An Investigation into Increasing the Extent of Energy Efficiency Knowledge and Skills in Engineering Education

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***Abstract**: Today, many sectors across society are recognising the need to swiftly reduce their growing energy demand, as well as meeting remaining demand with low emissions options. A key ingredient to addressing such issues is equipping professionals – in particular engineers – with emerging energy efficiency knowledge and skills. This paper responds to an identified engineering education gap in Australia, by investigating options to increase energy efficiency content for both undergraduate and postgraduate engineers. The authors summarise the findings of the multi-stage methodology funded by the National Framework for Energy Efficiency (2008-2009), highlighting identified key barriers and benefits to such curriculum renewal. The findings are intended for use by engineering departments, accreditation agencies, professional bodies and government, to identify opportunities for moving forward based on rigorous research, and then to strategically plan the transition. This process, focused on energy efficiency, may also provide valuable parallels for a range of sustainable engineering related topics.*

1. Introduction

Society is increasingly calling for professionals across government, industry, business and civil society to be able to problem-solve issues related to climate change and sustainable development as part of their work. The Council of Australian Governments responded to this need, particularly the need to reduce energy demand and source low emissions options, by signing the *National Partnership Agreement on Energy Efficiency* in July 2009, which included a commitment to assist business and industry obtain the knowledge, skills and capacity to pursue cost-effective energy efficiency opportunities (DRET, 2009). Engineering will play a critical part among the professions, with Engineers Australia (EA, undated) acknowledging 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'.*

In 2007 the National Framework for Energy Efficiency (NFEE) funded 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). Responses from 27 of the 32 universities teaching engineering education, in every state and territory in Australia, suggested that energy efficiency education is currently highly variable and *ad hoc* across universities and engineering disciplines. The report concluded that there is an urgent need to embed energy efficiency knowledge and skills into engineering curriculum, beyond once-off courses, special interest topics, or highly specialised masters programs.

In responding to this identified gap in energy efficiency knowledge and skills, a significant barrier is the time lag in integrating new content within existing curriculum (Desha *et al*, 2009). While flagship courses and specialised 'streams' on energy efficiency have begun to emerge for a small percentage of engineering students, there is a 'business-as-usual' timeframe of up to two decades to fully and

appropriately embed new concepts across the engineering curriculum. Hence, if we are to reach the majority of the 6,000 graduates (Kaspura, 2009) entering the workforce each year in Australia, there is a need to swiftly increase the extent of energy efficiency knowledge and skills in engineering education nationally, at both undergraduate and postgraduate levels.

This research has been undertaken to provide guidance on mechanisms that can assist engineering curriculum renewal in the area of energy efficiency education, in a timely manner. The findings of this research, for which the full report is available online (Desha, Hargroves and Reeve, 2009) are intended for use by engineering departments, accreditation agencies, professional bodies and government, to identify opportunities for moving forward (based on rigorous research), and then to strategically plan the transition. This process, focused on energy efficiency, also provides possible parallels for a range of sustainable engineering related topics.

2. Investigative Methodology

The project methodology involved a multi-stage process, including a literature review, a survey, and applying the relevant parts of the Community Based Social Marketing (CBSM) approach (McKenzie-Mohr, 2007) to education for energy efficiency within the engineering education community of practice. The aspects of CBSM that were relevant to this project included:

1. Identification of a broad list of desired behaviours (i.e. 'actions', or 'options') that lecturers could undertake to increase the extent of energy efficiency in the curriculum, with 19 identified.
2. Identification of the impact and likelihood of each of the 19 options, from a global literature review and national survey of engineering educators teaching courses involving energy related content.
3. Short-listing the 19 options to consider 10 in more detail, through phone and email survey consultation, with a sample of 23 engineering educators from the 2007 survey database.
4. Investigation of the barriers and benefits to the 10 shortlisted options relevant to the current Australian higher education institution (HEI) context.
5. Consideration of strategies and tools that may be effective in reducing the barriers and improving the benefits of the options, to help educators embed energy efficiency content into engineering curriculum.

This paper outlines the findings of these five steps for consideration by engineering departments, accreditation agencies, professional bodies and government (activities and funding priorities). The authors look forward to receiving feedback from engineering educators as they read and use this report to bring about curriculum renewal in energy efficiency education.

3. Summary of Results

3.1 Identified and prioritised options

Table 1 presents the averaged likelihood and impact scores from the literature review, phone poll and email survey, for the identified options for increasing the extent of energy efficiency content within engineering curriculum in Australian universities. The table and the following plot (Figure 1) indicate an encouraging scenario with regard to the number of options that have relatively high impact and likelihood, providing a wide range of opportunities for addressing curriculum renewal for energy efficiency. The options were then shortlisted to 10 options for detailed consideration, discounting those with likelihood scores of 2.5/5 or less, or impact scores of 3.2/5 or less (Table 1, italics).

Although this investigation shortlisted 10 options for consideration, the authors note that a department may wish to create a staged list of options to be gradually implemented over time. For example, a department may decide to address the first three shortlisted options immediately, but may also be interested in 'Offer a major stream in the engineering degree on energy efficiency' as a low likelihood, high impact option, which they understand will require some strategic interventions from the pro-Vice Chancellor level with regard to some funding allocation.

Table 1. Behaviour data average scores, ordered from highest to lowest likelihood

List	Description	Likelihood (Average)	Impact (Average)
1	Include a case study on energy efficiency	4.1	3.2
2	Include a guest lecturer to teach a sub-topic	4.0	3.6
3	Offer supervised research topics on energy efficiency themes	4.0	3.2
-	~~*Offer industry placements in energy efficiency (Work Integrated learning)*~~	~~*4.0*~~	~~*2.9*~~
4	Offer energy efficiency as a topic in a problem-based learning course	3.7	3.7
5	Include *assessment* that aligns with the energy efficiency theme within the course (e.g. exam questions and assignments)	3.7	3.4
6	Include tutorials that align with the energy efficiency theme in the course (e.g. presentations/ discussions/ problem solving)	3.7	3.3
-	~~*Show a DVD of a related documentary*~~	~~*3.6*~~	~~*2.8*~~
7	Overhaul the course to embed energy efficiency	3.4	3.7
8	Include one workshop on energy efficiency in the course (i.e. experiments)	3.1	3.5
9	Include a field trip related to energy efficiency	3.1	3.5
-	~~*Add energy efficiency readings to the required reading list*~~	~~*3.1*~~	~~*2.2*~~
-	~~*Show a DVD of a keynote lecture on energy efficiency*~~	~~*3.0*~~	~~*2.6*~~
10	Develop a new course on energy efficiency	2.9	4.1
-	~~Include a topic-specific lecture set (i.e. a sub-topic) within the course~~	~~*2.8*~~	~~*3.2*~~
-	~~*Include elective modules on energy efficiency within the course*~~	~~*2.4*~~	~~*3.3*~~
-	~~*Offer a 'major' stream in the engineering degree on energy efficiency*~~	~~*2.2*~~	~~*4.2*~~
-	~~*Include several workshops on energy efficiency in the course (i.e. including laboratory style experiments)*~~	~~*2.0*~~	~~*3.6*~~
-	~~*Develop a new degree program on energy efficiency (e.g. B Energy Eng)*~~	~~*1.1*~~	~~*4.1*~~

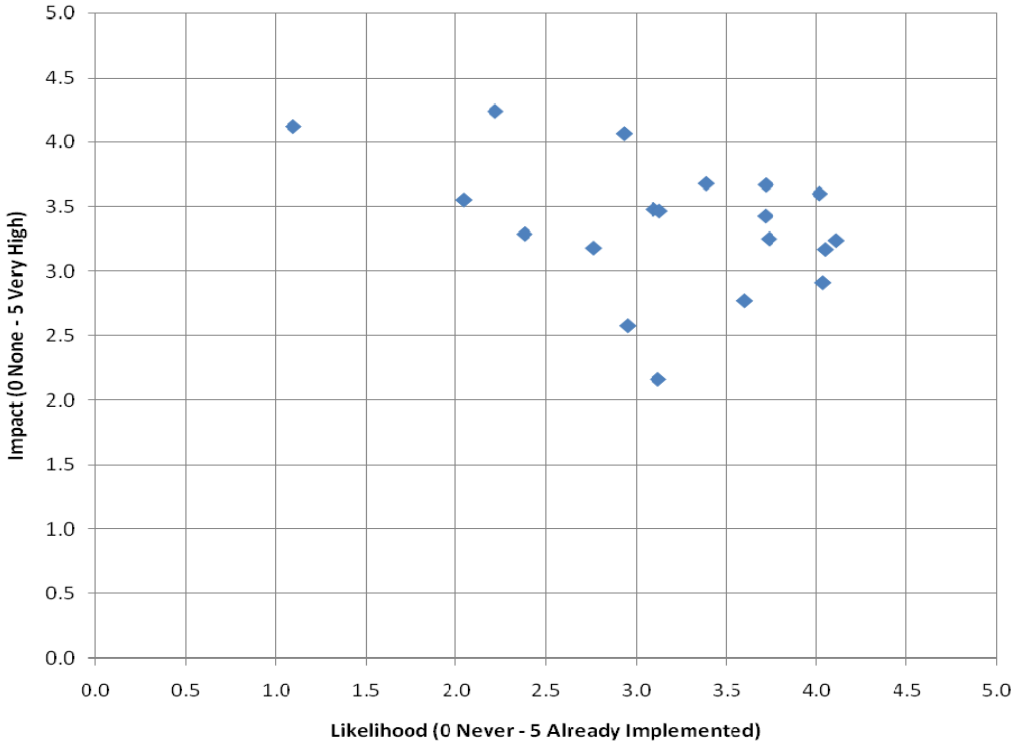

Figure 1: Plotted matrix, based on the results of the phone poll and email survey

3.2 Identified barriers and benefits for the shortlisted 10 options

Before a department can begin to use the shortlisted options to develop strategies for implementation, the CBSM methodology identifies the critical step of understanding the barriers and benefits to the options of interest at the actual level of implementation of the option (McKenzie-Mohr, 2007). Tables 3 and 4 summarise the common barriers and benefits to increasing the extent of energy efficiency in the curriculum for each of the 10 shortlisted options. The tables also highlight a number of option-specific barriers and benefits (a detailed literature review of the barriers and benefits for each behaviour can be found in the online report).

Table 3. Identified key barriers to energy efficiency education for the shortlisted options

Key Barriers and Benefits to Implementation	Prioritised Options (See previous Table)									
	1	2	3	4	5	6	7	8	9	10
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							●	●		●
Other Barriers										
– Silo-culture	●									
– Annual topic renewal		●								
– Lack of quality guest lecturers			●							
– Difficulty in making a pedagogical shift					●					
– Lack of student maturity					●					
– Difficulty of assessment						●				
– Institutional organisational structure							●			
– Lack of collaboration among colleagues							●			
– Timetabling issues								●		

Table 4. Identified key benefits to energy efficiency education for the shortlisted options

Key Barriers and Benefits to Implementation	Prioritised Options (See previous Table)									
	1	2	3	4	5	6	7	8	9	10
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				●	●	●			●	

Key Barriers and Benefits to Implementation	Prioritised Options (See previous Table)									
	1	2	3	4	5	6	7	8	9	10
– Lecturer professional development (content)		●				●				
Other Benefits										
– Improved student access to best practice	●									
– Improved pedagogy - use of case studies	●									
– Access to additional research funding		●								
– Improved student contact with employers		●								
– Lecturer access to disciplinary mentors			●							
– Curriculum load neutral					●					
– Improved enrolment										●

3.3 Identified tools and strategies to address the barriers and benefits

The research identified that the tools to reduce the barriers and increase the benefits for particular options will be case-specific, given that each department will likely have a different set of barriers and benefits to address. In this context, drawing on the CBSM literature, the authors highlight the following key tools to reduce the identified key barriers to curriculum renewal, while making the most of the identified 'benefits':

– *Incentives*	Both financial and non-financial incentives can be used to encourage staff to engage with curriculum renewal.
– *Convenience/ Remove External Barriers*	Making the curriculum renewal process more convenient than continuing with the old processes.
– *Commitment*	Publically announcing roles and responsibilities for the prioritised options within the department.
– *Social Diffusion*	Encouraging key staff members to implement the prioritised options, allowing take-up by other staff as they see benefits.
– *Prompts*	Reminding staff about a particular option, delivered in close space and time to the change trying to be achieved.
– *Norms - Descriptive and Injunctive*	Encouraging staff to act based on observed behaviours of others, then later through formalising the requirement.
– *Communication*	Using a variety of mechanisms including 'attention', 'content', 'feedback', 'framing' and 'mediums' to keep the curriculum renewal efforts visible to staff.

For the tools to be successful, the CBSM literature identifies the need for an overarching strategic plan which maps out the timeframe, responsibilities, and resource requirements. In this investigation, the development of strategies involved identifying key components that can use one or more of the above tools to bring about the behavioural change – in this case increasing the extent of energy efficiency content in the engineering curriculum. There may be more than one tool to address a barrier or benefit, but this might drive up costs. Furthermore, one strategy may be able to incorporate a number of tools, which may also reduce the overall cost of implementing the option. Despite the lack of literature and scarcity of precedents, the authors were able to identify from the literature, a number of strategic components that could be of use to engineering departments considering how to increase the extent of energy efficiency within their programs. These include:

- Including knowledge and skills in energy efficiency within their graduate attribute list for their programs
- Committing senior management support
- Recruiting staff with expertise
- Providing training
- Hosting topical event/s
- Understanding 'Hot Topic' areas
- Providing access to web-based courses
- Fostering interdisciplinary networks
- Providing financial assistance
- Creating a Working Party
- Setting future targets
- Creating a clear timeline
- Permitting workload discussions
- Providing seed funds for new research

- Providing seed funds for teaching research
- Harnessing other institutional overhauls
- Identifying and using modular content
- Investigating graduate employment options
- Directly involving potential employers
- Engaging external support for advice

In addition to opportunities within the HEIs, the authors also identified key roles for accreditation agencies, professional bodies and government, which could help to drive timely curriculum renewal. In particular the literature identified a role for accreditation bodies to include energy efficiency within accreditation requirements. The literature also identified a key role for professional bodies in providing content development and professional development support for educators. Finally the role of government was highlighted as essential in providing clear signals on the key role of energy efficiency in all major infrastructure and service provision across society, and to support capacity building initiatives put forward by the HEIs, accreditation agencies and professional bodies.

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