent) thought that the increase in content should be in the specific area of *applying* energy efficiency theory and knowledge. More than half (52 percent) thought their course could include more information about energy efficiency opportunities. The survey also showed a clear preference for resources to be available through open access, online learning modules (90 percent) as opposed to restricted access sources (6 percent) or intensive short courses undertaken in person (13 percent) or remotely (10 percent).

While there was clearly a desire to integrate energy efficiency content, the 2007 Australian survey indicated a substantial shortfall in the inclusion of energy efficiency theory, knowledge, application and assessment in engineering education on the whole. Even mainstream contextual topics such as 'carbon dioxide and other greenhouse gas emissions from energy generation' and 'the link between greenhouse gas emissions and global temperature change' were only covered in detail by up to a third of surveyed courses, and mentioned by less than half. Moreover, student survey results indicated only a low to moderate appreciation of how energy efficiency might be directly related to their future careers. Lecturers and students agreed that there was little if any coverage of topics such as 'product stewardship and responsibility', 'decoupling energy utility profits from kilowatt-hours sold' or 'incremental efficiency versus whole system design'. The survey results indicated that this disconnect – between lecturers recognizing an absence of content, and a lack of action in integrating the content – was likely to be due to the presence of a variety of barriers to implementation. For example, nearly two thirds (58 percent) considered the potential for course content overload to be an issue, while more than half (52 percent)

considered having insufficient time to prepare new materials as a challenge to such curriculum renewal.

This survey contributes to a growing global understanding of the current state of education in this sustainability topic. There is clearly an urgent need to embed energy efficiency knowledge and skills into engineering curriculum, beyond once-off courses, special interest topics in later years, or highly specialized masters programs. These survey findings are also immediately relevant for senior management in engineering departments, Australian professional organizations, and government departments considering future programs and funding allocations, as they provide an indication of the preferred options for increasing energy efficiency education.

3.2 Societal drivers promoting and impeding education for sustainable development

Reports such as the Higher Education Funding Council for England's 2006 report on the 'Barriers and Challenges to Education for Sustainable Development' (Levett-Therivel, 2006) suggest that although actual progress in curriculum renewal has been slow for engineering education, there is increasing pressure for curriculum renewal towards engineering education for sustainable development from a range of actors. This includes pressure from the 'top down' (for example from accrediting institutions, professional organizations, advisory boards, education institutions and government) and from the 'bottom up' (for example from faculty members and students themselves). Table 1 provides a brief explanation of the drivers that are promoting such education, synthesizing the literature.

Driver	Factors promoting engineering education for sustainable development
Market/ Business	<ul style="list-style-type: none"> - <i>Shifting requirements by potential employers</i> - increasing requirements for engineers to demonstrate sustainable development capacity. - <i>Increasing cost of resources and associated taxes/markets</i> - increasing demand for capacity to reduce water and energy consumption. - <i>Shifting investment preferences</i> - increasing attraction to engineers who can reduce energy demand and environmental liabilities. - <i>Introduction of 'sustainability' rankings</i> - increasing pressure to improve rankings in indexes (e.g. Dow Jones Sustainability Index). - <i>Market leadership opportunities</i> - increasing pressure to achieve/maintain leadership position and capture early mover advantages. - <i>Increasing student demand and market potential</i> - students seeking sustainable development content within their institutions of study.
Information/ Technology	<ul style="list-style-type: none"> - <i>Increased scientific understanding</i> - accumulating scientific knowledge regarding environmental issues, creating pressure for performance improvement in all sectors. - <i>New technologies</i> - increasing calls for incorporating a range of new technologies into designs (e.g. renewable energy options). - <i>New examples of leadership</i> - emerging examples of leading efforts across sectors will drive competitors. - <i>Increasing faculty interest in related research and teaching innovation</i> - increasing incentives offered by governments and organizations. - <i>Increasing focus in declarations and conference action plans</i> - creating benchmarks for new kinds of engineering professionals.

Driver	Factors promoting engineering education for sustainable development
Institutional/ Civil Society	<ul style="list-style-type: none"> - <i>Shifting accreditation requirements for graduate engineers</i> - formalising sustainability knowledge and skill requirements. - <i>Mandatory disclosure and reporting</i> - increasing disclosure and reporting requirements (e.g. greenhouse gas emissions). - <i>Increasing professional advocacy</i> - with leaders stating the pivotal role of engineering in addressing 21st Century challenges. - <i>Shifting requirements for practising engineers by professional organizations</i> - where mission statements, code of ethics statements and codes of practice are being updated. - <i>Increasing commitment and action by highly regarded university peers</i> - increasingly vocal commitments and alliances.

Table 1. Key factors promoting engineering education for sustainable development

A number of key barriers are also evident in the literature, which appear to be limiting efforts by engineering educators to undertake significant and rapid engineering curriculum renewal, as summarized in Table 2.

Barrier	Factors limiting engineering education for sustainable development
Market/ Business	<ul style="list-style-type: none"> - <i>Persistent 'old economy' industry practices</i>, wherein employers continue to employ graduates to undertake unsustainable practices. - <i>Uncertainty around future requirements to change</i> - where varying government messages create considerable uncertainty around impending requirements to change. - <i>Perceived threat to employability and position</i>, from taking action ahead of market or sector wide requirements to do so. - <i>Short-termism in the Higher Education Institution (HEI) sector</i>, where short-term pressures demand increasing staff to student ratios, and increasing student intake, rather than program innovation. - <i>A shortage of engineering graduates</i>, resulting in a 'take what you can get' scenario, to then up-skill internally.
Information/ Technology	<ul style="list-style-type: none"> - <i>Growing disconnect between engineering and science</i>, where engineering professionals may not be 'in-step' in understanding the complexity and interdisciplinary nature of 21st Century challenges. - <i>Lack of convenient access to emerging and rigorously reviewed information</i>, where academics may have difficulty getting information and those who have good access may be overwhelmed. - <i>Lack of access to information in foreign languages</i>, which may impede the integration of emerging technologies and innovations.
Institutional/ Civil Society	<ul style="list-style-type: none"> - <i>Lack of strong requirements for change</i>, where there is a lack of certainty about current and future legislative requirements and support. - <i>Lack of academic staff competencies in EESD</i>, with a relatively low rate of professional development among educators.

Table 2. Key drivers limiting engineering education for sustainable development

Hence, there exist a number of significant societal drivers promoting curriculum renewal within engineering education, which are being tempered by a number of barriers that are limiting the progress. These barriers and others have been strong enough to-date, to prevent a transition towards engineering education for sustainable development in the majority of universities around the world. Many engineering departments are doing little more than including one or two 'sustainability' courses within existing programs, leaving isolated individuals or small teams within departments to undertake *ad hoc* curriculum renewal efforts. In reality, most current engineering degrees are still focused on what could broadly be classified as 'fossil fuel based old industry', involving linear 'heat, beat and treat' processes that don't tend to consider rethinking waste, minimizing inputs, maximizing productivity, capturing synergies or other externalities as part of the process (Benyus, 1997).

3.3 Curriculum drivers promoting and impeding energy efficiency education

Given these observations regarding societal drivers promoting and limiting engineering education for sustainable development, in 2009 the NFEE funded an investigation into identify challenges and opportunities for timely curriculum renewal in energy efficiency education, at the level of the lecturer (Desha & Hargroves, 2009b). Specifically, the project focused on developing and releasing a strategic document to assist the curriculum renewal process for energy efficiency education, drawing upon a behavior change methodology developed by McKenzie-Mohr and Smith (2007). The findings were intended for use by engineering departments, accreditation agencies, professional bodies and government, to identify opportunities for moving forward, and then to strategically plan the transition. The project also provided a significant opportunity to explore options to support lecturers, program co-ordinators and staff to strategically approach, in an informed way, the challenge of increasing the levels of education for energy efficiency as a proxy for other sustainable development topics.

Through a comprehensive literature review followed by a national survey of engineering educators, the researchers short-listed 10 favored options amongst HEIs to integrate emerging energy efficiency content within current engineering programs, as shown below (in order of priority):

1. Including a case study on energy efficiency.
2. Including a guest lecturer to teach a sub-topic.
3. Offering supervised research topics on energy efficiency themes.
4. Offering energy efficiency as a topic in a problem-based learning course.
5. Including assessment that aligns with the energy efficiency theme within the course (e.g. exam questions and assignments)
6. Including tutorials that align with the energy efficiency theme in the course (e.g. presentations/ discussions/ problem solving)
7. Overhauling the course to embed energy efficiency
8. Including one workshop on energy efficiency in the course (i.e. experiments)
9. Including a field trip related to energy efficiency
10. Developing a new course on energy efficiency

Table 2 provides a summary of the identified common barriers to one or more of the shortlisted options, highlighting that putting in place mechanisms to address a particular barrier can have multiple flow-on benefits for addressing other barriers. For example, for key staff who are tasked with integrating new content, setting up an annual allocation of

teaching buy-out funds, or having an avenue for temporarily altering staff teaching-research-service workload allocation to engage in rapid curriculum renewal, would help to address the barrier of insufficient time for preparation, which affects 7 of the 10 options. Similarly, an annual small-grants program available for educators to pilot rapid curriculum renewal initiatives would help to address the barrier of prohibitive cost. A 'tiered' approach could be applied, where the first three options, including the use of case studies, guest lecturers and supervised research, may immediately be targeted, with other options then implemented among various programs in the following budget cycles.

Key Issues for Implementation	Shortlisted Options for Curriculum Renewal									
	1. Case Study	2. Guest Lecturer	3. Supervised Research	4. PBL Topic	5. Include Assessment	6. Tutorials	7. Course Overhaul	8. Workshop	9. Field Trip	10. New Course
Common Barriers										
Lack of available data/ information	●	●		●	●	●	●		●	●
Lack of time for preparation	●	●		●	●	●		●		●
An overcrowded curriculum	●		●	●		●			●	●
Prohibitive cost	●		●	●	●	●		●	●	●
Lack of knowledge	●	●	●	●	●		●		●	●
Lack of value attached	●		●			●				
Lack of industry contacts		●	●					●		
Resistance to top-down directive			●				●			
Students' prior learning habits					●				●	
Lecturer apathy		●					●			
Administrative coordination							●	●		●
Common Benefits										
Improved marketability	●	●					●	●		●
Cross-functionality of content	●						●			●
Additional research opportunities		●								●
Networking opportunities for students		●	●					●		
Networking opportunities for lecturers		●	●					●		
Experience in incorporating emerging concepts into curriculum			●				●			
Addressing the time-lag for graduates			●				●			
Improved pedagogy - problem based learning				●	●	●			●	
Improved pedagogy - generic skills				●	●	●			●	
Lecturer professional development		●				●				

Table 1. Identified key barriers and benefits to timely curriculum renewal in energy efficiency education *Source:* (Desha et al., 2009b)

4. Enabling capacity building for energy efficiency

With such considerations in mind, higher education institutions can strategically allocate budget and human resourcing to integrate new content – in this case energy efficiency knowledge and skills – into existing education and training programs. However, the successful transition of engineering education to incorporate such new material is reliant on a number of factors as discussed in the following paragraphs.

4.1 Institutional leadership and support

According to a study by an American campus sustainability assessment project, higher education institutions which are leading in embedding sustainable development knowledge and skills within the curriculum share a number of characteristics: *“First, these ‘sustainability leaders’ have adopted serious strategies for systematically addressing the sustainability of the institution. They have policies stating their commitment to sustainability goals, and they have specific plans in place that explain how they intend to achieve them. Second, these institutions have provided the resources needed to implement their sustainability plans. They hire staff, form committees, allocate budgets, and show clear administrative support for sustainability initiatives. Third, these sustainability leaders know where they have been, where they are, and where they are headed in terms of sustainability. They measure and track their progress toward sustainability, and regularly meet and update goals and targets”* (The Campus Sustainability Assessment Project, undated).

A 2008 report to the Australian Teaching and Learning Council on addressing the supply and quality of engineering graduates for the new century observed four supporting actions that were common in institutions facilitating significant change, namely: 1) vision; 2) leadership; 3) stakeholder engagement; and 4) resources (King, 2008). Hence, where a period of rapid curriculum renewal is required, it needs to be supported with appropriate resources for the relevant staff members, and undertaken in a realistic timeframe. Staff members need to be encouraged to consider their own strengths and professional development opportunities in contributing to decisions about how their courses embed sustainability knowledge and skills. Existing and proactive efforts by staff in curriculum renewal (i.e. the ‘leaders’ or ‘champions’ to date) should be acknowledged, supported and rewarded. A strong collaborative foundation across sub-communities (for example across different disciplines, or different campuses) is also an important mechanism to successfully address surprises or issues as they arise during the curriculum renewal process.

University support could include the provision of funding, marketing and flexibility in rules regarding developing new courses and modifying existing courses. A number of these suggestions involve investing funds, which can be a challenge. However, institutional benefits are clear and in the short term opportunities could be creatively explored for example through industry course sponsorship, the appointment of funded ‘sustainability chairs’ and professional development bursaries.

4.2 Strategic planning and implementation

For the various curriculum renewal options to be successful, an overarching strategic plan is needed, which maps out timeframes, responsibilities and resource requirements. In the NFEE investigation, a number of key components were identified that might be considered

in a strategic plan to rapidly develop graduates who can fill critical energy efficiency knowledge and skills gaps (Desha et al., 2009b):

- Planning from the outset, the best approach for the department given the opportunities and risks with niche degrees versus embedding content throughout programs and offering short courses.
- Building a strong collaborative foundation across campus sub-communities to successfully address surprises or issues as they arise.
- Accessing the growing online library of academically rigorous open-access teaching and learning resources to accelerate course development and renewal;
- Undertaking bridging and outreach opportunities across industry and government, undergraduate and postgraduate programs, and high schools and the community, to recruit students to the renewed programs;
- Making use of national and international collaboration with other academic institutions and non-profit organizations, to jointly deliver courses on energy efficiency topics.
- Integrating such capacity building into campus operations as a two-way collaboration between academics and students.

4.3 Catalysts for accelerating curriculum renewal

To address the existing time lag dilemma evident within engineering education, it is important to set clear timeframes for capacity building processes. Three catalysts that can set such timeframes are briefly discussed here:

- *Program accreditation:* Within regulated disciplines such as engineering, accreditation is a strong driver of change, setting a review period of 3-5 years for universities to continually reflect on and demonstrate how they have addressed existing and emerging accreditation requirements in their programs, in order for their programs to remain endorsed by the accrediting institution. However accreditation is quite a weak driver for engineering education for sustainable development in reality, due to the lack of clear direction on how much or within what timeframe to embed sustainability into engineering curriculum. Furthermore, accreditation agencies and their academic representatives on accreditation committees and boards do not necessarily have adequate understanding of future needs and expectations for curriculum, resulting in a lack of ability to change accreditation requirements. This situation was highlighted more than a decade ago by the Australian Higher Education Council in their report on *Professional Education and Credentialism* (Higher Education Council, 1996), which outlined difficulties facing universities and professional bodies when defining pathways for professional education.
- *Employment:* Both government and industry are significant potential catalysts in their role as current and future employers of undergraduate and postgraduate students, setting clear expectations about changing future employment and training needs. For example, both government and industry could assist professional organizations and the universities themselves (for example through advisory boards) to identify current and future industry demands for graduates with specific knowledge and skill capabilities, and in the demands of undergraduate and postgraduate students themselves. Government and industry could require employees who are undertaking professional development, to include a certain number of hours each year learning about sustainability related technology and innovations.

- *Regulation and policy:* Government can play a role in catalyzing rapid curriculum renewal through providing both penalties and incentives. This could be for example through regulation, requiring industry to accelerate efforts such as energy efficiency assessments. Government could also play a role in influencing professional accreditation requirements to provide the necessary 'calls for action' in priority knowledge and skills areas, to review and revise the coverage and extent of accreditation requirements. Government could change the criteria and selection for research funding, and link a portion of federal funding for higher education institutions to institutional learning and teaching performance with regard to integrating energy efficiency knowledge and skills into curricula.

An example of a government catalyst role can be seen in the example of the Australian federal government's 'Energy Efficiency Opportunities' program, launched in July 2006, which required more than 220 businesses (representing around 45 percent of national energy demand) that use more than 0.5 PJ (approximately 139,000 MWh) of energy per year, to undertake an energy efficiency assessment and report publically on opportunities with a payback period of up to 4 years (DRET, undated). Further to this, Victoria was the first state to require all EPA license holders using more than 0.1 PJ (27,800 MWh) to implement opportunities with a payback period of up to 3 years, through its 'Industry Greenhouse Program' (Victorian Environmental Protection Agency, undated). As a result of implementing these programs, both state and federal government has identified a significant skills shortage in the area of undertaking energy efficiency assessments.

Subsequently the federal government initiated a 'Long Term Training Strategy for the Development of Energy Efficiency Assessment Skills', beginning in 2009 with an extensive survey process across the energy intensive industries, energy service providers, and universities (Council of Australian Governments, 2009). In 2007, the CSIRO (Commonwealth Scientific and Industrial Research Organization) through its 'Energy Transformed Flagship' engaged researchers from The Natural Edge Project to provide capacity building notes for professionals and students looking to up-skill in energy efficiency opportunities, aimed at both undergraduate education and professional development, as discussed below.

5. Capacity building resources

In 2007, the CSIRO funded the development of three education and training modules (30 lectures) in line with its goal for its 'energy transformed' program, 'to facilitate the development and implementation of stationary and transport technologies so as to halve greenhouse gas emissions, double the efficiency of the nation's new energy generation, supply and end use, and to position Australia for a future hydrogen economy'. It was intended that these modules would provide a base capacity-building training program that would prepare engineers/technicians/facilities managers/architects etc. to address the issues of greenhouse gas emissions and work towards creating sustainable energy solutions throughout the course of their professional life. Within this context the modules would provide an introduction to energy efficiency and low emissions technologies.

The resultant *Energy Transformed* education package (Smith et al., 2007) contains over 600 pages of peer-reviewed content that is freely available online, covering a wide range of issues related to energy for use in undergraduate education, providing industry, business and households with the knowledge they need to realize at least 30 percent energy

efficiency savings as rapidly as possible. The text also provides an updated overview of the latest advances in low carbon technologies, renewable energy and sustainable transport.

The contents of the *Energy Transformed* program are separated into three 'modules':

- *Module A*: Understanding, identifying and implementing energy efficiency opportunities for industrial/commercial users - by technology.
- *Module B*: Understanding, identifying and implementing energy efficiency opportunities for industrial/commercial users - by sector.
- *Module C*: Integrated approaches to energy efficiency and low emissions electricity, transport and distributed energy.

The component chapters and lessons in the package are summarized in Table 4.

Module	Content
A	<p><i>Chapter 1: Climate Change Mitigation in Australia's Energy Sector</i></p> <p>1.1: Achieving a 60 percent reduction in greenhouse gas emissions by 2050 1.2: Carbon down, profits up - multiple benefits for Australia 1.3: Integrated approaches to energy efficiency & low carbon technologies 1.4: A whole systems approach to energy efficiency in new & existing systems</p> <p><i>Chapter 2: Energy Efficiency Opportunities for Commercial Users</i></p> <p>2.1: The importance & benefits of a front-loaded design process 2.2: Opportunities for energy efficiency in commercial buildings 2.3: Opportunities for improving the efficiency of HVAC systems</p> <p><i>Chapter 3: Energy Efficiency Opportunities for Industrial Users</i></p> <p>3.1: Opportunities for improving the efficiency of motor systems 3.2: Opportunities for improving the efficiency of boiler and steam Distribution systems 3.3: Energy efficiency improvements available through co-generation</p>
B	<p><i>Chapter 4: Responding to Increasing Demand for Electricity</i></p> <p>4.1: What factors are causing rising peak and base load electricity demand in Australia? 4.2: Demand management approaches to reduce rising 'peak load' electricity demand 4.3: Demand management approaches to reduce rising 'base load' electricity 4.4: Making energy efficiency opportunities a win-win for customers and the utility: decoupling energy utility profits from electricity sales</p> <p><i>Chapter 5: Energy Efficiency Opportunities in Large Energy Using Industry Sectors</i></p> <p>5.1: Opportunities for energy efficiency in the aluminum, steel and cement sectors 5.2: Opportunities for energy efficiency in manufacturing industries 5.3: Opportunities for energy efficiency in the it industry and services sector</p> <p><i>Chapter 6: Energy Efficiency Opportunities in Light Industry and Commercial Sectors</i></p> <p>6.1: Opportunities for energy efficiency in the tourism and hospitality sectors 6.2: Opportunities for energy efficiency in the food processing and retail sector 6.3: Opportunities for energy efficiency in the fast food industry</p>
C	<p><i>Chapter 7: Integrated Approaches to Energy Efficiency and Low Emissions Electricity</i></p> <p>7.1: Opportunities & technologies to produce low emission electricity from fossil fuels 7.2: Can renewable energy supply peak electricity demand? 7.3: Can renewable energy supply base electricity demand? 7.4: Hidden benefits of distributed generation to supply base electricity demand</p> <p><i>Chapter 8: Integrated Approaches to Energy Efficiency and Transport</i></p> <p>8.1: Designing a sustainable transport future 8.2: Integrated approaches to energy efficiency & alternative transport fuels - passenger 8.3: Integrated approaches to energy efficiency and alternative transport fuels - trucking</p> <p><i>Chapter 9: Integrated Approaches to Energy Efficiency and Distributed Energy</i></p>

Module	Content
	9.1: Residential building energy efficiency and renewable energy opportunities: towards a climate-neutral home
	9.2: Commercial building energy efficiency and renewable energy opportunities: towards climate-neutral commercial buildings
	9.3: Beyond energy efficiency and distributed energy: options to offset emissions

Table 4. Energy Transformed: Sustainable Energy Solutions for Climate Change Mitigation
Source: (Smith et al., 2007)

In summary, these modules bring together the knowledge of how countries, specifically Australia, can achieve at least 60 percent cuts to greenhouse gas emissions by 2050, in line with the activities of the CSIRO Energy Transformed Flagship research program which is focused on research that will assist Australia to achieve this target. The materials provide industry, governments, business and households with knowledge to realize at least 30 percent energy efficiency savings in the short term while providing a strong basis for further improvement. It also includes an overview of advances in low carbon technologies, renewable energy and sustainable transport. While the package has an Australian focus, it outlines sustainable energy strategies and provides links to numerous online reports which can assist climate change mitigation efforts globally. It seeks to inform other initiatives that are encouraging the reduction of greenhouse gas emissions, for example through behavior change, sustainable consumption, and changes to economic incentives and policy.

The online format of this education and training program has been designed using the results of the 2007 and 2009 NFEE funded research, including the following considerations:

- Extensive peer review was sought during the writing process (see acknowledgements) to assist with creating awareness of the materials.
- The length of content (i.e. number of pages) for each lecture is intended to make it easy for rapid uptake, using a 20-30 page highly structured and straightforward format that suits most learning environments.
- Each lecture provides links to numerous online reports that outline sustainable energy strategies and which assist climate change mitigation efforts in Australia and globally.
- The presentation of the content has been designed for flexibility, to cater for a range of learning processes, from self-paced modular learning through to PowerPoint presentations, tutorial discussions and problem-based learning.

Each 'lecture' begins with an 'Educational Aim' which provides an overview of the module. This is followed by a section called, 'Essential Reading', wherein key references used in the module that is readily accessible (i.e. with regard to language and layout) are listed and hyperlinked where practical. The lecture then proceeds with around ten 'Learning Points' that are around 3-4 sentences each, which step through the core knowledge. Each learning point has been worded so that key words can be easily extracted for PowerPoint slides or handouts. Following the learning points, the lecture includes several pages of 'Background Information', which provide both contextual information and deeper insights into the knowledge area. This is also intended to provide a straightforward and short briefing to lecturers/ trainers who may not have prior knowledge of the specific content. Following the learning points, a list of 'Optional Reading' is provided as an additional resource for assignments or further research, and a set of 'Key Words for Searching Online' are listed to assist with beginning an internet exploration.

6. Conclusion

This chapter has discussed the need for urgent capacity building in the engineering profession in the area of energy efficiency, focusing on higher education institutions. We have considered the complexity of the issue within the higher education sector, where the problem is two-fold: energy efficiency knowledge and skills are not yet being taught; and the process for curriculum renewal is generally slow and *ad hoc*. Moreover, there are a number of organisational and curriculum influences that are working to both promote and impede capacity building in energy efficiency, requiring a strategic and systematic approach to ensure that the engineering profession is being up-skilled as quickly as possible. This includes leadership and support at an institutional level, strategic planning and implementation of curriculum renewal initiatives, and within clear timeframes. Three examples of energy efficiency capacity building initiatives in Australia have been highlighted; namely two research initiatives undertaken through the National Framework for Energy Efficiency (NFEI), and modular content developed through the CSIRO's energy transformed program.

In conclusion, the research undertaken to date provides a clear understanding of the state of engineering education for energy efficiency in Australia. Furthermore, the *Energy Transformed* education package funded by the CSIRO provides a significant tool for engineering educators to access, to provide immediate and robust capacity building, from undergraduate through to postgraduate education.

7. Acknowledgements

The 2007 survey, 2009 investigation and the *Energy Transformed* education package were undertaken by The Natural Edge Project using funds provided by CSIRO and the National Framework for Energy Efficiency. Non-staff related on-costs and administrative support was also provided by the Centre for Environment and Systems Research and the Urban Research Program at Griffith University, and the Fenner School of Environment and Society and Engineering Department at the Australian National University.

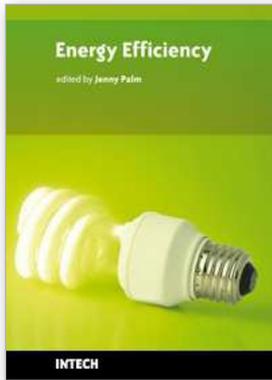
Principal reviewers for the three research initiatives included: Adjunct Professor Alan Pears - RMIT, Geoff Andrews - Director, Genesis Now Pty Ltd, Dr Mike Dennis - ANU, Engineering Department, Victoria Hart - Basset Engineering Consultants, Molly Olsen and Phillip Toyne - EcoFutures Pty Ltd, Glenn Platt - CSIRO, Energy Transformed Flagship, and Francis Barram - Bond University. The following persons provided peer review for specific lectures in the *Energy Transformed* program; Dr Barry Newell - Australian national University, Dr Chris Dunstan - Clean Energy Council, D van den Dool - Manager, Jamieson Foley Traffic & Transport Pty Ltd, Daniel Veryard - Sustainable Transport Expert, Dr David Lindley - Academic Principal, ACS Education, Frank Hubbard - International Hotels Group, Gavin Gilchrist - Director, BigSwitch Projects, Ian Dunlop - President, Australian Association for the Study of Peak Oil, Dr James McGregor - CSIRO, Energy Transformed Flagship, Jill Grant - Department of Industry Training and Resources, Commonwealth Government, Leonardo Ribon - RMIT Global Sustainability, Professor Mark Diesendorf - University of New South Wales, Melinda Watt - CRC for Sustainable Tourism, Dr Paul Compston - ANU AutoCRC, Dr Dominique Hes - University of Melbourne, Penny Prasad - Project Officer, UNEP Working Group for Cleaner Production, University of Queensland,

Rob Gell – President, Greening Australia, Dr Tom Worthington - Director of the Professional Development Board, Australian Computer Society.

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Energy Efficiency

Edited by Jenny Palm

ISBN 978-953-307-137-4

Hard cover, 180 pages

Publisher Sciyo

Published online 17, August, 2010

Published in print edition August, 2010

Global warming resulting from the use of fossil fuels is threatening the environment and energy efficiency is one of the most important ways to reduce this threat. Industry, transport and buildings are all high energy-using sectors in the world and even in the most technologically optimistic perspectives energy use is projected to increase in the next 50 years. How and when energy is used determines society's ability to create long-term sustainable energy systems. This is why this book, focusing on energy efficiency in these sectors and from different perspectives, is sharp and also important for keeping a well-founded discussion on the subject.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Cheryl Desha and Karlson 'Charlie' Hargroves (2010). Energy Transformed - Building Capacity in the Engineering Profession, Energy Efficiency, Jenny Palm (Ed.), ISBN: 978-953-307-137-4, InTech, Available from: <http://www.intechopen.com/books/energy-efficiency/energy-transformed-building-capacity-in-the-engineering-profession>

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