Energy Efficiency Education in Engineering: Engagement Strategy & Good Practice Guide

Produced by

Queensland University of Technology

On behalf of

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Energy Efficiency Education Resources for Engineering

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Project Background

Energy efficiency is widely recognised as the simplest and most cost-effective way to manage rising energy costs and reduce Australia's greenhouse gas emissions. Yet capturing its potential benefits has proved difficult. Promoting and implementing energy efficiency measures across multiple sectors requires significant development and advancement of the knowledge and skills base in Australia. Engineering has been specifically identified as a profession with opportunities to make substantial contributions to a clean and energy-efficient future.

To further enable skill development in this field, the Department of Industry commissioned a consortium of Australian universities to collaboratively develop four innovative and highly targeted resources on energy efficiency assessments, for use within undergraduate engineering curricula. These include the following, informed by three national stakeholder engagement workshops coordinated by RMIT:

1. Ten short **'multi-media bite'** videos for each engineering college of Engineers Australia and an introduction (led by Queensland University of Technology with the University of Adelaide);
2. Ten **'flat-pack'** supporting teaching and learning notes (led by University of Adelaide with the Queensland University of Technology);
3. Two **'deep-dive case studies'** including calculations (led by University of Wollongong); and
4. A '**virtual reality experience'** in an energy efficiency assessment (led by Victoria University with LaTrobe University).

Specifically, these resources address the graduate attributes of '**identifying**', '**evaluating**' and '**implementing**' energy efficiency opportunities in the workplace, incorporating a range of common and discipline specific, technical and enabling (non-technical) knowledge and skill areas.

The four resources were developed with reference to the 2012 Industry Consultation Report and Briefing Note funded by the Australian Government's former Department of Resources, Energy and Tourism (RET), and through further consultation workshops with project partners and industry stakeholders. At these workshops, participants confirmed the need for urgent capacity building in energy efficiency assessments, accompanied by **clear guidance for any resources developed**, to readily incorporate them into existing undergraduate courses and programs. Industry also confirmed three key graduate attributes of priority focus for these education resources, comprising the ability to: **think in systems**; **communicate between and beyond engineering disciplines**; and **develop a business case** for energy efficiency opportunities.

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Executive Summary

This guide has been developed to describe current and desired practice to embed energy efficiency into the curriculum, in the context of the Australian Stage 1 Competency Standard for professional engineers. It is intended that this guide will be used as a reference document by engineering deans and others responsible for curriculum revision, and to members of program accreditation panels.

The guide draws on the findings of previous Stakeholder Engagement Project consultations and previous research projects undertaken by the Recipient for the Department of Resources, Energy and Tourism. It also builds on the previous work undertaken in the Australian Learning and Teaching Council project 'Defining Your Discipline', and previous investigations on the use of accreditation to drive energy efficiency curriculum renewal .

The document includes questions and answers regarding take-up of energy efficiency resources, for each of the major disciplines identified in the RET Energy Efficiency Briefing Note produced for the Department in 2012.

1. Engagement Strategy

In this section we outline an engagement strategy (the Strategy) for use by universities and other stakeholders to raise awareness and engage engineering faculty and lecturers in energy efficiency education and to promote the uptake of the resources. We begin by clarifying what we mean by 'strategic engagement' for curriculum renewal, and then consider who and how to engage to effectively integrate energy efficiency within engineering curriculum in Australia.

Curriculum renewal is complex, involving many content and process considerations. Traditionally curriculum renewal within Higher Education has been rather *ad hoc* and variable in outcomes, driven by individual efforts. Over the last decade or so, the higher education sector has seen a significant shift in the consciousness of curriculum renewal, towards systemic, planned and integrated efforts. As documented by Desha and Hargroves (2014), examples of leadership in this space can be found in business, law, medicine and engineering.

As shown in **Figure 1**, efficient and effective curriculum renewal requires a systemic process of identifying the desired graduate attributes for a given program, learning pathways that can lead to these attributes being developed, auditing the curriculum for where corresponding learning outcomes may be present, then using this information to develop and update units/courses within the program as appropriate. Finally, implementing the renewed curriculum and evaluating its delivery against the identified attributes and pathways that relate to integrating the desired knowledge and skill area.

An example of a resultant curriculum structure is shown in **Figure 2**, where the coursework is peppered with the new knowledge and skills to be developed, through a mixture of 'Flagship' (i.e. topic-focused) courses, 'Armada' (i.e. topic-connecting, supporting) courses, other fundamental courses to the discipline of engineering being studied, and complementary elective coursework.

Critical to the success of systemic curriculum renewal is strategic engagement with end-users (i.e. universities) and moderators of undergraduate engineering curriculum (i.e. employers, professional bodies and accreditation providers). Within the complexity of curriculum renewal, there is interplay between substantial barriers and opportunities for academics engaging in curriculum renewal activities (Desha *et al*, 2009). The most significant barriers are cost and resourcing issues, followed closely by awareness and interest in the new knowledge and skills to be included within the curriculum. Opportunities perceived by academics span student retention and recruitment through to individual professional development and research outcomes. There is also a need to maintain ongoing review of desired graduate attributes. For example, issues such as climate change adaptation and emission mitigation are evolving rapidly, while technology change and industrial system design are accelerating, and require new skills and knowledge.

It is within this context that this project aimed to develop four targeted resources that address emergent knowledge and skills associated with energy efficiency assessments, providing academics with content in ways that are pedagogically suited to efficient integration within their curricula. A variety of engagement mechanisms were used by the project consortium to inform the design and development of energy efficiency teaching resources in partnership with key stakeholders from industry, academia, and government.

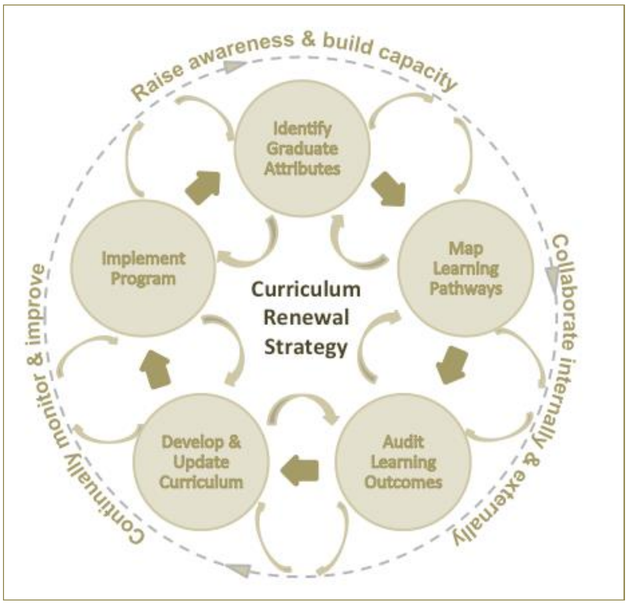

Figure 1: The Deliberative and Dynamic Model for Rapid Curriculum Renewal (Source: Desha and Hargroves, 2014)

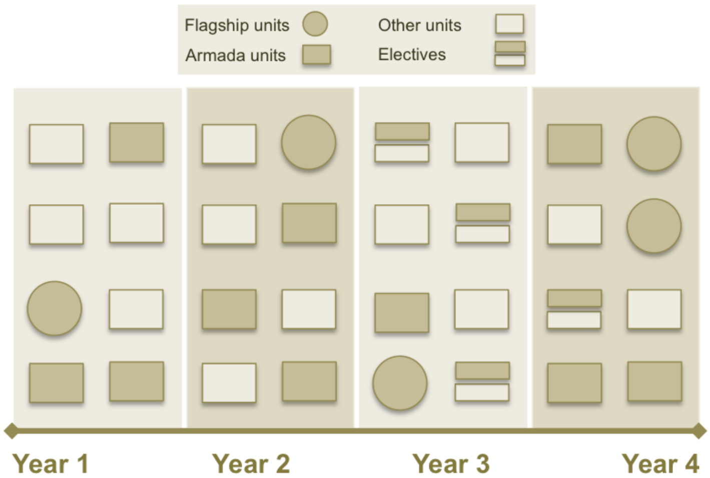

Figure 2. Illustration of an integrated curriculum, including 'flagship' (i.e. focused), 'armada' (i.e. supporting) other core units and elective options (Source: Desha and Hargroves, 2014)

However, the research is clear that such engagement towards resource development alone will not lead to change. The uptake of pre-prepared resources must sit within a broader context of institutional curriculum renewal, where strategic engagement is critical to uncover graduate attributes, learning pathways, the extent of renewal required, and where pre-prepared resources can be effectively integrated within existing and new course-work. Successful engagement in this way will result in a 'best fit' of the pre-prepared resources, complementing institutional strengths and fitting within the broader context of the institution's curriculum renewal strategy.

It is within this context that this project aimed to develop a strategic engagement document, including a good practice guide for delivering timely and effective curriculum renewal – in this case to embed knowledge and skills related to energy efficiency assessments. The following pages highlight *who* and *how* to engage to effectively integrate energy efficiency within engineering curriculum in Australia.

1.1. Engaging with key stakeholders to catalyse and inform

As illustrated in **Figure 3**, a range of organisations are interested in the competencies that students attain from undergraduate studies, as part of their pathway towards becoming professional engineers. In Australia this is defined by the two standards produced by Engineers Australia, for graduates (Stage 1 Competency Standard), and for practising engineers to gain 'Chartered' membership (Stage 2 Competency Standard) (see also **Appendix A**).

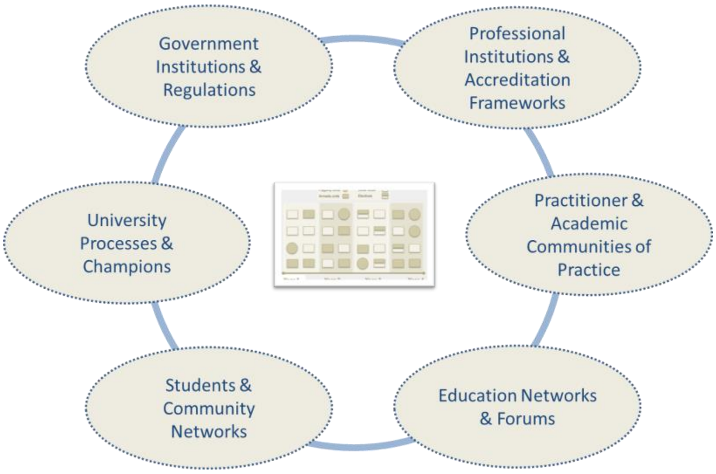

Figure 3. Strategic engagement to inform curriculum renewal

In the following paragraphs we discuss these stakeholder perspectives in relation to energy efficiency. Notwithstanding changes in government leadership and programs, and the dynamics of economic and political agendas, this commentary highlights precedent and potential for engagement to catalyse and inform curriculum renewal. From this snapshot it is evident that academics involved in engineering education have numerous ways to engage with curriculum renewal, of varying visibility and accessibility. However, it is common for new material to be introduced as an elective because of an academic's interest, rather than in any strategic plan. The challenge is then to further embed this as its importance grows. New programs then emerge organically, relying on existing networks and relationships. It is therefore important for academics to be actively involved in one or more of these stakeholder networks to be able to harness the most useful opportunities for strategic engagement at a given time.

1.1.1. Government institutions & regulations

Teaching and learning in higher education in Australia underwent a significant curriculum review in 2013-2014 across all disciplines, as part of the new *Australian Qualifications Framework* (AQF), alongside other requirements by the *Tertiary Education Quality Assurance Agency* (TEQSA). This review related to defining levels of higher education, together with knowledge, skills and application for discipline competencies in these levels. Within this regulatory environment, considerations regarding energy efficiency education in engineering have occurred in consultation with Engineers Australia, primarily through the former Department of Resources, Energy and Tourism. Beyond energy efficiency the inclusion of environment and sustainability in engineering programs has occurred largely on an institutional basis. Beyond engineering, the topic areas of 'environment' and 'sustainability' have been considered in consultation with the Environment Institute of Australia and New Zealand. Such reviews, their planning and findings have presented some opportunities for academics and universities to engage in energy efficiency conversations. Two examples include:

- Federal Government – Office for Learning and Teaching (2012-2013): Through the *Office for Learning and Teaching Grants*, the federal government funded a consortium led by Murdoch University to develop sustainable energy related graduate attributes and learning pathways for undergraduate students (see Lund *et al*, 2014).
- Federal Government – Office for Learning and Teaching (2013-2014): Through the *Office of Learning and Teaching Grants*, the federal government funded a consortium to develop undergraduate threshold learning outcomes for environment and sustainability education, to be endorsed by the EIANZ (see Office of Teaching and Learning project website).

Considering the topic area of energy efficiency, the last decade has seen substantial action nationally with regard to identifying, exploring and raising awareness about energy efficiency opportunities across major sectors of the Australian economy. Led by the previous Department of Resources, Energy and Tourism (RET), and through the Commonwealth of Australian Governments (COAG) including the National Framework for Energy Efficiency (NFEE), there has been interest in vocational and higher education curriculum renewal to develop professionals who can engage with energy efficiency initiatives. Examples of engagement towards curriculum renewal include:

- State Government – New South Wales (2012-2013, $1 million): Through the state's *Energy Efficiency Training Program*, the state government funded two universities (University of New South Wales and University of Wollongong) through a competitive tender, to develop and trial energy efficiency curriculum for undergraduate and postgraduate students spanning civil, environmental, electrical and electronic engineering disciplines (Desha *et al*, 2015).
- Federal Government – Department of Resources, Energy and Tourism, and the Department of Industry (2013-2014, $600,000): Through the *Energy Efficiency Opportunities Program*, the federal government funded two projects (Australian National University, and this EEERE consortium led by the Queensland University of Technology) to develop open-source and online energy efficiency resources for engineering (Desha *et al*, 2013).

1.1.2. Professional Institutions and accreditation frameworks

Australia is one of several countries that have one professional entity (i.e. Engineers Australia (EA)), representing and advocating for all engineering disciplines. This entity also oversees the accreditation of engineering programs (undergraduate and postgraduate) that prepare graduates to enter professional engineering practice for all disciplines nationally, in around 34 universities. Engineers Australia is a signatory of the Washington Accord, through which the graduates of the programs accredited at the professional engineers level are recognised by the 16 other signatories (as from June 2014).Engineers Australia's structure includes nine discipline-oriented colleges including biomedical, chemical, civil, environmental, electronic, information technology and electrical, mechanical, and structural engineering. Each of these colleges has connections with other organisations, listed on the EA website.

Engineers Australia has played a national advisory role in energy efficiency education (2011-2014): through the federal government's *Energy Efficiency Advisory Group*. This group comprised academic, industry and government representatives to advise on capacity building opportunities. In 2014 EA also published an energy white paper on challenges and opportunities for the engineering in Australia, responding to the federal government's Issues Paper on the same topic, highlighting the imperative for engagement with the energy agenda by the profession. Looking to energy efficiency and beyond with regard to emergent capacity building needs, there is significant scope for increasing curriculum related engagement with support from EA, with low levels of academic participation and low numbers of 'chartered' academic members reflecting a lack of current engagement between EA and academics.

1.1.3. Practitioner and academic communities of practice

In Australia there are a number of energy efficiency related organisations who are active in promoting capacity building, including those listed as partners in this project consortium. These organisations have created a variety of professional development opportunities for engineers, including forums and packaged educational resources. For example, the Australian Power Institute (API) and Mining Education Australia (MEA) have developed systems and resources targeted at specific shortfalls in capacity; these are available online and through face-to-face training for continued professional development. Building on quite specific relationships with higher education providers, there is significant potential for these communities to have broader collaboration and alliances in curriculum design and delivery. A number of academic communities also have potential to further engage in informing and promoting the need for energy efficiency education, including the Australian Council of Engineering Deans (ACED), the Australian Council of Environmental Deans and Directors (ACEDD), the Australian Academy for Technological Sciences and Engineering (ATSE), and the Engineering Associate Deans, Learning and Teaching (ADLTs) for faculties and schools.

1.1.4. Education networks and forums

Global leadership in education for sustainable development is provided through the American Association for Sustainability in Higher Education (AASHE) and the UK's Higher Education Academy (HEA). Learning from the dissemination strategies of these initiatives, in Australia we now have the "Teach Sustainability" portal, and the "Energy Efficiency Exchange (EEX)". The Australasian Association of Engineering Education (AAEE or A^2E^2) provides a major forum for discussion across all engineering disciplines. There are several global engineering education conferences for which topic-based themes periodically appear, providing platforms for dialogue and sharing. These include the annual Research in Engineering Education Symposium (REES) and its associated network (REEN), The International Federation of Engineering Education Societies (IFEES), and the World Summit on Sustainable Development Higher Education series. These are complemented by various informal community-of-practice networks with free membership, and direct engagement opportunities.

1.1.5. Students and community networks

Students and community networks have a high turn-over of membership and often informal organisational structures. However, in a deregulated operating environment, the benefits of involving students in curriculum renewal processes are substantial. This includes ensuring a grounded approach to addressing student needs and expectations for their studies, direct provocation with regard to potential topic areas of interest, and appreciation of student awareness about topics to be integrated and how this can be done. Most existing student network activities are in the area of campus operations, related to new buildings and refurbishments, and occupant behaviours (i.e. with regard to lighting, computer use, recycling etc.). There is limited involvement by students within other formal university structures, beyond course and program evaluation processes relating to student satisfaction; this is an area of significant potential engagement.

1.1.6. University processes and champions

At the coal face of curriculum renewal are the internal university processes and champions in any given university, who are critical to the success of curriculum renewal intentions being implemented. As discussed in Desha and Hargroves (2014), there is significant potential for improving the process of curriculum renewal to be more systematic and systemic in outcomes. This spans the vertical hierarchy of the university, from Tutor and Lecturer through to Subject Area Coordinator, Academic Program Director, Head of School, Assistant Dean Teaching and Learning and Dean.

1.2. Summary of engagement opportunities

From the discussion of strategic engagement opportunities, in the following sub-sections we summarise key engagement opportunities to inform and assist curriculum renewal. These call for a variety of interventions, funding or other support by stakeholders discussed in the previous section.

1.2.1. Engagement for education research

There are a number of 'education research' entities within Australian universities; however some are much more oriented towards 'action research' agendas, while others are more focused on observation and commentary. Here we identify potential *future research dimensions* that take advantage of academic and industry interest in *action-research projects* to improve the extent of energy efficiency taught in engineering programs:

- ***Mechanisms for integrating pre-prepared resources into the curriculum***: Enquiry into how to make the most of funding into development of open-source resources, exploring how to overcome barriers in curriculum integration, building on theories of curriculum renewal and institutional change. ***Potential outcomes***: Processes/ approaches and examples for integrating resources into university degree programs plus evidence of students developing desired competencies.
- ***Mechanisms for adopting systems thinking towards transformative solutions***: Enquiry into how conventional curriculum design (i.e. lectures, tutorials and workshops with often separate pieces of assessment) can be used to develop student competencies in systems thinking. Use of energy efficiency as the driver for curriculum renewal considerations, and topic area for integration. ***Potential outcomes:*** Insights into curriculum renewal opportunities for degree programs where structural changes must be limited. Potential specific items of curriculum material development.
- ***Student engagement through addressing interdisciplinary problems:*** Enquiry into how student retention can be improved (particularly in early undergraduate years) through the use of problem-based learning around interdisciplinary issues. Using energy efficiency and other real world problems as a context, exploring the opportunity for longitudinal application – i.e. stepping-up the complexity over the years of study. ***Potential outcomes***: Case studies of lived experiences in using energy efficiency as the over-arching context for problem-based learning, with design problems and resources for use elsewhere. Insight and potential solutions for real industry problems.
- ***Mainstreaming emergent knowledge & skills in engineering curriculum***: Enquiry into the broader research question of how university education can keep pace with rapidly emergent knowledge and skills in fields such as energy efficiency and enhance immediacy for students by integrating topical elements into curriculum. This builds on curriculum renewal theory and organisational change theory. ***Potential outcomes***: Processes or approaches for identifying important new knowledge and skills, and how they relate to emerging social, economic and technology developments, then incorporating this within engineering programs. Improved industry relationships in timely catering to employer needs for graduate capabilities.

1.2.2. Engagement for curriculum renewal

Building on the stakeholders highlighted above, and drawing from the federal government funded activities in energy efficiency to date (i.e. by consortium members), **Table 1** summarises a suite of potential mechanisms to foster timely curriculum renewal in energy efficiency education.

Table 1. Summary of engagement opportunities

Strategic Engagement Opportunity	Potential Catalysts "●" & Collaborators "←→"					
	Government Institutions & Regulation	Engineers Australia	Communities of Practice	Education Networks & Forums	Students & their Networks	University Processes & Champions
Recognition/reward programs - *Rewarding mainstreaming practices to integrate energy efficiency in the curriculum (within and between universities)* - *National recognition (having value for performance appraisals)*	●		●	←→	←→	←→
Energy efficiency engineering education network - *Building on Energy Efficiency Advisory Group outcomes (2011-2014)* - *Continued advisory role in matters of mainstreaming*	●			●		←→
Visiting speakers/ fellows - *Funded speaking tours and international visits for provocation & sharing lessons learnt elsewhere*	●	●	●	←→	←→	←→
Publications on energy and energy efficiency - *Public access database of resources on energy efficiency* - *Policy, discussion & technical papers to keep pace with innovation and context* - *Additional resource development in priority areas of capacity building*	●	●	←→			←→
Accreditation forums/ seminars/ workshops - *Opportunities to for informed discussion about Stage 1 Competency requirements in the context of global & local regulatory & market context* - *Formal mechanisms to enquire about new content when courses are reviewed*	←→	●	←→	←→	←→	←→
Curriculum resources showcase - *Annual trade-fair style booth & online engagement opportunity to find quality pre-prepared resources (free & for purchase)* - *Combination of free & paid displays depending on resource type*		←→	←→	●		→
EA Chartered status Academic engineer training program - *Program roll-out for academic engineers to achieve chartered status (Stage 2 Competency Standard), including evidence of curriculum innovation in addressing Stage 1 competency requirements.*		●		←→		●
Energy efficiency – innovation & employment networking events - *Events organised through student groups & student engagement at universities, to promote employment & research connections*			←→		●	●

2. Good Practice Guide

This section provides guidance to stakeholders engaging with the educational resources in the form of a 'good practice guide', spanning 'what' and 'how' to teach engineering students energy efficiency related knowledge and skills. It accompanies the 'Briefing Note for Energy Efficiency' (see **Appendix B**, 30pp), which was funded by the federal government in 2012 to explain how energy efficiency – and specifically energy efficiency assessments – relate to the engineering profession. It is noted that undergraduate courses can target more than one discipline (and discipline), consistent with what is expected of many engineers in the field, to engage with integrated approaches and be able to work with other specialists, knowing enough to evaluate or corporate in project work.

2.1. What is meant by good practice in teaching Energy Efficiency?

'Good practice' is a term often interchanged with 'best practice', but which has a very different meaning. In contrast to *best practice*, which implies striving for leadership and innovation, when we discuss *good practice* in this document, we mean educational considerations that:

1. Meet *program accreditation requirements* of Engineers Australia;
2. Provide a *common benchmark* for which energy efficiency knowledge and skills should form part of an engineering undergraduate program.
3. Enable curricula to be developed and delivered *within normal staff resourcing circumstances*;
4. Integrate knowledge and skills that fit within normal professional development expectations.

In the following sections we discuss good practice with regard to content and process considerations, drawing on formal and informal expectations by the stakeholders consulted in this project. It is acknowledged upfront that for each university offering engineering curriculum the operating context will be unique, as highlighted in **Table 2**.

Table 2. University contexts contributing to 'good practice' outcomes

University context	Influence on good practice outcomes
Organisational community	*Expectations within communities of association such as the 'Group of eight', 'Australian Technology Network', the 'Regional Universities Network' and the Innovative Research Universities.*
University mission statements	*Specific university mission statements and other strategic documents, which can override or underpin curriculum renewal activities*
Operating funds	*Availability of funds to undertake activities such as curriculum renewal, professional development, seek expert contribution to design and/or delivery*
Geographical location	*Needs of surrounding employers and expectations of students*
Industry interaction	*Academic experiences directly or indirectly through research projects, with real-world applications of the theory being taught*
Approach to teaching and learning	*Overarching requirements for curriculum in the institution to be implemented through approaches such as 'problem based learning', 'inverted learning', 'blended learning', 'distance education', and 'capstone education'*

Considering this broad context for addressing educational needs in a given program, it is obvious that 'good practice' cannot be defined as an explicit list of knowledge and skill needs, or ways in which this should be delivered. Rather, the unique qualities of each university will determine which practices it has in common with others, and how it addresses a challenge such as integrating energy efficiency into its engineering curriculum. However, achievement of accreditation compliance and graduate attributes that meet institutional, industry and student expectations provide an umbrella. In the following sub-sections, we present overarching guidance to accompany the detail provided in the publically available '*Briefing Note for Energy Efficiency*'.

2.1.1. Content considerations

Despite growing awareness of the importance of energy efficiency in both industry and academia, the current depth and breadth of energy efficiency content in courses does not reflect this. In the field of energy efficiency, some engineering disciplines have progressed further than others in considering how to integrate such knowledge and skills within the curriculum. Indeed, in some disciplines there are already a variety of tools and resources to standardize what is taught. Two content considerations are highlighted here, to integrate energy efficiency within the curriculum. Details regarding the energy efficiency priority knowledge and skill priorities can be found in the '***2012 Industry Consultation Report'*** (see summary of workshop findings in **Appendix C**) funded by the federal government.

1. Energy efficiency in the broader context

The topic of 'energy efficiency' is one knowledge and skill topic area within a larger field of 'sustainability' and 'sustainable development', which is one of the many fields that are guiding the development of engineering curriculum. As illustrated in **Figure 4**, this 'thin slice' of knowledge and skills is currently a focus of government and industry, as a key way to address several challenges of: reducing the impact of rising energy prices; avoiding infrastructure costs through reducing peak energy use; mitigating further climate change through curbing greenhouse gas emissions; enabling the transition to alternative energy sources that can meet lower consumption needs; and enhancing quality of life and business productivity.

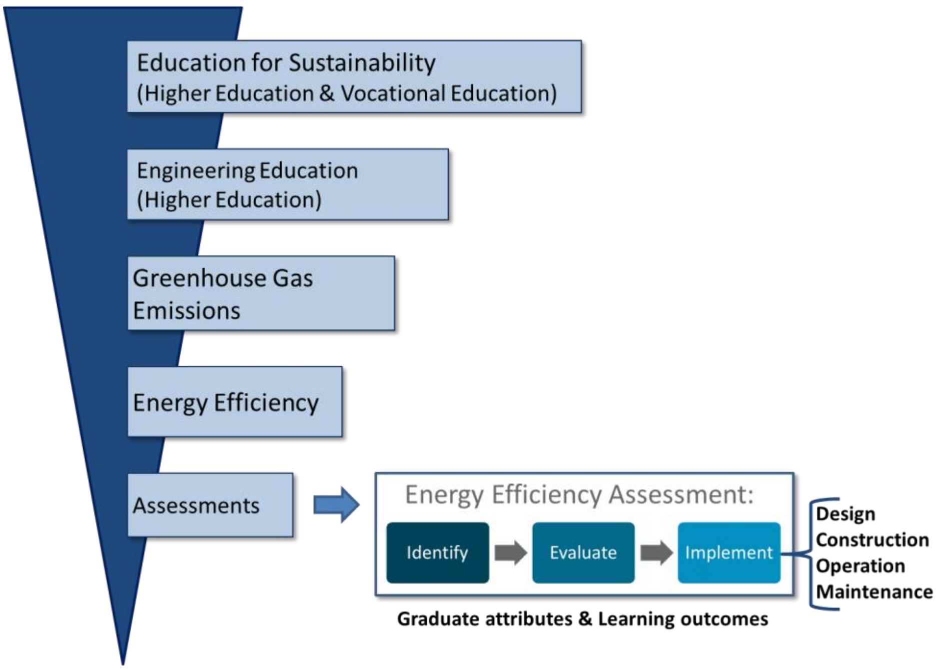

Figure 4. Energy efficiency as part of a broader context (Source: Adapted from Desha *et al*, 2013)

It can be seen from **Figure 4**, that integrating energy efficiency within the curriculum is a key way to demonstrate that sustainability knowledge and skills are being developed. Furthermore, the graduate attributes and associated knowledge and skills developed in the topic area of energy efficiency build towards developing critical graduate attributes related to sustainability and sustainable development.

2. Developing 'enabling' and 'technical' knowledge and skills

Topics within 'energy efficiency' knowledge and skills span one or both of two categories:

1. ***Enabling knowledge and skills***, which include communication, stakeholder engagement, project management, change management and leadership.
2. ***Technical knowledge and skills***, which include formulae, calculations, metrics, design, monitoring and evaluation.

This is highlighted in **Figure 5**, where discipline-specific, technical and enabling knowledge and skills fit within a larger context of whole systems thinking. Between the technical and enabling knowledge and skills there are a set of 'cross-disciplinary' skills that lend themselves to being taught across engineering disciplines, rather than within the silos of each discipline, permitting problems to be considered in context. Indeed there is scope for teaching across traditional boundaries of professions engaging stakeholders with interests in contractual arrangements, financial options, and risk management etc, all of which are important components of achieving energy efficiency improvements.

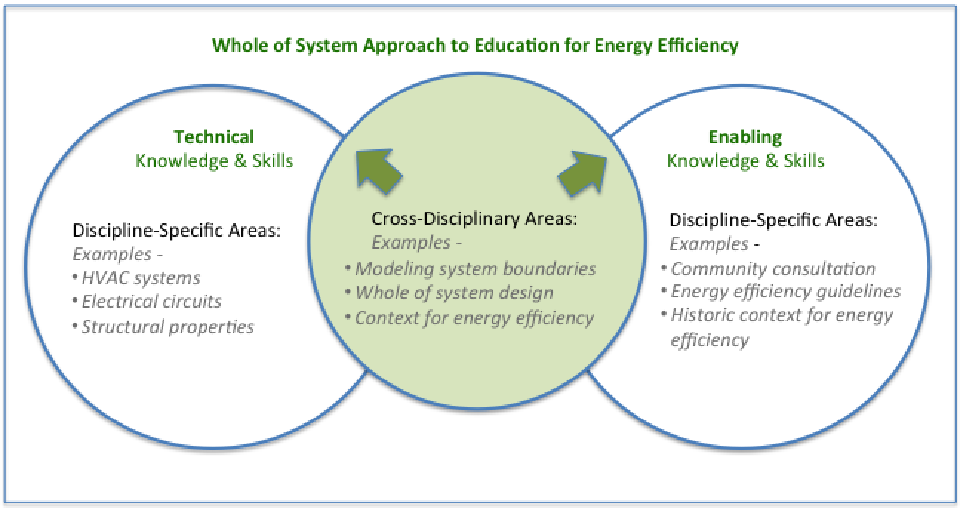

Figure 5. Diagram of knowledge and skills in energy efficiency education (Source: RET, 2012)

Key enabling knowledge and skill-sets include:

1. 'Big picture' thinking, whole systems design and whole-of-life analysis, as well as 'services thinking' where a clear understanding of the services that users want drives design and implementation of systems
2. Ability to effectively communicate efficiency opportunities and to present a basic financial case for initial up-front investment in more energy efficient technologies.
3. Awareness and capacity to draw upon the specialist skills of other disciplines and professions.

Technical knowledge and skill-sets can be considered within the context of 'identifying', 'evaluating' and 'implementing' energy efficiency assessments. Key areas previously identified span broad issues and the specifics of energy assessments, include:

1. Knowledge of relevant legislation and codes
2. Appreciation of the difference between 'Peak' and 'Base' energy load
3. Understanding of the link between energy and greenhouse gas emissions
4. Awareness of synergies between energy efficiency and other environmental performance
5. Ability to quantify the economic and business benefits of energy efficiency
6. Ability to evaluate performance to verify anticipated performance and savings.

2.1.2. Process considerations

Considering the variety of requirements within existing highly regulated engineering programs, curriculum renewal has a tendency to be quite complex and time-consuming. As discussed in the previous section, for each institutional context there are also many cultural, demographic, geographic and economic aspects that affect what constitutes 'good practice' for that institution. For each university and program, available options will therefore be different for integrating new knowledge and skill areas within the curriculum. Two process considerations are highlighted here, as examples of how to integrate energy efficiency within the curriculum.

1. Program and resource management opportunities

Curriculum renewal in the absence of good program management and resource management can be an overwhelming, frustrating, demoralising and lip-service experience for academic staff. As highlighted in Figure 1, it is critical to have a systemic approach to the process if the experience and outcomes are to be in the best interests of university staff and students.

Research relating to process challenges for embedding energy efficiency in the curriculum highlights several opportunities for 'good practice' as highlighted in **Table 3**. These resonate with the types of engagement opportunities listed in Table 1, between government, industry, academia and professional associations.

Table 3. Good practice elements for program and resource management

Good practice element	Details
Recognise the intent for integration	*Senior level recognition of the intent to integrate energy efficiency into the curriculum including a timeframe, enabling the formation of structures such as working groups and champions, and allocation of time and resources.* *(e.g. via senior advisory board/ working group/ executive)*
Plan for existing and new resources	*Identifying where new and existing high quality learning resources need to be integrated in the desired topic areas.* *(e.g. via content reconnaissance, expert advice, industry consultation)*
Engage with Teaching & Learning	*Engagement with teaching and learning support where appropriate, to streamline integration* *(e.g. with curriculum mapping, learning outcomes, curriculum renewal processes)*
Recognise/reward – staff	*Rewarding individuals and teams who initiate practices to integrate energy efficiency in the curriculum* *(e.g. monetary, fellowships, citations)*

Recognise/reward – students	*Supporting of student competitions, within and alongside program requirements (e.g. funding and endorsement)*
Collaborate with Industry – research	*Supporting educators to engage with industry through a variety of confidential and open-access research projects that address energy efficiency challenges (e.g. seed funding, proposal support, paper incentives)*
Collaborate with Industry – teaching	*Supporting educators to engage with industry through teaching endeavours. (e.g. content support (case studies, assessment problems, data access), guest lectures, site visits, student placements)*
Collaborate with Industry – engagement	*Initiating periodic conversations for industry and academia on energy efficiency (e.g. round table, forums, seminars)*

2. Interdisciplinary education opportunities

Good practice opportunities arise in shared curriculum development between disciplines for particular common component knowledge and skills, where technical and enabling knowledge and skills are cross-disciplinary in nature, as shown in **Figure 6**. For example, this could take the form of a ‘core’ flagship course (i.e. a subject/ unit) that provides an interdisciplinary learning experience in energy efficiency for all engineering students in a program, through to courses in one discipline offered as elective options for students in other disciplines.

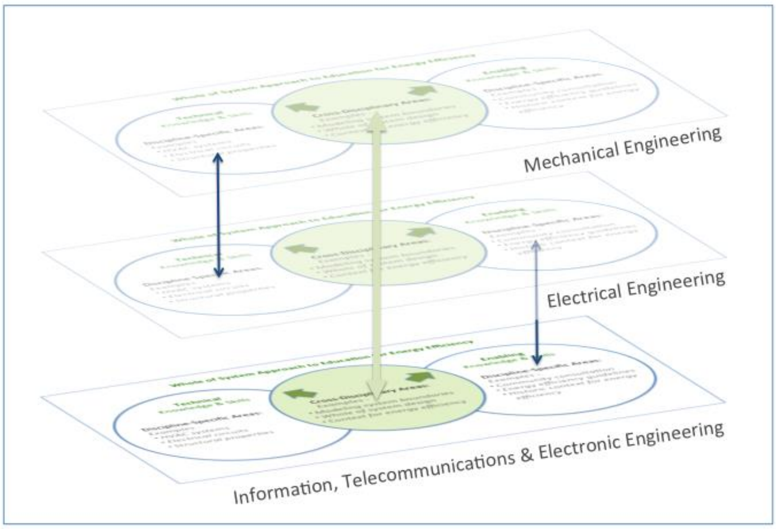

Figure 6. Illustration of the potential for shared curriculum in energy efficiency education (Source: RET, 2012)

There are clear benefits in adopting an interdisciplinary approach to integrating a new knowledge and skill-set, including:

1. A focused teaching environment to introduce or progress core knowledge and skill areas.
2. A clear context for engaging industry and employers interested in energy efficiency outcomes
3. Student benefits in interdisciplinary learning
4. Expanded community of practice in energy efficiency, spanning disciplines
5. Greater flexibility for graduates regarding employment

Considerations in adopting an interdisciplinary approach to energy efficiency knowledge and skill integration include:

- Who will be tasked with leading the interdisciplinary approach and how they will be supported.
- Potential implications for disciplines through team-teaching and service-teaching (i.e. elective offerings), and assessment methods.
- Timetabling coordination to ensure that the proposed curriculum is able to be implemented.

2.2. Evaluating energy efficiency knowledge & skill development

In any transition, it is important to know whether intentions and actions lead to desired outcomes. This section highlights good practice options for evaluating energy efficiency knowledge and skill development, *internally* at the level of program management, and *externally* through formal accreditation processes. The 2012 'Energy Efficiency Education Briefing Note' funded by the federal government, forms the basis of good practice considerations discussed here. It is intended to be a key communication tool to share what is possible in embedding energy efficiency, and to inform efforts to achieve such possibilities.

2.2.1. Internal program evaluation

In integrating energy efficiency knowledge and skills, good practice pedagogical activities will ensure that the content derives from a holistic approach to energy efficiency and is easily used and adapted within curricula. It will include: clear aims and objectives; learning outcomes with appropriate depth of coverage, and be developed by a reputable author or organisation, which could be internal or external to the university. Critical questions include:

1. What is being taught in energy efficiency education?

Review the implemented curriculum against the intended (mapped) learning pathways for:

1. Enabling knowledge and skill development
2. Common technical knowledge and skill development
3. Discipline-specific knowledge and skill development

2. Where is energy efficiency education being experienced by students?

Review the program and enquire into student perspectives regarding their experience of:

1. Flagship courses on energy efficiency
2. Other core (common) course contribution to developing the knowledge and skills
3. Other (elective) course contribution to developing the knowledge and skills
4. Any perceived contradictions or gaps between intent of courses and energy efficiency

3. How is energy efficiency education being taught and experienced?

Review the implemented curriculum for a range of learning and teaching tools, for example:

1. A set of case studies on energy efficiency examples in engineering,
2. Worked examples of the application of energy efficiency,
3. Lecture notes on energy efficiency opportunities, specifically by sector and technology, and
4. Mini-lectures or provocations (i.e. lecture guides and study materials) on key topics.
5. Guest lectures by external experts in the topic areas of interest.
6. Real or virtual field trips related to the topic areas.
7. Assessment alignment with the knowledge and skills to be developed.

2.2.2. External accreditation considerations

In 2011, Engineers Australia (EA) adopted a revised Stage 1 Competency Standard, to include additional clarity with regard to graduate attributes and component knowledge and skill expectations. Interwoven within the current version of the standard are a number of expectations regarding sustainability competencies (**Appendix A**). Here we provide examples of accreditation review questions that might be directed at understanding the extent to which the engineering program being considered addresses the sustainability components of the Competency Standard. We do this through the topic area of 'energy efficiency', which has been acknowledged by EA in the 2014 Energy White Paper as an urgent and far-reaching agenda item for the profession.

Table 4. Example accreditation questions directed at energy efficiency knowledge and skills

Item	Example Questions
1.	**Knowledge and skill base**
1.1	*Comprehensive, theory based understanding of the underpinning natural and physical sciences and the engineering fundamentals applicable to the engineering discipline* How does this program develop a comprehensive understanding of efficient utilisation of energy and its role in engineering?
1.2	*Conceptual understanding of the mathematics, numerical analysis, statistics, and computer and information sciences which underpin the engineering discipline* How does this program prepare students to study energy and energy efficiency?
1.3	*In-depth understanding of specialist bodies of knowledge within the engineering discipline* How does each discipline in this program develop an in-depth understanding of energy efficiency?
1.4	*Discernment of knowledge development and research directions within the engineering discipline* How do students find out about emerging research and research directions in energy efficiency?
1.5	*Knowledge of engineering design practice and contextual factors impacting the engineering discipline* How does this program develop knowledge of energy and its efficient use as a critical contextual factor impacting the engineering discipline?
1.6	*Understanding of the scope, principles, norms, accountabilities and bounds of sustainable engineering practice in the specific discipline* How does this program address the role of efficient use of energy in contemporary engineering practice, with a particular focus on sustainability?
2.	**Engineering application ability**
2.1	*Application of established engineering methods to complex engineering problem solving* How does this program develop whole system thinking and assessment skills?
2.2	*Fluent application of engineering techniques, tools and resources* How does this program develop the ability to apply energy related techniques, tools and resources that support understanding of energy flows and identification of potential for efficiency improvement?
2.3	*Application of systematic engineering synthesis and design processes* How does this program develop the ability to apply systemic processes to energy evaluation?
2.4	*Application of systematic approaches to the conduct and management of engineering projects* How does this program develop the ability to systematically implement energy efficiency considerations in projects?
3.	**Professional and personal attributes**
3.1	*Ethical conduct and professional accountability* How does this program address ethical conduct and accountability in the area of energy?
3.2	*Effective oral and written communication in professional and lay domains* How does this program develop oral and written communication with regard to energy efficiency opportunities?
3.3	*Creative, innovative and pro-active demeanour* How does this program develop creative, innovative and pro-active behaviour towards energy and its utilisation?
3.4	*Professional use and management of information* How does this program develop the ability to professionally use and manage energy information?
3.5	*Orderly management of self, and professional conduct* How does this program develop the ability to manage self and professional conduct?
3.6	*Effective team membership and team leadership* How does this program develop the ability to manage, lead and participate in interdisciplinary teams?

3. Conclusions & recommendations

This document presents an engagement strategy and good practice guide to accompany the energy efficiency education resources prepared by the project consortium. The aim of the document is to enable the development of curricula that incorporate a suite of knowledge and skill outcomes that, if possessed by practising engineers, would provide the basis for equipping them to effectively participate in energy assessments, including identifying, evaluating and implementing opportunities. It should be emphasised that focuses on energy assessment as a component of energy considerations, which is a key activity in which most engineers will participate in their professional activity. Through 'implementation' it includes techniques and skills applied during the design, construction, operation and maintenance of plant and equipment.

Looking beyond the topic of energy efficiency, all engineering education providers in Australia have the potential – and a professional obligation – to holistically and efficiently integrate emergent critical knowledge and skill needs within their curricula. In this report we have explicitly considered what 'strategic engagement' should occur to ensure that this occurs, and what 'good practice' means in the context of equipping students with energy efficiency assessment capabilities. In the absence of a similar report for undergraduate engineering education, it is proposed that the document is useful in a much broader context, for guidance in curriculum renewal in any topic area.

With regard to ***strategic engagement***, four remarks are made:

1. Curriculum renewal is a complex process, involving the interaction of large and complex bureaucracies and a relatively time-poor and resource-poor cohort of academics.
2. The potential for rapid curriculum renewal is underpinned by a systemic approach to 'who' and 'how'. This extends beyond the institution itself, to taking advantage of the needs and interests of key stakeholders.
3. Entities wanting curriculum renewal need to support – structurally and financially – networks that engage academics. This extends to academic councils and professional institutes listed in this report.
4. Academics need to be engaged in networks and forums related to education in their topic areas. Consolidation of these is recommended where practicable, to maximise the use of limited funds and minimise duplication of efforts.

With regard to ***good practice***, three remarks are made:

1. This document builds on nearly a decade of preparatory work involving a relatively small group of stakeholders and individuals with global awareness of good practice and who have a variety of experiences in curriculum renewal processes, and teaching and learning in energy related fields. The content of this report should be regarded accordingly, as provocation and suggestive of what should be common practice going forward.
2. 'Good practice' spans content (i.e. knowledge and skills), professionalism (i.e. pedagogy and professional development), and process (i.e. strategic engagement, procedures for curriculum renewal). This report should be read with this regard for teaching and learning expectations.
3. 'Good practice' includes a relationship with 'timeliness', which is enabled through making the most of existing opportunities, including:
    - *Content*: the availability of existing and accessible resources in the topic area
    - *Professionalism*: drawing on and further cultivating existing staff strengths
    - *Process*: utilising existing networks, relationships and initiatives.

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APPENDIX A:

Competency Standards - Extracts

Stage 1 Competency Standard for Graduate Engineers
Stage 2 Competency Standard for Chartered Engineer Status

Engineers Australia Stage 1 Competency Standard (Extract)

The following text summarises the expected competencies and elements of competencies, of graduating 'Professional Engineers' in Australia (see Engineers Australia website for component indicators that form the knowledge and skill base for these competencies):

The three Stage 1 Competencies are covered by 16 mandatory Elements of Competency. The Competencies and Elements of Competency represent the profession's expression of the knowledge and skill base, engineering application abilities, and professional skills, values and attitudes that must be demonstrated at the point of entry to practice.

The suggested indicators of attainment in Tables 1, 2 and 3 (not provided – but the example of engineering application is useful) provide insight to the breadth and depth of ability expected for each element of competency and thus guide the competency demonstration and assessment processes as well as curriculum design. The indicators should not be interpreted as discrete sub-elements of competency mandated for individual audit. Each element of competency must be tested in a holistic sense, and there may well be additional indicator statements that could complement those listed.

1. KNOWLEDGE AND SKILL BASE

- 1.1. Comprehensive, theory based understanding of the underpinning natural and physical sciences and the engineering fundamentals applicable to the engineering discipline.
- 1.2. Conceptual understanding of the, mathematics, numerical analysis, statistics, and computer and information sciences which underpin the engineering discipline.
- 1.3. In-depth understanding of specialist bodies of knowledge within the engineering discipline.
- 1.4. Discernment of knowledge development and research directions within the engineering discipline.
- 1.5. Knowledge of engineering design practice and contextual factors impacting the engineering discipline.
- 1.6. Understanding of the scope, principles, norms, accountabilities and bounds of sustainable engineering practice in the specific discipline.

2. ENGINEERING APPLICATION ABILITY

- 2.1. Application of established engineering methods to complex engineering problem solving.
- 2.2. Fluent application of engineering techniques, tools and resources.
- 2.3. Application of systematic engineering synthesis and design processes.
- 2.4. Application of systematic approaches to the conduct and management of engineering projects.

3. PROFESSIONAL AND PERSONAL ATTRIBUTES

- 3.1. Ethical conduct and professional accountability
- 3.2. Effective oral and written communication in professional and lay domains.
- 3.3. Creative, innovative and pro-active demeanour.
- 3.4. Professional use and management of information.
- 3.5. Orderly management of self, and professional conduct.
- 3.6. Effective team membership and team leadership.

Engineers Australia Stage 2 Competency Standard (Extract)

The following text summarises the expected competencies required for 'Chartered Professional Engineers' in Australia (see Engineers Australia website for additional standards and descriptions comprise these competencies). Note that these are currently under review.

The Stage 2 competency standards are generic in the sense that they apply to all disciplines of engineering in four units, spanning 16 elements. Each unit contains 3-5 elements of competencies and associated indicators of attainment. The units and elements are summarised here:

A. SELF

1. Deal with ethical issues - *means you demonstrate an understanding of the ethical issues associated with your work or practice area, and how these are managed collectively by your organisation, project or team, and you demonstrate an ability to identify ethical issues when they arise, and to act appropriately*
2. Practise competently - *means assessing and applying the competencies and resources appropriate to the engineering task*
3. Responsibility for engineering activities - *means adopting a personal sense of responsibility for your work*

B. COMMUNITY

4. Develop safe and efficient solutions - *means that you are aware of current workplace health and safety requirements, and you take into consideration short and long-term implications of the engineering activities*
5. Engage with the relevant community and stakeholders - *means that you recognise the relevant community and stakeholders, and can identify and respond to relevant public interest issues*
6. Identify, assess and manage risks - *means that you should develop and operate within a hazard and risk framework appropriate to the engineering activity*
7. Meet legal and regulatory requirements - *means that you should be able to identify the laws, legislation, regulations, codes and other instruments which you are legally bound to apply*

C. WORKPLACE

8. Communication - *means that you communicate efficiently, honestly and effectively*
9. Performance - *means that you work within an operational system to achieve corporate objectives while recognising personal obligations to the profession*
10. Taking action - *means that you initiate, plan, lead or manage engineering activities*
11. Judgement - *means that you exercise sound judgment in engineering activities*

D. CREATING VALUE

12. Advance engineering knowledge - *means that you comprehend and apply advanced theory-based understanding of engineering fundamentals*
13. Local engineering knowledge - *means that you comprehend and apply local engineering knowledge*
14. Problem analysis - *means that you define, investigate and analyse engineering problems and opportunities*
15. Creativity and innovation - *means that you develop creative and innovative solutions to engineering problems*
16. Evaluation - *means that you evaluate the outcomes and impacts of engineering activities*

APPENDIX B:

Energy Efficiency Education - Briefing Note

A note to the Australian Engineering Profession on energy efficiency and capacity building needs, by major discipline

APPENDIX C:

Energy Efficiency Education – Industry Consultation Final Report

Extract of Section 4 of the final report ("Summary of Workshop Findings"), summarising academic and industry consultation regarding three graduate attributes and their component knowledge and skill areas.

4. Summary of Workshop Findings

The following paragraphs summarise the raw data from all three workshops, which is provided in **Appendix D** and **Appendix E** [of the full final report]. In considering the raw data it is important to recognise that frequency of a theme is not an absolute measure of its importance, as this can be confounded by other factors (e.g. the persuasive speaking style of other workshop participants). In the write-up, the research team used additional tools including personal notes, audio-recordings and internal crosschecking to ensure that the summary holistically represents the workshops.

4.1 Industry Perceived Gaps and Education Implications

Several ‘emergent themes’ (i.e. ideas that had resonance) were apparent in the findings from the three workshops and the pre-workshop consultation with the colleges in relation to i) critical energy efficiency knowledge and skills gaps perceived by industry, and ii) curriculum considerations by educators. These findings have been aggregated in Tables 3-5 for each of the three key graduate attributes:

- Ability to effectively participate in energy assessments
- Ability to evaluate opportunities
- Ability to implement opportunities (i.e. including design, construct, install, maintain).

The three tables have been constructed as a way to convey key messages. In this context they provide a detailed snapshot of current industry and academic community perceptions of what is needed and how this relates to current accreditation requirements. The implications for each ‘component knowledge and skill’ for learning pathway and curriculum design have been identified in each table by highlighting, whether they are technical or enabling, and discipline-specific or cross disciplinary. The final column shows how the industry perceptions relate to the Engineers Australia Stage 1 Competency Standard, and how subsequent curriculum considerations can address industry gaps, and thereby address their corresponding Stage 1 Competency requirements (see **Appendix A**).

For example, in Table 3, considering the first half of the table “Perceived Critical Gaps - Industry clustered themes”:

- Nine gaps were recognised by industry (first column)
- The first most discussed critical gap perceived by industry was *‘Knowledge of energy principles, energy and relative amounts of energy needed for certain processes’* (first column)
- This gap relates to the Stage 1 competency 1.1 *‘Comprehensive, theory based understanding of the underpinning natural and physical sciences and the engineering fundamentals applicable to the engineering discipline’* (final column)
- This gap has aspects of technical, discipline-specific and cross-disciplinary learning (represented by the dots).

Considering the second half of Table 3 “Component knowledge and skills and learning pathways - Academic clustered themes”:

- Nine component knowledge and skills were identified by academics (first column)
- The component knowledge/ skill that addressed most gaps was the ‘Ability to participate in the design phase’ (first column)
- This knowledge/ skill area relates to the industry gaps numbered 2, 3, 5, 6, 7, 8, 9
- This knowledge/ skill area includes aspects of technical, enabling, discipline-specific and cross-disciplinary learning (final column).

4.2 Future Opportunities

Considering the emergent consensus around the term ‘energy efficiency’ as it relates to engineering, participants from all disciplines frequently went beyond RET-directed energy efficiency considerations (i.e. process improvement opportunities), discussing the need for education about energy use, fossil fuel energy alternatives (e.g. renewables) and reducing overall consumption (see findings in the main report and raw data in appendices). This was despite all engagement questions being framed to address RET’s scope.

This points to a broader interpretation of the term “energy efficiency” in the academic and industry communities, where there appear to be a number of different definitions of energy efficiency in use. While the department views energy efficiency as a distinct and separable component of energy and sustainability considerations, the emergent community of industry and academic professionals practicing within the sector view energy efficiency, energy use and sustainability as inseparably linked. Hence, responses to RET’s enquiry are evident throughout the findings, in addition to a number of broader considerations.

Emergent themes for action identified in the workshops are summarised by issue, opportunity, and potential key role players in Table 6. Some participants viewed their discipline as playing a specific role in (e.g. chemical and mechanical engineering) energy efficiency, while participants from other disciplines such as environmental engineering, envisioned a unique, future role for themselves in bringing together strands of knowledge from other disciplines in a collaborative way. Throughout the phone and workshop consultation, the ITEE college participants demonstrated a high level of awareness with regard to their relevance to energy efficiency in a variety of industries; from housing and electricity supply, to communications technology and transport programming. The action list in Table 6 does not explicitly mention these, but there is the potential for such discipline-based nuances to be accommodated in future measures.

Table 3: Workshop Findings - Ability to Effectively Participate in Energy Assessments

Graduate Attribute: Ability to Effectively Participate in Energy Assessments **Emergent Knowledge and Skill Areas (Industry), and corresponding component knowledge and skills (Academia)**	**Technical**	**Enabling**	**Discipline-specific**	**Cross-disciplinary**	**Mapping Gaps & Competencies**
Perceived Critical Gaps - Industry clustered themes ***(Ordered by extent of written and discussed consideration)***					**EA Stage 1 Competencies**
1. Communication skills (including engaging with personnel, report writing, presentation skills, listening skills, question-and-answer skills, ability to 'translate' to different business areas) ◊		●		●	**3.2, 3.4**
2. Systems awareness, whole systems thinking, holistic approaches (Framing systems) ◊	●			●	**1.1, 1.2, 1.5, 2.1, 2.2, 2.3, 3.1**
3. Collaboration, cross-disciplinary approaches, ability to work in a group ◊		●		●	**3.5, 3.6**
4. Understanding of the auditing process (including the importance of appropriately framing questions)	●	●	●	●	**2.4, 3.1, 3.4, 3.5**
5. Knowledge of measuring technologies and metrics, ability to identify inputs/outputs/losses	●		●	●	**1.2, 2.1**
6. Knowledge of energy principles, energy & relative amounts of energy needed for certain processes	●		●	●	**1.1**
7. Knowledge of benchmarking /best practice/standards and requirements	●		●		**1.5, 1.6**
8. Workshop facilitation skills		●		●	**3.3, 3.6**
9. Research skills		●		●	**2.1, 3.4**
Component knowledge and skills and learning pathways - Academic clustered themes ***(Ordered by number of industry gaps addressed)***					**Addressing Industry Gaps**
Ability to participate in design phase *Understanding design components, Working with team members, Communication, Making energy assessments of a proposed design/solution, Influencing design decisions*	●	●	●	●	**1, 2, 3, 5, 6, 7, 9**
Ability to conceptualise the "Big picture" *Systems awareness, Critical analysis, Process modelling, Awareness of the limits of software packages, Engaging a holistic, interdisciplinary approach to problem-identification, Consideration and identification of all inputs, outputs and control options, Awareness of human interaction with systems and potential for behavioural change*	●	●		●	**2, 3, 5, 6, 7**

Ability to apply core engineering technical skills to EE problems *Applying thermodynamics, Modelling processes, Evaluating energy consumption in signal reductions processes (ITEE), Identifying hidden losses*	●		●	●	**2, 5, 6, 7**
Ability to make and test assumptions *Working with imperfect data sets, Modelling processes, Conceptualising systems and representing them diagrammatically*	●			●	**2, 4, 5, 9**
Understanding of core energy principles and their connection to discipline-specific foundation knowledge	●		●	●	**5, 6, 7**
Ability to make energy measurements *Measuring and monitoring skills*, *Estimation skills*	●		●		**5, 9**
Understanding of industry 'best practice' *Awareness of regulatory requirements and industry programs, Researching similar scenarios and outcomes, Benchmarking and measuring*	●		●	●	**4, 7**
Ability to communicate verbally *Managing interpersonal relationships, Utilising appropriate questioning technique, Effective listening*		●		●	**1, 8**
Ability to communicate non-verbally *Summarising data and concise report writing, Accurate note-taking in the field, Proficient documentation skills*		●		●	**1, 8**

◊ These items (generated by industry), were perceived as important across all sectors, with certain industries appearing to rank them as particularly important. This was most apparent during the phone consultations. For example, the comments from some chemical engineers suggest that they perceived chemical engineering as having a special role as a facilitator of energy efficiency improvements, and some environmental engineers saw a particular role for their discipline in facilitating collaboration or being able to bring other disciplines together, while ITEE engineers were acutely aware of their discipline's application to a wide range of sectors and industries.

Table 4: Workshop Findings - Ability to Evaluate Energy Efficiency Opportunities

Graduate Attribute: Ability to Evaluate Energy Efficiency Opportunities **Emergent Knowledge and Skill Areas (Industry), and corresponding component knowledge and skills (Academia)**	**Technical**	**Enabling**	**Discipline-specific**	**Cross-disciplinary**	**Mapping Gaps & Competencies**
Perceived Critical Gaps - Industry clustered themes ***(Ordered by extent of written and discussed consideration)***					**EA Stage 1 Competencies**
1. Systems thinking - Identify all inputs and outputs, measurement and verification, create a baseline	●	●	●	●	**1.5**
2. Diagnostic skills, Critical thinking	●		●	●	**1.5, 2.2, 2.3**
3. Understanding of core engineering principles, including basic physics, thermodynamics and heat transfer, fluid mechanics, electrical machines			●	●	**1.1, 1.2**
4. Knowledge of EE technology	●		●		**1.1, 1.3, 1.4**
5. Ability to compare what has worked well elsewhere and how it could be applied to a similar situation (adaptable application). ‡	●		●	●	**2.1, 2.2, 2.4**
6. Financial education and evaluation skills, economic and business case analysis skills, ability to calculate expected Return on Investment (RoI), ability to communicate economic benefits of EE improvements (TBL/ Emissions Accounting) Δ		●	●	●	**1.1, 1.3, 1.4**
7. Knowledge of best practice/ legislation/ codes/ benchmarking/ (including social and ethical considerations), need to also be able to keep up to date	●			●	**1.5, 1.6, 3.1**
8. Creative/ lateral thinking / Innovative thought processes, understand how and where to draw on external knowledge sources, capitalising on collaborative approaches/ team work		●		●	**2.1, 2.3, 2.6**
9. Reporting skills / documentations skills (potential opportunities, recording calculations)		●		●	**3.2, 3.3, 3.4**
10. Mentoring / working with subject matter expert (novice and expert team)		●		●	**2.1, 2.3, 2.6**
11. Building professional networks and business relationships »		●	●	●	**3.1, 3.3, 3.5, 3.6**

Component knowledge and skills and learning pathways - Academic clustered themes ***(Ordered by number of industry gaps addressed)***					**Addressing Industry Gaps**
Awareness of EE practices, ability to benchmark *Researching practices within other sectors, other industries and other companies, Knowledge of all available technologies, Researching abilities/constraints of new and emerging technologies*		●		●	**1, 2, 3, 4, 5, 7, 10, 11**
Ability to keep the 'big picture' in perspective *Knowledge of energy use on a broad scale in relevant industry (as opposed to knowledge of specifics related to their area of responsibility)*, *Relating systems within a broader system, Conceptualising the relative impact of an improvement (weighing potential barriers/benefits)*		●		●	**1, 2, 5, 8, 10, 11**
Ability to apply technical skills (mix of discipline-specific and cross-disciplinary skills) *Competence with engineering system/process in order to identify the root causes of inefficiency, Working with 'machine language', Design of HVAC systems for example*	●		●	●	**1, 2, 3, 4**
Understanding of financial considerations *Estimating return on investment vs. capital expenditure, Weighing costs vs. long term savings, Making a business case for improvements*		●		●	**6, 8, 9**
Ability to create robust assumptions *Auditing data quality and assessing confidence levels in results*	●			●	**1, 2, 3**
Ability to think laterally *Creative thinking, Critical thinking, Problem solving*		●		●	**1, 2, 8**

‡ Participants lamented that access to information about energy efficiency practices at other companies was often restricted or difficult to come by. Several participants suggested that there was a potential role for federal government to play in requiring transparency or creating a reference library of case studies. This theme emerged from both the phone consultation and the workshops.

Δ This theme emerged very strongly from the workshops. Being able to create a business case for an improvement that accurately reflects capital expenditure and future payback periods was cited as a major hindrance to stepping up to evaluate EE opportunities, and re-occurred frequently in discussions. At least one participant commented that engineering students should not have to make an in-depth financial analysis in order to effectively evaluate opportunities.

» This 'critical gap' appeared to occur most frequently (although not exclusively) in comments from participants with industry experience in buildings and residential housing, suggesting that it may be particularly relevant to this sector.

Table 5: Workshop Findings - Ability to Implement Energy Efficiency Opportunities

Graduate Attribute: Ability to Implement Energy Efficiency Opportunities **Emergent Knowledge and Skill Areas (Industry), and corresponding component knowledge and skills (Academia)**	**Technical**	**Enabling**	**Discipline-specific**	**Cross-disciplinary**	**Mapping Gaps & Competencies**
Perceived Critical Gaps - Industry clustered themes ***(Ordered by extent of written and discussed consideration)***					**EA Stage 1 Competencies**
1. Being able to present a sufficient business case for EE improvements, calculating return on investment, justifying investment on capital for future financial and efficiency benefits, relating cost per unit production	●	●		●	1.5, 1.6, 2.3, 2.4, 3.2
2. Multi-disciplinary project management skills *Understanding/ communicating scope, Engaging with stakeholders & clients, Procurement management, Physical resources management, OHS responsibilities, Change management, Contract and contractor management, HAZOP type assessments*		●	●	●	2.4, 3.4, 3.5, 3.6
3. Ability to engage and communicate with customers, clients and key stakeholders; understanding stakeholder motivations and how to interest them; ability to communicate with non-engineers in a straight-forward, non-judgemental way		●		●	3.2
4. Systems approach and future-mindedness		●		●	1.5, 1.6
5. Knowledge of regulation and codes	●	●	●	●	1.1, 1.3, 1.4
6. Change management and change *improvement* skills, interpersonal skills and ability to influence behaviour (considering future directions)		●		●	1.4, 2.4, 3.1, 3.6
7. Availability and awareness of mentoring and internship opportunities and funding programs that could assist in getting the project off the ground, Awareness of funding programs that customers may be able to access▼		●	●	●	3.4, 3.5
Component knowledge and skills and learning pathways - Academic clustered themes ***(Ordered by number of industry gaps addressed)***					**Addressing Industry Gaps**
Application of leadership skills *Belief that they are able to make a difference, Negotiation skills, Change management skills, Project management skills, Mentoring peers, Working in teams, Focused problem solving tasks*		●		●	1, 2, 3, 6, 7
Ability to consider opportunities in the context of the 'big picture' *Whole of systems approach, Broad awareness of issues, Future mindedness, thinking long-*	●	●	●	●	1, 2, 4, 6, 7

term, Ability to 'step back' and make a persuasive argument in context of broad industry energy use and cost (i.e. not just on small department budget or a segment of an operational budget), Thinking beyond a particular software/ discipline					
Ability to engage key stakeholders *Making value propositions, Using relevant/engaging key terms, Communicating financial incentives/ business case, Influencing behaviour and decisions*		●		●	**1, 2, 3, 6**
Ability to communicate with key stakeholders *Communicating simple (but not simplistic) message, without jargon, Communicating without judgement, Managing interpersonal relationships*	●	●	●	●	**1, 2, 3**
Good understanding of relevant core technical skills *Knowledge of control systems (HVAC) for example in mechanical engineering, Environmental science needs to include science*	●		●		**4, 5**

▼This was a variant on the theme of financial constraints and the necessity of presenting a convincing business case for energy efficiency improvements. It was not always clear whether participants were stating that new sources of external funding needed to be created, or if they knew of sources that were available, but were inaccessible to them. Although this theme was re-occurring, the amount of funding required was not discussed.

Table 6. Opportunities for moving forward with education for energy efficiency*

Issue Raised	Opportunity for Action
Lack of peer network between Academics and Industry	Mentioned more often by built environment industry professionals during the workshops and in the phone consultations. Perhaps this is an indication of cultural differences between different sectors, and there is an opportunity to raise awareness about this 'network' benefit. Barriers to research or teaching projects included issues related to commercial in confidence, copyright, licensing, commercialisation – layers of bureaucracy that limit interaction between industry and academics on research or teaching. ***Opportunity*** to facilitate collaboration, by creating project funding with clear ownership requirements/ common access results, to remove this barrier. ***Opportunity*** to initiate a business engineering forum/ round table on energy efficiency, generating momentum around breaking down barriers through other projects.
Academic interaction with real world is not current	***Opportunity*** for supporting initiatives to connect educators with industry (i.e. encourage interactions). This could include for example, funded industry placements (teaching buy-out), case study development support (with the educator working directly with industry to develop the case study for a period of time), industry-led group projects with appropriate assessment that is curriculum friendly (received support in all workshops – willingness from industry to be a part of this). Current lack of funding options through Universities or Engineers Australia.
Limited access to industry information	***Opportunity*** for assisting academics in accessing up to date and relevant information to embed into their curriculum. This could be through requiring industry transparency around energy efficiency data (e.g public disclosure), making available a reference library of 'real' data online that can be used by students.
Lack of funds for curriculum renewal in budget constrained environments	***Opportunity*** for supporting the development of resources that address identified critical gaps in engineering. This includes the major emergent theme of communicating/ facilitation, making the business case for energy efficiency and self-awareness (i.e. 'knowing what you don't know'). This could be through supporting detailed 'real-world' case studies (connecting industry with academics and funding development) and promoting the resultant resource to educators and students.
Lack of industry mentoring network - students	***Opportunity*** to assist universities in developing enabling and technical knowledge and skills through industry mentoring. ***Opportunity*** to raise profile of enabling skills development and industry mentoring, through student workplace positions (through attaining their 12 week work experience requirement for graduation)
Silos limit sharing and cross-disciplinary teaching	***Opportunity*** to create cross-disciplinary learning resources for 'specialising' in energy efficiency capabilities e.g. financial training for <u>environmental/ civil/ electronic</u> engineering; e.g. communication/ systems thinking/ business planning/ facilitation training for <u>mechanical, chemical and environmental</u> engineers. There are examples of universities that do this around Australia (refer to 2012 NFEE report) – and it could be substantially expanded.
Accreditation review timeframe insufficient for rapid response to curriculum renewal	***Opportunity*** for encouragement through incentives in addition to accreditation, to catalyse curriculum renewal for energy efficiency education. This could include awards, competitions, academic teaching incentives and recognition of good work (energy efficiency teaching citations) ***Opportunity*** for accreditation-related communication between Engineers Australia and universities in between 5-yearly reviews, to promote action on an energy efficiency curriculum focus. e.g. as a 'priority area'

** Issues documented in order of prevalence of discussion across the three workshops and pre-workshop consultation*