ENERGY EFFICIENCY & ENGINEERING EDUCATION

BRIEFING NOTE FOR
ENGINEERING PRACTITIONERS AND EDUCATORS

INCREASING ENERGY EFFICIENCY KNOWLEDGE & SKILLS

Version: 31 August 2012

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1. Introduction

‘Improving energy efficiency will help to lower the energy intensity of the Australian economy overall, and this, together with a decrease in the emissions intensity of the production of that energy, will be the main contributor to Australia’s carbon abatement.’

National Partnership Agreement on Energy Efficiency – Australian COAG Agreement, 2009

Local and international communities are increasingly calling for government, industry, business and civil society to resolve issues related to climate change and sustainable development. Consumer expectations of minimal environmental impact are accelerating, and market forces are beginning to favour products and services that have lower greenhouse gas emissions.

With the introduction of a carbon price in Australia, engineers and product designers will be required to provide high quality products and services with increased energy efficiency, and reduced greenhouse gas emissions and costs. This is driving demand and growing competition for the provision of such products and services. Energy efficiency will play a major role in helping Australia achieve its emission reduction targets in 2020 and beyond, and energy efficient practices will be essential if Australian industries are to maintain their competitiveness in a carbon-constrained world.

The Council of Australian Governments (COAG) has recognised the important role energy efficiency will play through the development and implementation of the National Strategy on Energy Efficiency (NSEE). The Commonwealth Department of Resources, Energy and Tourism (RET) is responsible for implementing several measures in the NSEE relating to industrial energy efficiency. This includes working with industry and the tertiary education sector to increase the energy efficiency skills base of Australia’s emerging workforce. RET has formed the Energy Efficiency Advisory Group (EEAG), comprised primarily of academics with expertise in engineering education and university curriculum renewal, to provide expert advice on this work. In 2011, RET commissioned the Queensland University of Technology (QUT), with in-kind support from Engineers Australia to conduct consultations to obtain industry perspectives on the findings of its previous work. This document forms part of that consultation process, which:

1. Engaged with industry to identify key discipline-specific skills and competencies;
2. Engaged with engineering educators to identify associated graduate attributes and learning outcomes in order to deliver the skills and competences identified; and
3. Explored how links between industry and universities can be strengthened to support graduate learning outcomes that meet industry needs.

1.1. Project Aims & Acknowledgements

Engineers Australia has previously expressed concern over the slow implementation of energy efficiency measures and a lack of simple and understandable objectives that are not weighed down by incomprehensible policy and bureaucratic language. This project addresses these issues by consulting with industry, professional bodies and academics. Although this paper is targeted at the formative engineering qualification (usually a bachelor degree), the knowledge and skills discussed may also be used for postgraduate education and for professional development.

This document is intended as a preliminary guide to energy efficiency for EA’s colleges, discussing both interdisciplinary and discipline-specific (specialist) attributes identified as desirable in engineering graduates. It also outlines the knowledge and skills needed to establish these...
attributes (learning pathways). RET and the authors look forward to receiving feedback from college members and others as they read and use this document for work including bringing about curriculum renewal for energy efficiency. RET and the authors regard this document as a ‘living document’ i.e. a document that will be refined and expanded in light of feedback.

With thanks to the RET Energy Efficiency Advisory Group members who contributed to the workshops, in particular Emeritus Professor Robin King (Engineering Education Consultant), and Dr Michele Rosano (Curtin University). The authors would also like to acknowledge Mr Luiz Ribeiro and Mr Stuart Richardson at RET for their vision, mentoring and support throughout this project. Professor Alan Pears is thanked for his review and editorial contribution to the project scope and briefing notes. Engineers Australia colleagues Mr John Anderson (Director, Engineering Practice and Continuing Professional Development), Dr David Robinson (Director, Education and Assessment), Mr Michael Bevan (Associate Director, Registration) and Mr Peter Hoffman (Associate Director, Accreditation) are thanked for their encouragement and support throughout the project, ensuring relevance to existing processes and communities of practice.

Each of the colleges of Engineers Australia are also thanked for their in-kind contribution to reviewing these briefing papers, in particular the following college representatives: Mr Graeme Macaulay (Biomedical), Ms Georgie Wright (Chemical), Mr Matthew O’Hearn (Civil), Ms Mai Yeung (Electrical), Mr David Gamble (Environmental), Mr Peter Hitchiner (ITEE), Mr Earl Heckman (Mechanical), Mr Richard Eckhaus (Structural), and Professor Peter Knights (EEAG member, University of Queensland) who coordinated the mining and metallurgy contribution. The research team would also like to thank industry, professional association, government and academic practitioners for contributing to the project, with input received from more than 130 individuals through workshops, individual and group phone calls, and email correspondence.

1.2. Commitments to Energy Efficiency

To respond effectively to energy efficiency issues, it will be essential to equip emerging professionals with knowledge and skills to address sustainability issues and energy challenges in all aspects of their work. Engineering will be critical amongst these professions, with Engineers Australia 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.’

Indeed, the institution has had a strong commitment to sustainable development principles for over 20 years and includes these principles as part of its Code of Ethics. Engineers Australia has also endorsed a Sustainability Charter and a comprehensive policy on the future of energy and climate change, supporting energy efficiency as a fundamental step towards achieving sustainable resource use.

There is evidence that industry bodies have made significant moves that align with both consumer demands and the institution’s sustainability principles. For example, a recent survey by the National Framework for Energy Efficiency (NFEE) found that six out of ten of the largest engineering companies operating in Australia are providing in-house training to their staff on energy efficiency to supplement their formal training, and four out of ten have included such requirements in graduate recruitment.

By comparison, there appears to be a lag in the ability of higher education institutions to meet these requirements. Findings from 2007 and 2011, surveys of energy efficiency education across all Australian universities teaching engineering suggested that education is highly variable and ad hoc across universities and engineering disciplines.
It was concluded that there is an urgent need to embed energy efficiency knowledge and skills into engineering curricula, beyond one-off courses, special interest topics in later years or postgraduate programs. The studies identified a range of options for improving and prioritising energy efficiency topics, including incorporating field trips, workshops and relevant content into existing units, as well as undertaking ‘whole-of-program’ curriculum renewal to embed energy efficiency as a foundation across units and courses.

A clear gap exists between the need for energy efficiency knowledge and skills in the workplace and the capacity of universities to consistently produce graduates with these knowledge and skills. A number of barriers to capacity building have resulted in a time lag for curricula renewal in the higher education sector. In addition to opportunities at the university departmental level, research has identified some important roles for government, professional bodies and accreditation agencies that will support educators and drive timely curriculum renewal.

RET has consulted with industry, professional bodies and academia on building engineering energy efficiency capacity and is undertaking a range of initiatives to help achieve this aim. The Department of Industry Innovation, Science, Research and Tertiary Education (DIISRTE) is also working to build such capacity in engineering and a range of other trades and professions.

1.3. What do we mean by Energy Efficiency in Engineering?

Engineers and product designers are increasingly being called upon to innovate in a range of new areas, such as improving the energy efficiency of engineered systems, processes and products, along with developing, installing, commissioning and maintaining renewable and low emissions energy generation technologies. The stage is set for energy efficiency to become a major consideration in coming years across a range of engineering and design professions.

Since 1988, the Intergovernmental Panel on Climate Change (IPCC) has warned that all nations need to address their carbon dioxide (CO₂) equivalent emissions, and achieve significant global reductions in the order of 60-80 per cent by 2050. However, the International Energy Agency (IEA) also forecasts that, if policies remain similar to those currently in place, world energy demand is set to increase by over 50 per cent between now and 2030. Hence, although renewable and low-emission options are already available, energy demand must be reduced to allow a timely and cost effective transition to a low-carbon economy. Indeed, the IEA and others estimate that energy efficiency will need to deliver around half of the energy related abatement by 2050 if lowest cost transition pathways are to be pursued.

One of RET’s roles is to assist industry in transitioning to a low emissions economy. This aligns with the NFEE’s objectives and Engineers Australia’s ambitions. There are many drivers for improving energy efficiency, such as maintaining competitiveness in a resource-constrained future, and improving productivity, product quality, and working conditions. It is important for both educators and students to understand the synergies between mitigating climate change and financial benefits, future resilience and best use of resources.

1.4. An Agenda for Practitioners and Educators

Effective communication between various engineering disciplines and other professionals regarding energy efficiency opportunities is critical. There is also a critical need for communicating capacity building needs and opportunities, between professionals practising in government and business, and educators. Not only can this accelerate capacity building efforts, it can bring multiple other benefits such as improved networking opportunities, applied research possibilities, and graduate screening for future employment.
It is important to use consistent language in this ‘conversation’ to avoid confusion and misaligned expectations. For example, Engineers Australia uses a set of terms when describing national competency standards, and the requirements for meeting them (elements and indicators). Universities and higher education bodies tend to use another set of similar, related terms when describing the characteristics of successful graduating students (graduate attributes), and the training needed to develop these (learning pathways). A glossary is attached at the end of this briefing note to make sure the intentions of this document are clear.

The following diagram summarises the educational model that underpins this project’s engagement with industry and educators. It assumes that rapid capacity building can take place using a ‘whole of curriculum’ approach. This includes a number of elements of curriculum renewal distilled from literature and case studies, along with pilot trials and workshops undertaken by the authors with engineering educators around the world. This project focuses on two critical steps within this process: ‘identify graduate attributes’ and ‘map learning pathways’ within engineering programs to develop these attributes.

Figure 1: A Model for Rapid Curriculum Renewal, showing the focus of this Briefing Note, on identifying graduate attributes, and mapping learning pathways

1.5. Relevance of this Study

The study intends to identify key graduate attribute gaps related to energy efficiency for engineering students in Australia, to inform universities as to potential areas for future focus. As energy costs continue to rise, and pressures increase to reduce fossil fuel consumption across Australian industries and sectors, demand for engineers with energy efficiency competencies will grow. RET is working with Engineers Australia members and industry representatives to identify discipline-specific gaps in engineering graduate attributes in relation to energy efficiency, which will be used in developing content and resources to assist universities to embed energy efficiency learning pathways into existing courses that address these gaps. There has been much debate over the engineering education sector’s to sustainable development internationally, and this project will be a world leading effort to provide specific guidance on areas for future focus, including in the design of government programs to address the identified skills shortfalls.
2. Energy Efficiency and Major Disciplines

The following pages highlight for each EA college, and the mining and metallurgy engineering sector (in alphabetical order), the importance of energy efficiency to everyday practice and the future of the discipline. This includes:

- The context for energy efficiency
- Sample knowledge and skills
- Example applications
- Discipline-specific considerations.

There is some crossover between disciplines, and each discipline may wish to engage further with the ideas and examples presented here.

2.1. Energy Efficiency and Biomedical Engineering

Context:

This college includes engineers from a variety of backgrounds, spanning knowledge of electronic, mechanical, chemical and materials engineering, with the life sciences of medicine, biology and molecular biology. As such, there are a wide variety of activities, products and services that consume energy within the scope of a ‘biomedical project’, from product research and development, material selection and manufacturing of the product, through to use and end-of-life recycling/re-use/disposal.

Given that attention to sustainability and particularly energy use continues to grow, energy efficiency presents opportunities for biomedical engineers in research and practice. This is particularly topical in Australia, given the issues around diagnostic integrity and longer-term maintenance of more than $1 billion worth of generally ageing medical technology equipment in the nation’s hospitals. A focus on energy efficiency as part of other quality standards also has the potential to assist the college in facilitating post-disaster and development aid where energy supplies may be limited and unreliable.

Sample Knowledge and Skills:

Biomedical engineering spans a number of significant streams of application including ‘clinical’, ‘rehabilitation’, ‘biomedical impact’ and ‘biomedical technology aids’ (as identified by the 2012 Australian Biomedical Engineering Conference). Across these streams, efficiency related knowledge and skills being recognised by the international biomedical engineering community include new and “greener” designs, operating procedures, research techniques and waste minimization strategies, as well as the design and manufacture of implant devices with lower energy requirements, decontamination and recycling of waste products and hospital equipment.

Example – Products and Manufacturing:

There is significant interest in energy efficiency in manufacturing systems, given the potential for innovation in functions such as sterilising, compressed air generation, plastics manufacturing and circuit board design. There is also significant interest in improving, over the next decade, the operation of existing medical equipment to address public safety and reduce risks of failure. During the required equipment retrofitting, energy efficiency considerations may provide an opportunity to prolong the life of the equipment, reduce running costs and reduce greenhouse gas emissions. Looking forward, wireless body sensor networks are an emerging area of innovation, promising patient care that is more mobile and contextualised. Work is currently underway to
improve functionality and energy efficiency of the related devices.\textsuperscript{18} Although these devices are small, break-throughs at this level may have application for much larger systems and environments with significant energy efficiency improvement opportunities.

**Discipline-Specific Considerations:**

In Biomedical Engineering, discipline-specific considerations could include:

- An understanding of the life-cycle of components for biomedical devices
- Familiarity with the energy performance of new testing
- Diagnosis and implant equipment (to help inform procurement choices)
- Considering end-of-life of products/ materials; making reuse more energy efficient
- Optimising function or selection of medical devices to minimise wasted/ one-time-use energy
- Advancement of technologies used in sterilisation
- Improving the energy efficiency of medical (e.g. hospital and clinic) environments.

The following are example energy efficiency elements/ indicators:

- An understanding of energy efficiency opportunities in a hospital setting
- An understanding of the life-cycle of components for biomedical devices
- Ability to undertake a ‘whole of life and operation’ cost-benefit analysis for procurement of new equipment.

**Example learning outcomes and pathways**

Considering such elements and indicators, a number of related knowledge and skill areas i.e. learning outcomes, can then be identified, which could be ‘learned’, ‘practiced’, and ‘demonstrated’ during the course of an undergraduate curriculum. An example learning pathway is shown here (derived for demonstration purposes at an expert panel workshop in 2011)\textsuperscript{19} for a hypothetical four year engineering undergraduate program, using the graduate attribute of “Ability to Participate in/Contribute to Energy Efficiency Assessments.”

This example demonstrates a natural progression for developing energy efficiency related knowledge and skills. Furthermore there are opportunities for various parts of the curriculum – in particular the first and second years – to include modules of energy efficiency related content. These could occur, for example, within a common course/ unit/ subject, or as reference resources for each unit.

**Notes:**

- This matrix provides an example learning pathway for various example engineering knowledge and skills provided for the graduate attribute “Ability to Participate in/Contribute to Energy Efficiency Assessments”, and complementary matrices can be developed for other graduate attributes. It is based on a brainstorming activity and is not a comprehensive or prescriptive guide to knowledge and skills in relation to particular graduate attributes.
- The lines, triangles and rectangles indicate seeding ideas/language, growing the amount of embedded content, then substantial consideration of that knowledge or skill.
Table 1. Energy Efficiency & Biomedical Engineering

<table>
<thead>
<tr>
<th>Component Knowledge (K) &amp; Skills (S)</th>
<th>Year of Study</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Graduate Attribute:</strong> Ability to Participate in/Contribute to Energy Efficiency Assessments</td>
<td>1</td>
</tr>
<tr>
<td>K1  Design rules</td>
<td>Learn</td>
</tr>
<tr>
<td>K2  Understanding motivations for behaviour change</td>
<td>Learn</td>
</tr>
<tr>
<td>K3  Pros/cons of building new versus refurbishment</td>
<td>Learn</td>
</tr>
<tr>
<td>K4  Maintenance schedules for optimisation of energy efficiency</td>
<td>Learn</td>
</tr>
<tr>
<td>S1  Mapping occupant behaviours</td>
<td>Learn</td>
</tr>
<tr>
<td>S2  Change management (new practices)</td>
<td>Learn</td>
</tr>
<tr>
<td>S3  Occupational Health and Safety</td>
<td>Learn</td>
</tr>
<tr>
<td>S4  Communicate business case for EE technologies</td>
<td>Learn</td>
</tr>
<tr>
<td>S5  Building industry energy efficiency ‘hot spots’ &amp; green solutions</td>
<td>Learn</td>
</tr>
</tbody>
</table>
2.2. Energy Efficiency and Chemical Engineering

Context:

According to the Institution of Chemical Engineers,

‘The Institution of Chemical Engineers sees sustainable development as the most significant issue facing society today ... The sustainable use of resources is vital and can be achieved by identifying better ways of deploying economic and regulatory measures to drive investment in process technologies which deliver sustainability.’

As such, Chemical Engineering is in a position to make a substantial contribution to societies around the world in improving energy efficiency, particularly through industries involved in the production of such things as food, plastics, ceramics, pharmaceuticals, metals and glass.

Sample Knowledge and Skills:

Chemical Engineering can offer a great deal to sustainable development and increasing energy efficiency by contributing to sustainable chemical plant design, improving process operation, reducing toxic chemical usage, and dramatically reducing waste. According to Dr Robin Batterham, the then President International Council of Chemical Engineering in 2005,

‘Chemical engineers have much to contribute in a world that is moving towards sustainability. Indeed our role is somewhat unique. We possess a detailed knowledge of process engineering coupled with an understanding of novel science and technology across a broad range of disciplines. Chemical engineers can utilise this potent mix of skills to develop new approaches to some of our most challenging global problems.’

Example – Green Chemistry:

Every year in the United States alone, an estimated 3.5 million tons of highly toxic, petroleum-based solvents are used as cleaners, degreasers, and ingredients in adhesives, paints, inks, and many other applications. More environmentally friendly solvents have existed for years, but their higher costs have kept them from wide use. A technology developed by Argonne National Labs produces non-toxic, environmentally friendly ‘green solvents’ from renewable carbohydrate feed stocks, such as cornstarch. This discovery has the potential to replace about 80 percent of petroleum-derived cleaners, degreasers and other toxic and hazardous solvents. The process makes low-cost, high-purity ester-based solvents, such as ethyl lactate, using advanced fermentation, membrane separation, and chemical conversion technologies. These processes require very little energy and eliminate the large volumes of waste salts produced by conventional methods. This method of producing biodegradable ethyl lactate solvents can also cut the price by up to 50 percent, from US$1.60 - $2.00 per pound to less than US $1.00 per pound. Overall, the process uses as much as 90 percent less energy and produces ester lactates at about 50 percent of the cost of conventional methods.

Discipline-Specific Considerations:

In Chemical Engineering, discipline-specific considerations could include familiarity with:

− New scientific developments in materials synthesis (to help inform materials choices)
− Considering end-of-life of products/ materials, making reuse more energy efficient
− Optimising function or selection of heat exchangers to recover lost energy
− Advancement of technologies used in carbon sequestration; improving the energy efficiency of chemical extraction processes.

The following are example energy efficiency elements/indicators:
- Ability to conceptualise and compare energy efficiency opportunities within manufacturing processes
- Ability to communicate energy efficiency challenges and opportunities in a given process

**Example learning outcomes and pathways**

Considering such elements and indicators, a number of knowledge and skill areas can then be identified, which could be ‘learned’, ‘practiced’, and ‘demonstrated’ over the duration of the undergraduate curriculum. An example discipline map is shown here for a hypothetical 4-year engineering undergraduate program, for the specific example graduate attribute of “Ability to Participate in/Contribute to Energy Efficiency Assessments” (derived for demonstration purposes at an expert panel workshop in 2011). Considering this example, it can be seen that there is a natural progression for developing energy efficiency related knowledge and skills. Furthermore there are opportunities for various parts of the curriculum – in particular the first and second years – to include modules of energy efficiency related content. These could for example occur within a common course/unit/subject, or could appear as reference resources for each of the units.

**Notes:**

- This matrix provides an example learning pathway for various example engineering knowledge and skills provided for the graduate attribute “Ability to Participate in/Contribute to Energy Efficiency Assessments”, and complementary matrices can be developed for other graduate attributes. It is based on a brainstorming activity and is not a comprehensive or prescriptive guide to knowledge and skills in relation to particular graduate attributes.

- The lines, triangles and rectangles indicate seeding ideas/language, growing the amount of embedded content, then substantial consideration of that knowledge or skill.
Table 2. Energy Efficiency & Chemical Engineering

<table>
<thead>
<tr>
<th>Component Knowledge (K) &amp; Skills (S) (learning outcomes)</th>
<th>Year of Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graduate Attribute: Ability to Participate in/Contribute to Energy Efficiency Assessments</td>
<td>1</td>
</tr>
<tr>
<td>K1 Knowledge of Physics</td>
<td>Learn</td>
</tr>
<tr>
<td>K2 Knowledge of Thermodynamics</td>
<td>Learn</td>
</tr>
<tr>
<td>K3 Knowledge of Heat transfer, Fluids</td>
<td>Learn</td>
</tr>
<tr>
<td>K4 Knowledge of opportunities for optimising usage: reducing demand, recovery and clean energy technologies</td>
<td>Learn</td>
</tr>
<tr>
<td>K/S 1 Knowledge of sensor control systems (Life cycle analysis, materials selection)</td>
<td>Learn</td>
</tr>
<tr>
<td>S1 Skills in engineering modelling design and analysis</td>
<td>Learn</td>
</tr>
<tr>
<td>S2 Ability to integrate recycling technologies/ recyclability of materials for energy efficiency gains</td>
<td>Learn</td>
</tr>
<tr>
<td>S3 Ability to assess/energy audit of manufacturing processes (LCA), including embodied energy in materials – Project</td>
<td>Practice</td>
</tr>
</tbody>
</table>
2.3. Energy Efficiency and Civil Engineering

Context:

According to the Institution of Civil Engineers,

‘Civil engineering plays a crucial role in creating the infrastructure needed for modern life around the world. Practitioners in the civil engineering sector apply knowledge and experience to create projects that meet human needs and clean up environmental problems.’

Sample Knowledge and Skills:

Civil engineering can offer a great deal to sustainable development and increasing the energy efficiency of infrastructure, for instance by designing:

- buildings with alternate lower embodied energy materials
- buildings that can be repurposed for multiple uses
- structures that can be easily disassembled to allow greater recycling rates
- roads that use greater levels of recycled materials and reduce environmental pressures
- homes that are passively heated and cooled
- transport systems that allow for multi-modal flexibility.

Example – Future or Roads:

In the coming decades the design, delivery, and maintenance of roads will be increasingly influenced by issues related to sustainability, presenting a range of opportunities for new and improved approaches. An example of this is the impact of climate change and associated extreme weather events, such as the extensive flooding in January 2011 in Queensland, Australia. Other examples include diminishing access to road construction supplies (such as aggregate), water scarcity, and the potential for increases in oil and electricity prices. Many of these considerations have not had a noticeable influence on roads in the past and will require new thinking and strategies. Given that roads typically have a design life of 20 to 40 years, with bridges being designed for up to 100 years, the level of consideration of future trends related to environmental and carbon impacts, economic risks, and social movements associated with roads will have a significant impact on their long-term associated costs and future. The good news is that there is a bright future for roads. Road building is inherently an efficient practice that seeks to minimise costs related to construction and maintenance, with a range of practices that can be called upon as the basis of strategies to address current and future environmental issues.

Discipline-Specific Considerations:

In Civil Engineering, energy efficiency considerations could include:

- ensuring quality and durability of materials used in built environment (reduces frequency of need to replace them) and giving consideration to their embodied energy
- ensuring a building project complies with green star rating system (including the effect that the development would have on its surrounding environment)
- investigating available and emerging methods of heat/energy recovery.

The following are example energy efficiency elements/indicators:
− The ability to deliver property development that is sympathetic to the environment and topography (for example including infrastructure layout, energy efficient living spaces, building envelopes and site characteristics, traffic flows and street layouts to minimise travel)
− The ability to deliver energy efficient commercial buildings (for example including air conditioning – heating/cooling, smart glass, solar energy and alternatives, air flows, cooling, star ratings, intelligent sensors and actuators, carbon offsetting, efficient use of construction machinery and processes)
− The ability to deliver energy efficient transportation systems

Example learning outcomes and pathways
Considering such elements and indicators, a number of knowledge and skill areas can then be identified, which could be ‘learned’, ‘practiced’, and ‘demonstrated’ over the duration of the undergraduate curriculum. An example discipline map is shown here for a hypothetical 4-year engineering undergraduate program, for the specific example graduate attribute of “Ability to Participate in/Contribute to Energy Efficiency Assessments (derived for demonstration purposes at an expert panel workshop in 2011).”

Considering this example, it can be seen that there is a natural progression for developing energy efficiency related knowledge and skills. Furthermore there are opportunities for various parts of the curriculum – in particular the first and second years – to include modules of energy efficiency related content. These could for example occur within a common course/unit/subject, or could appear as reference resources for each of the units.

Notes:
− This matrix provides an example learning pathway for various example engineering knowledge and skills provided for the graduate attribute “Ability to Participate in/Contribute to Energy Efficiency Assessments”, and complementary matrices can be developed for other graduate attributes. It is based on a brainstorming activity and is not a comprehensive or prescriptive guide to knowledge and skills in relation to particular graduate attributes.
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Table 3. Energy Efficiency & Civil Engineering

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<th>Component Knowledge (K) &amp; Skills (S)</th>
<th>Year of Study</th>
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<tbody>
<tr>
<td><strong>Graduate Attribute:</strong> Ability to Participate in/Contribute to Energy Efficiency Assessments</td>
<td>1</td>
</tr>
<tr>
<td><strong>K1</strong> Systems basic (multidisciplinary view)</td>
<td>Learn</td>
</tr>
<tr>
<td><strong>K2</strong> Lifecycle energy costs</td>
<td>Learn</td>
</tr>
<tr>
<td><strong>K3</strong> Orientation implications for energy use</td>
<td>Learn</td>
</tr>
<tr>
<td><strong>K4</strong> Embodied energy of materials (&amp; selection)</td>
<td>Learn</td>
</tr>
<tr>
<td><strong>K5</strong> Water &amp; wastewater treatment</td>
<td>Learn</td>
</tr>
<tr>
<td><strong>K6</strong> Social aspects of professional negotiation</td>
<td>Learn</td>
</tr>
<tr>
<td><strong>K7</strong> Understanding roles and contribution of other professions</td>
<td>Learn</td>
</tr>
<tr>
<td><strong>K/S 1</strong> Rating systems for buildings</td>
<td>Practice</td>
</tr>
</tbody>
</table>
2.4. Energy Efficiency and Electrical Engineering

Context:

Electrical Engineering is in a position to make a substantial contribution to societies around the world in improving energy efficiency particularly through:

- electricity generation, transmission, distribution
- electrical installations in buildings and on industrial sites
- electrical equipment manufacture
- instrumentation and control systems applications in industry
- communications networks
- electronic plant and equipment
- integration and control of computer systems.

Sample Knowledge and Skills:

These may include designing renewable energy generation systems, smart electricity grids that can balance small scale decentralised generation, control systems to optimise energy efficiency in industrial and manufacturing processes, office equipment that consumes less energy and can be easily remanufactured, improved power management systems for industry, advanced heat recovery systems, electricity transmission infrastructure that reduced transmission losses, and automated building management systems.

Example – Remanufacturing Office Equipment:

Interface Australia and Fuji Xerox Australia are companies that are implementing these strategies to improve their competitive advantage. Fuji Xerox Australia products, technologies and services are designed with low carbon performance in mind. The company is known for its Extended Producer Responsibility program, where equipment and parts are taken back from the customer at ‘end of life’ and remanufactured or recycled to achieve over 99 per cent resource recovery. As Fuji Xerox Australia’s Managing Director Andy Lambert explains, ‘We made a commitment to halve the energy consumption of our devices ten years ago. As a result, when replacing old equipment with new, our customers can benefit from energy consumption reductions ranging up to 71%.’

Fuji Xerox Australia has committed to purchasing 100 per cent of all the energy it uses from renewable energy sources.

Discipline-Specific Considerations:

In Electrical Engineering, energy efficiency could include consideration of energy efficiency opportunities systemically across the fields of electricity, electronics and electromagnetism associated with large scale electrical systems (such as power transmission and motor control). Energy efficiency opportunities could be explored within power networks, or achieving energy efficiency in wireless networks (optimisation of network design with photovoltaics power).

During two workshops with academic representatives, the following example energy efficiency elements/indicators were generated:

- Ability to conceptualise and compare, evaluate and optimise alternative approaches to electrical engineering problems, in consideration of energy efficiency and other sustainability issues
- Effective communication and advocacy of complex electrical engineering aspects of energy efficiency issues to the community (as a technical expert)
Example learning outcomes and pathways
Considering such elements and indicators, a number of knowledge and skill areas can then be identified, which could be ‘learned’, ‘practiced’, and ‘demonstrated’ over the duration of the undergraduate curriculum. An example discipline map is shown here for a hypothetical 4-year engineering undergraduate program, for the specific example graduate attribute of “Ability to Participate in/Contribute to Energy Efficiency Assessments (derived for demonstration purposes at an expert panel workshop in 2011).”

Considering this example, it can be seen that there is a natural progression for developing energy efficiency related knowledge and skills. Furthermore there are opportunities for various parts of the curriculum – in particular the first and second years – to include modules of energy efficiency related content. These could for example occur within a common course/unit/subject, or could appear as reference resources for each of the units.

This matrix provides an example learning pathway for various example engineering knowledge and skills provided for the graduate attribute “Ability to Participate in/Contribute to Energy Efficiency Assessments”, and complementary matrices can be developed for other graduate attributes. It is based on a brainstorming activity and is not a comprehensive or prescriptive guide to knowledge and skills in relation to particular graduate attributes.

The lines, triangles and rectangles indicate seeding ideas/language, growing the amount of embedded content, then substantial consideration of that knowledge or skill.

Table 4. Energy Efficiency & Electrical Engineering

<table>
<thead>
<tr>
<th>Component Knowledge (K) &amp; Skills (S)</th>
<th>Year of Study</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Graduate Attribute:</strong> Ability to Participate in/Contribute to Energy Efficiency Assessments</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>K/S1</td>
<td>Electrical fundamentals, energy efficiency, control, energy conversion</td>
<td>Learn</td>
<td>Practice</td>
<td>Demonstrate</td>
</tr>
<tr>
<td>K/S2</td>
<td>Applications (including specific areas: control, services modelling)</td>
<td>Learn</td>
<td>Practice</td>
<td>Demonstrate</td>
</tr>
<tr>
<td>K/S3</td>
<td>Information retrieval &amp; research skills</td>
<td>Learn</td>
<td>Practice</td>
<td>Demonstrate</td>
</tr>
<tr>
<td>K/S4</td>
<td>Systems engineering, complexity, lifecycle thinking</td>
<td>Learn</td>
<td>Practice</td>
<td>Demonstrate</td>
</tr>
<tr>
<td>S1</td>
<td>Interdisciplinary teamwork / projects</td>
<td>Learn</td>
<td>Practice</td>
<td>Demonstrate</td>
</tr>
</tbody>
</table>
2.5. Energy Efficiency and Environmental Engineering

Context:

According to the Society for Sustainability and Environmental Engineering in Australia, Environmental Engineering is a rapidly growing, multi-disciplinary branch of engineering, concerned with devising, implementing and managing solutions to protect and restore the environment, within an overall framework of sustainable development.

As such, environmental engineering is in a position to make a substantial contribution to societies around the world achieving sustainability. Environmental Engineers can assist other engineering disciplines to identify opportunities to reduce greenhouse gas emissions through studying project design, construction and operation, and minimising any adverse effects that projects may have on the environment. Two main principles that underpin Environmental Engineering are particularly relevant to energy efficiency:

- **Sustainability**: Ensuring projects produce sustainable outcomes. This includes, but is not limited to: applying the precautionary principle; undertaking full life-cycle analyses; minimising impacts; using resources economically and efficiently, particularly non-renewable resources; and evaluating engineering outcomes using triple bottom line techniques.

- **Systems thinking**: Ensuring that natural and constructed systems, as well as engineering systems, are considered during the life of a project. This involves ‘big picture’ and holistic ways of thinking to ensure that impacts of the project on natural and built environments are minimised while opportunities provided by those environments are harnessed.

These guiding principles are included in the Australian Government’s ‘Define your discipline’ project (ALTC 2011), and are listed a number of times in the EA Stage 1 Competency Standard.

Sample Knowledge and Skills:

RET is interested in improving energy efficiency in mining, minerals processing and building – areas in which Environmental Engineers operate. There are opportunities for improving energy efficiency in these sectors through impact assessment, evaluation and design of equipment and processes for the treatment and safe disposal of waste material associated with minerals processing, and the conservation and wise use of natural resources. There are also potential to make energy efficiency improvements through identifying low energy material options, water reclamation, waste treatment and recycling.

**Example:**

The 2011 European Union Energy Efficiency Directive includes changes to legislation regarding impact assessment, including balancing environmental objectives with competitiveness and energy security. Considerations span assisting with a whole system approach to reducing energy demand from residential through to commercial and industrial applications, purchasing products, services and buildings with high energy efficiency performance, retrofitting existing building stock, developing energy management systems (augmenting existing ISO14001 documentation), and energy performance contracting.

**Discipline-Specific Considerations:**

Understanding processes and ‘big picture thinking’ is where Environmental Engineers can make the greatest contribution to improving energy efficiency. They have the potential to play the role of a solution integrator, and can adopt a larger, whole-systems perspective; however some basic educational gaps will need to be filled to allow this to happen more effectively. Further,
environmental engineers often come from diverse backgrounds. This diversity influences their approach to energy efficiency, and can function as both an asset and a liability.

While environmental engineering can be a bit ‘fuzzy’, and harder to define than other professions, some of the ‘soft’ skills developed in this discipline are highly beneficial to making energy efficiency improvements. These skills include:

− flexibility and interdisciplinary skills
− ability to understand and concentrate on the ‘big picture’ and ‘whole system’
− ability to assess multiple forms of environmental impact
− ability facilitate and integrate solutions involving inputs from multiple disciplines
− ability to deal with clients and ‘sell’ greener solutions based on long-term financial benefits.

**Example learning outcomes and pathways**

Considering such elements and indicators, a number of knowledge and skill areas can then be identified, which could be ‘learned’, ‘practiced’, and ‘demonstrated’ over the duration of the undergraduate curriculum. An example discipline map is shown here for a hypothetical 4-year engineering undergraduate program, for the specific example graduate attribute of “Ability to Participate in/Contribute to Energy Efficiency Assessments” (derived for demonstration purposes at an expert panel workshop in 2011).36

Considering this example, it can be seen that there is a natural progression for developing energy efficiency related knowledge and skills. Furthermore there are opportunities for various parts of the curriculum – in particular the first and second years – to include modules of energy efficiency related content. These could for example occur within a common course/ unit/ subject, or could appear as reference resources for each of the units.

− This matrix provides an example learning pathway for various example engineering knowledge and skills provided for the graduate attribute “Ability to Participate in/Contribute to Energy Efficiency Assessments”, and complementary matrices can be developed for other graduate attributes. It is based on a brainstorming activity and is not a comprehensive or prescriptive guide to knowledge and skills in relation to particular graduate attributes.

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### Table 5. Energy Efficiency & Environmental Engineering

<table>
<thead>
<tr>
<th>Component Knowledge (K) &amp; Skills (S)</th>
<th>Year of Study</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Graduate Attribute: Ability to Participate in/Contribute to Energy Efficiency Assessments</strong></td>
<td>1</td>
</tr>
<tr>
<td>K1 Energy efficiency opportunities in the built environment</td>
<td>Learn</td>
</tr>
<tr>
<td>K2 Variety of measurement tools or model availability to quantify EE opportunities</td>
<td>Learn</td>
</tr>
<tr>
<td>K3 Limitations and opportunities of ecosystems in EE solutions</td>
<td>Learn</td>
</tr>
<tr>
<td>S1 Coordinate interdisciplinary teams of engineers</td>
<td>Learn</td>
</tr>
<tr>
<td>S2 Communicate environmental, social and economic impacts of EE innovations</td>
<td>Learn</td>
</tr>
<tr>
<td>S3 Choose low embedded energy materials</td>
<td>Learn</td>
</tr>
</tbody>
</table>
2.6. Energy Efficiency and ITEE

Context:

According to the European Commission in 2008, ‘…the continued growth of the European economy … needs to be decoupled from energy consumption … ICTs have an important role to play in reducing the energy intensity and increasing the energy efficiency of the economy’. 37

As such Information, Telecommunications and Electronics Engineering (ITEE) is in a position to make a substantial contribution to societies around the world in achieving improved energy efficiency by contributing in most industry sectors, through the development of ‘hardware, software, control systems and sophisticated electronics that regulate energy demand and supply’. 38

Example – News Ltd on track to save $170,000 a year through PC management

News Ltd has reduced power use by its thousands of PCs by 27% by employing new software. This has delivered an estimated saving on power bills of $170,000 a year so far, before taking into account additional savings from reduced air-conditioning costs due to computers being more frequently in sleep mode or switched off. News Ltd. initially operated the software in 'silent mode' (invisible to users) allowing it to benchmark performance, which revealed that PCs were on, but doing nothing for an average of 74% of the time. Initial messaging invited users to switch their computers into sleep mode when not in use, and to see their own efficiency scores. Idle time immediately dropped, and within 3 months it was down 31% on the previous average, or 27 hours less idle time per computer per week. Power use by the company's PCs dropped by 27%, or 1.74GWh a year. The software rollout is expected to deliver more emissions abatement than any other single project in the company's highly successful 'One Degree' program.

Example – Tonnes per terabyte: Telstra's new carbon metric

From the 2010-11 financial year, Telstra began to track its emissions intensity using a new indicator – tonnes of CO2 emitted per terabyte of data delivered on its networks. Telstra stated in its 2010-11 sustainability report "This measure reflects the efficiency with which we deliver our core product, which is digital information". Telstra emitted 1.93 tonnes of CO2 per terabyte of data delivered in 2010-11. Its 2011-12 emissions reduction goal was set at 15% (up from 10% for the previous year). The company also said that "A longer-term target will be set next year based on what we have learnt from using this measure to drive continual energy efficiency improvements across our business." See: http://telstra.com.au/abouttelstra/download/document/2011-sustainability-report.pdf

Sample Knowledge and Skills:

Information, telecommunications and electronics engineering can offer a great deal to sustainable development and increasing energy efficiency by design improvements in areas such as: software to enhance energy management in industry and manufacturing, smart communications networks to enhance electricity grid management, and building management systems.

Example – Data Servers: 39

An example of the opportunities for engineers to assist industry to increase energy efficiency is in the area of data management. Data management is essential for all medium to large businesses and it consumes large amounts of energy to run servers and maintain specific temperature and humidity levels. Reductions in energy use by servers and server farms of up to 80 per cent have
shown to be possible by targeting each major energy consuming step in the process. Engineers play a key role in such achievements in areas including:

- infrastructure architecture
- virtualisation and consolidation
- efficient rack equipment
- power supply and distribution
- rack cooling
- equipment layout and air flow
- room external cooling load
- computer room air-conditioning
- heat and power recovery.

**Discipline-Specific Considerations:**

Preliminary research has also identified discipline-specific considerations that might be evident. Owing to the federal government’s focus on identifying energy efficiency opportunities through energy assessments, the example graduate attribute “Ability to Participate in/Contribute to Energy Efficiency Assessments” has been used.

In ITEE Engineering, this could include creating software tools to assist energy efficient design and management in other disciplines (buildings and architecture, TBL accounting) and achieving energy efficiency in wireless networks (optimisation of network design with photovoltaic power, and in computers and integrated circuits). It could also include measures in lighting, heating and air-conditioning, lifts and pumps etc, computers/ servers/ telecommunications (photovoltaic sources).

The following example energy efficiency elements/ indicators were generated:

- Possess an advanced technical knowledge in the specialist area of energy generation and distribution
- Knowledge/cognisance of emerging energy efficiency fields, equipment efficiency <-> trade-offs, lifecycle modelling and sustainability
- *(Need to teach higher level issues as ‘fundamentals’ because the old fundamentals of stress/strain etc can be handled by computers)*

**Example learning outcomes and pathways**

Considering such elements and indicators, a number of knowledge and skill areas can then be identified, which could be ‘learned’, ‘practiced’, and ‘demonstrated’ over the duration of the undergraduate curriculum. An example discipline map is shown here for a hypothetical 4-year engineering undergraduate program, for the specific example graduate attribute of “Ability to Participate in/Contribute to Energy Efficiency Assessments (derived for demonstration purposes at an expert panel workshop in 2011)”\(^{41}\)

Considering this example, it can be seen that there is a natural progression for developing energy efficiency related knowledge and skills. Furthermore there are opportunities for various parts of the curriculum – in particular the first and second years – to include modules of energy efficiency related content. These could for example occur within a common course/ unit/ subject, or could appear as reference resources for each of the units.
− This matrix provides an example learning pathway for various example engineering knowledge and skills provided for the graduate attribute “Ability to Participate in/Contribute to Energy Efficiency Assessments”, and complementary matrices can be developed for other graduate attributes. It is based on a brainstorming activity and is not a comprehensive or prescriptive guide to knowledge and skills in relation to particular graduate attributes.

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Table 6. Energy Efficiency & ITee

<table>
<thead>
<tr>
<th>Component Knowledge (K) &amp; Skills (S)</th>
<th>Year of Study</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Graduate Attribute:</strong> Ability to Participate in/Contribute to Energy Efficiency Assessments</td>
<td>1</td>
</tr>
<tr>
<td>K/S1 Electrical fundamentals, energy efficiency, control, energy conversion</td>
<td>Learn</td>
</tr>
<tr>
<td>K/S2 Applications (including specific areas: control, services modelling)</td>
<td>Learn</td>
</tr>
<tr>
<td>K/S3 Information retrieval &amp; research skills</td>
<td>Learn</td>
</tr>
<tr>
<td>K/S4 Systems engineering, complexity, lifecycle thinking</td>
<td>Learn</td>
</tr>
<tr>
<td>S1 Interdisciplinary teamwork / projects</td>
<td>Learn</td>
</tr>
</tbody>
</table>
2.7. Energy Efficiency and Mechanical Engineering

Context:

According to the American Society of Mechanical Engineers, ‘Sustainability means engineering products and developing manufacturing processes that do not consume irreplaceable resources’. Although international attention to sustainability is continuing to grow, enormous changes will be required before many truly sustainable alternative products and processes are available. Energy efficiency improvements are an immediate option to swiftly reduce energy demands, and will play a vital role in helping meet future sustainability and emissions reductions goals. This presents a range of new opportunities for mechanical engineers in energy related areas such as:

- machinery
- mechanical and mechatronic systems
- automated systems and robotic devices
- heat transfer processes
- thermodynamic and combustion systems
- fluid and thermal energy systems
- materials and materials handling systems
- manufacturing equipment
- process plant.

Sample Knowledge and Skills:

As an indication of the knowledge and skills being recognised by the international Mechanical Engineering community, the American Society of Mechanical Engineers held the ‘5th International Conference on Energy Sustainability’ in 2011 and listed the following areas of focus:

- alternate energy
- fuels and infrastructure
- energy systems design
- thermo-economic analysis
- micro and nano technologies
- renewable energy
- combined energy cycles
- transportation
- solar heating and cooling
- smart grid and energy storage.

Additional knowledge and skills relevant to energy efficiency include:

- data collection and analysis
- benchmarking
- developing mathematical models for energy and mass flows through processes and systems
- identifying and quantifying pathways of energy waste
- financial analysis of energy efficiency options
- using models and tools to identify and compare methods of reducing energy waste, and prepare business cases and strategies.
Example – Motor Systems:  

In Australia, every one per cent improvement in motor system efficiency avoids the use of about 400,000 MWh of electricity and the release of the equivalent of 400,000 tonnes of greenhouse gas emissions – the equivalent of taking 9,000 cars off the road. Estimates indicate that, in many processes, electric motor system energy efficiency improvements of 30-60 per cent. This could be achieved through options such as using premium efficiency motors and better load management. Premium efficiency motors are 2-10 per cent more efficient than standard efficiency motors and given the 10-25 year design life, premium efficiency motors are far more economical than standard efficiency motors over the long term. In addition, matching motor system sizes and operating speeds to loads can significantly reduce energy consumption. Motor energy consumption increases with the cube of operating speed. Control systems can be used to efficiently adjust the motor speed and torque to match the load. Typical motor-driven systems include pumps, fans, compressors and conveyors. Simply load-matching a driven system can improve its operating efficiency by up to 50 per cent.

Discipline-Specific Considerations:

Research has identified several considerations specific to this engineering discipline. In response to the Australian Government’s focus on identifying energy efficiency opportunities through energy assessments, the example graduate attribute “Ability to Participate in/Contribute to Energy Efficiency Assessments” has been used in the following example. Discipline-specific considerations in Mechanical Engineering for this graduate attribute could include:

- developing new manufacturing techniques that optimise energy efficiency
- improving energy input/ output of electrical power plant (energy required to build and operate the plant vs. energy the plant produces)
- analysing and changing the lifecycle of a product
- suggesting improved business practices for transport of materials.

The following example energy efficiency elements/ indicators were generated:

- Knowledge of energy efficiency technologies that build on fundamental knowledge
- Proficiency in calculating energy consumption in materials processing, including production, use, and disposal phases.
- Ability to identify energy efficiency opportunities in the areas of design and optimisation of materials and manufacturing systems

Example learning outcomes and pathways

Considering such elements and indicators, a number of knowledge and skill areas (learning outcomes) can then be identified, which could be ‘learned’, ‘practiced’, and ‘demonstrated’ during the course of an undergraduate curriculum. An example learning pathway is shown here for a hypothetical four-year engineering undergraduate program, using the graduate attribute of “Ability to Participate in/Contribute to Energy Efficiency Assessments (derived for demonstration purposes at an expert panel workshop in 2011).”

This example demonstrates a natural progression for developing energy efficiency related knowledge and skills. Furthermore, there are opportunities for various parts of the curriculum – in particular the first and second years – to include modules of energy efficiency related content.
These could occur, for example, within a common course/unit/subject, or as reference resources for each unit.

- This matrix provides an example learning pathway for various example engineering knowledge and skills provided for the graduate attribute “Ability to Participate in/Contribute to Energy Efficiency Assessments”, and complementary matrices can be developed for other graduate attributes. It is based on a brainstorming activity and is not a comprehensive or prescriptive guide to knowledge and skills in relation to particular graduate attributes.

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Table 7: Energy Efficiency & Mechanical Engineering

<table>
<thead>
<tr>
<th>Component Knowledge (K) &amp; Skills (S)</th>
<th>Year of Study</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>Graduate Attribute:</strong> Ability to Participate in/Contribute to Energy Efficiency Assessments</td>
<td></td>
</tr>
<tr>
<td>K1 Knowledge of Physics</td>
<td></td>
</tr>
<tr>
<td>K2 Knowledge of Thermodynamics</td>
<td>Learn</td>
</tr>
<tr>
<td>K3 Knowledge of Heat transfer, Fluids</td>
<td>Learn</td>
</tr>
<tr>
<td>K4 Knowledge of opportunities for optimising usage, including reducing demand, recovery technologies, and clean energy technologies</td>
<td>Learn</td>
</tr>
<tr>
<td>K/S 1 Knowledge of sensor control systems (Life cycle analysis, materials selection)</td>
<td>Learn</td>
</tr>
<tr>
<td>S1 Skills in engineering modelling design and analysis</td>
<td>Learn</td>
</tr>
<tr>
<td>S2 Ability to integrate recycling technologies/recyclability of materials for energy efficiency gains</td>
<td>Learn</td>
</tr>
<tr>
<td>S3 Ability to assess/energy audit of manufacturing processes (LCA), including embodied energy in materials – Project</td>
<td>Practice</td>
</tr>
</tbody>
</table>
2.8. Energy Efficiency and Mining and Metallurgy

Context:

According to the NSW Minerals Council,

‘The mining industry is constantly reviewing ways to increase the efficiency of their operations and be more competitive, this includes actively pursuing energy efficiency. With the price of energy increasing substantially across gas, oil and electricity and with this trend likely to continue, it makes good business sense to support energy efficiency measures.’

This is in line with AusIMM’s own commitment to ‘aiming for a sustainable minerals industry that provides benefits to all Australians’. To this end, AusIMM has formed a Sustainability Committee with three key focus points:

1. Equip and inform for technical appropriateness across professional roles.
2. Empower members to advance dialogue with colleagues and stakeholders.
3. Advocacy through AusIMM and liaison with other organisations on sustainable development related policies.

Sample Knowledge and Skills:

The NSW Minerals Council identifies a range of methods to monitor and improve energy efficiency that will involve engineers, including:

- energy audits, energy metering, process and productivity improvements, investment in efficient equipment and technology, equipment maintenance, strategic management of transport fleets, and selection of fuel types (eg. selecting liquefied natural gas or biodiesel over diesel fuel).

Example – Steel Manufacture:

The energy efficiency of steel manufacture can be increased by as much as 80 per cent by switching to a state of the art electric arc furnace system that process recycled steel (including options such as improved process control, oxy-fuel burners, DC-arc furnaces, scrap preheating, and post-combustion processes), adopting leading practices such as Net Shape Casting, and implementing options such as energy monitoring and management systems for energy recovery and distribution between processes and preventative maintenance. Using high levels of recycled steel in electric arc furnaces not only improves energy productivity but also materials and water productivity as well.

Discipline-Specific Considerations:

Preliminary research has also identified discipline-specific considerations that might be evident. Owing to the federal government’s focus on identifying energy efficiency opportunities through energy assessments, the example graduate attribute “Ability to Participate in/Contribute to Energy Efficiency Assessments” has been used. In Mining and Metallurgy Engineering this should include:

- planning for both underground and surface operations, such as finding energy efficiency opportunities in the integrated functions of mining and beneficiation (separating valuable material from waste)
- identifying the most appropriate ore bodies, and selective mining processes (as they affect the quantity of material to be handled in a beneficiation plant, and therefore energy consumption)
− finding energy efficiency opportunities in different transportation alternatives
− utilising coal seam gas (CSG) liberated during coal mining processes
− and ‘designing for closure’ to reduce legacy costs and energy requirements (i.e. Life of Mine Design and Planning).

The following example energy efficiency elements/ indicators were generated:
− Proficiency in identifying energy efficiency opportunities related to mining processes, including for example, comminution (crushing and grinding), beneficiation, transportation, dewatering, mine ventilation etc..
− Ability to ‘design for closure’, to reduce legacy costs and energy requirements (Life of Mine Design and Planning)
− Ability to undertake energy balance and consumption calculations, and greenhouse gas accounting, including analysis and optimisation skills

Example learning outcomes and pathways
Considering such elements and indicators, a number of knowledge and skill areas can then be identified, which could be ‘learned’, ‘practiced’, and ‘demonstrated’ over the duration of the undergraduate curriculum. An example discipline map is shown here for a hypothetical 4-year engineering undergraduate program, for the specific example graduate attribute of “Ability to Participate in/Contribute to Energy Efficiency Assessments (derived for demonstration purposes at an expert panel workshop in 2011).”

Considering this example, it can be seen that there is a natural progression for developing energy efficiency related knowledge and skills. Furthermore there are opportunities for various parts of the curriculum – in particular the first and second years – to include modules of energy efficiency related content. These could for example occur within a common course/ unit/ subject, or could appear as reference resources for each of the units.

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### Table 8: Energy Efficiency & Mining & Metallurgy

<table>
<thead>
<tr>
<th>Component Knowledge (K) &amp; Skills (S)</th>
<th>Year of Study</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>K1 Life-of-mine Design and Planning</td>
<td>Learn</td>
</tr>
<tr>
<td>K2 Unit operations and mine services</td>
<td>Learn</td>
</tr>
<tr>
<td>K3 Project evaluation tools (multi-criteria decisions &amp; finance fundamentals)</td>
<td>Learn</td>
</tr>
<tr>
<td>K/S 1 Energy consumption modelling</td>
<td>Learn</td>
</tr>
<tr>
<td>K/S 2 Project evaluation tools (multi-criteria decisions &amp; finance fundamentals for in-house gas accounting)</td>
<td>Learn</td>
</tr>
<tr>
<td>S1 Integration with multi-disciplinary teams</td>
<td>Learn</td>
</tr>
<tr>
<td>S2 Analysis &amp; Optimisation tools</td>
<td>Learn</td>
</tr>
</tbody>
</table>
2.9. Energy Efficiency and Structural Engineering

Context:

According to the Institution of Civil Engineers,

"Civil engineering plays a crucial role in creating the infrastructure needed for modern life around the world. Practitioners in the civil engineering sector apply knowledge and experience to create projects that meet human needs and clean up environmental problems."56

As international attention on energy efficiency continues to grow, structural engineers will be presented with a range of new opportunities, because, as noted by Engineers Australia, structural engineers are involved in a range of energy-related areas relevant to permanent and temporary structures such as:

- research
- planning
- design
- construction
- inspection
- monitoring
- maintenance
- rehabilitation and
- demolition

as well as structural systems and their components.57

Sample Knowledge and Skills:

Structural engineering can contribute a great deal to sustainable development and increasing the energy efficiency of infrastructure, for instance by designing buildings and structures:

- with alternate lower embodied energy materials
- that can be repurposed for multiple uses
- that can be easily disassembled to allow greater recycling rates
- for offshore wind turbines that can withstand wave and storm forces
- for onshore wind turbines
- that can incorporate ‘green’ roofs and walls.

Example – Building Materials:

Structural engineers have a significant influence over the materials used in buildings, particularly steel and cement. Each of these materials has low embodied energy options such as geo-polymer cements and steel made from high recycled content. According to the Sustainable Design Committee of the Structural Engineers Association of Northern California,

"Structural engineering is an integral part of sustainable design on a number of fronts: judicious and selective use of materials, resourceful use and application of structural systems, and provisions for future adaptability of the buildings that are designed today. Material selection can be optimized, and recycled and reclaimed or salvaged materials can be used."58
Discipline-Specific Considerations:

Preliminary research has also identified discipline-specific considerations that might be evident. In Structural Engineering this could include considerations for the use of natural lighting and clerestory windows; natural ventilation, shading and vegetated roofs; thermal regulation of buildings through the use of thermal mass and exposed concrete or masonry; design of roofs to receive the maximum benefit from installation of solar panels and the implications of all of the above for load bearing and load paths.

The following example energy efficiency elements/indicators could be used:

- Knowledge of available technologies for ‘green’ buildings, and an understanding of how these elements influence structural design.
- Proficiency in calculating energy consumption in building materials processing, including production, use, and disposal phases.
- Ability to identify energy efficiency opportunities in the design of buildings and selection of appropriate materials.

Example learning outcomes and pathways

Considering such elements and indicators, a number of knowledge and skill areas can then be identified, which could be ‘learned’, ‘practiced’, and ‘demonstrated’ over the duration of the undergraduate curriculum. An example discipline map is shown here for a hypothetical 4-year engineering undergraduate program, for the specific example graduate attribute of “Ability to Participate in/Contribute to Energy Efficiency Assessments” (derived for demonstration purposes at an expert panel workshop in 2011).59.

Considering this example, it can be seen that there is a natural progression for developing energy efficiency related knowledge and skills. Furthermore there are opportunities for various parts of the curriculum – in particular the first and second years – to include modules of energy efficiency related content. These could for example occur within a common course/unit/subject, or could appear as reference resources for each of the units.

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### Table 9: Energy Efficiency & Structural Engineering

**Component Knowledge (K) & Skills (S)**

**Graduate Attribute:** Ability to Participate in/Contribute to Energy Efficiency Assessments

<table>
<thead>
<tr>
<th>Component</th>
<th>Year of Study</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>K1</strong> Design rules</td>
<td>1</td>
</tr>
<tr>
<td>Learn</td>
<td>Practice</td>
</tr>
<tr>
<td><strong>K2</strong> Understanding motivations for behaviour change</td>
<td></td>
</tr>
<tr>
<td>Learn</td>
<td>Practice</td>
</tr>
<tr>
<td><strong>K3</strong> Pros/cons of building new versus refurbishment</td>
<td></td>
</tr>
<tr>
<td>Learn</td>
<td></td>
</tr>
<tr>
<td><strong>K4</strong> Maintenance schedules for optimisation of energy efficiency</td>
<td></td>
</tr>
<tr>
<td>Learn</td>
<td>Practice</td>
</tr>
<tr>
<td><strong>S2</strong> Change management (new practices)</td>
<td></td>
</tr>
<tr>
<td>Learn</td>
<td></td>
</tr>
<tr>
<td><strong>S4</strong> Communicate business case for EE technologies</td>
<td></td>
</tr>
<tr>
<td>Learn</td>
<td>Practice</td>
</tr>
<tr>
<td><strong>S5</strong> Building industry energy efficiency ‘hot spots’ &amp; green solutions</td>
<td></td>
</tr>
<tr>
<td>Learn</td>
<td>Practice</td>
</tr>
</tbody>
</table>
3. How could colleges support energy efficiency education?

3.1. Collaboration opportunities for moving forward

Initial consultation has suggested a significant disparity between current engineering curricula and current industry needs, exacerbated by the fact that most academic staff have not had practical industry experience in the last 10 years. Possible avenues for EA college-facilitated collaboration generated during industry consultation workshops include:

- On-campus initiatives, such as collaborative pilot projects between industry and academics
- Student projects based on real-world industry problems rather than mock scenarios, jointly assessed by lecturers and industry representatives
- Industry placement programs for experienced teaching academics to expand their networks and update their industry work experience.

Opportunities that could be pursued in collaboration with government, or with private funding, that were developed from national consultation are summarised here:

<table>
<thead>
<tr>
<th>Issue Raised</th>
<th>Opportunity for Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of peer network between Academics and Industry</td>
<td>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 an opportunity to raise awareness of the benefits of establishing a network. Barriers to research or teaching projects included issues related to commercial confidence, copyright, licensing, commercialisation – layers of bureaucracy that limit interaction between industry and academics on research or teaching. <strong>Opportunity</strong> to facilitate collaboration, by creating project funding with clear ownership requirements/ common access results, to remove this barrier. <strong>Opportunity</strong> to initiate a business engineering forum/ round table on energy efficiency, generating momentum around breaking down barriers through other projects.</td>
</tr>
<tr>
<td>Limited access to industry information</td>
<td><strong>Opportunity</strong> 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.</td>
</tr>
<tr>
<td>Lack of funds for curriculum renewal in budget constrained environments</td>
<td><strong>Opportunity</strong> for supporting the development of resources that address identified critical gaps in engineering. This includes the major emergent theme of communication/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.</td>
</tr>
<tr>
<td>Lack of industry mentoring network - students</td>
<td><strong>Opportunity</strong> to assist universities in developing enabling and technical knowledge and skills through industry mentoring. <strong>Opportunity</strong> to raise profile of enabling skills development and industry mentoring, through student workplace positions (through attaining their 12 week work experience requirement for graduation)</td>
</tr>
<tr>
<td>Silos limit sharing and cross-disciplinary teaching</td>
<td><strong>Opportunity</strong> to create cross-disciplinary learning resources for ‘specialising’ in energy efficiency capabilities e.g. financial training for environmental/ civil/ electronic engineering; e.g. communication/ systems thinking/ business planning/ facilitation training for mechanical, chemical and environmental engineers. There are examples of universities that do this around Australia (refer to 2012 NFEE report) – and it could be substantially expanded.</td>
</tr>
<tr>
<td>Accreditation review</td>
<td><strong>Opportunity</strong> for encouragement through incentives in addition to accreditation, to catalyse curriculum renewal for energy efficiency education. This could include awards, competitions,</td>
</tr>
</tbody>
</table>
These initiatives have the potential to offer mutual benefits for all parties - industry, universities, academics and students. Successful examples of several of these initiatives are already in place at many universities, however they are far from widespread; exceptions rather than the rule. In summary, there is enormous potential for professional bodies, workplaces, industry representatives and EA colleges to support the development of collaborative initiatives in order to improve the relevancy of engineering curricula, as well as contributing to the personal and professional development of work-ready engineering graduates.

3.2. Targeting Knowledge and Skills

In relation to RETs current focus areas of 'energy efficiency' assessments, and identifying, evaluating and implementing energy efficiency opportunities', there are clear and significant gaps in engineering capability. These gaps fall into one or both of the following two categories:

- Technical knowledge and skills, which include formula, calculations, metrics, design and evaluation; and
- Enabling knowledge and skills, which include communication, stakeholder engagement, project management, change management and leadership.

Industry energy consultants have overwhelmingly nominated foundational, cross-disciplinary skill-sets as the energy efficiency attributes most lacking in recent graduates. They also considered that these have the greatest potential to bring about improvements in energy efficiency. Included among these were 'big picture' thinking, whole systems design and whole-of-life analysis (in particular, the ability to weigh lifetime costs of an asset versus initial expenditure), which were frequently cited as the biggest barriers to efficiency improvements. This is related to the ability to effectively communicate efficiency opportunities to key stakeholders, and to present a basic financial case for initial up-front investment in more energy efficient technologies.

An awareness of the specialist skills of other disciplines is another attribute that industry representatives consider to be a foundation tool for achieving optimum outcomes via interdisciplinary collaboration. Many of these overarching skill sets, i.e. skill sets relevant to all engineering sub-disciplines, are reflected in the following three tables of emergent knowledge and skill areas (identified by Industry), and corresponding component knowledge and skills (identified by Academia) for each of three key graduate attributes:

- Ability to participate in energy efficiency assessments;
- Ability to identify energy efficiency opportunities; and
- Ability to evaluate energy efficiency opportunities.

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 address industry gaps and thereby address their corresponding Stage 1 Competency requirements.
### Table 1: Workshop Findings - Ability to Effectively Participate in Energy Assessments

<table>
<thead>
<tr>
<th>Graduate Attribute: Ability to Effectively Participate in Energy Assessments</th>
<th>Technical</th>
<th>Enabling</th>
<th>Discipline-specific</th>
<th>Cross-disciplinary</th>
<th>Mapping Gaps &amp; Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergent Knowledge and Skill Areas (Industry), and corresponding component knowledge and skills (Academia)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perceived Critical Gaps - Industry clustered themes (Ordered by extent of coverage by participants in discussions and written comments)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Communication skills (including engaging with personnel, report writing, presentation skills, listening skills, question-and-answer skills, ability to ‘translate’ to different business areas)</td>
<td></td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>3.2, 3.4</td>
</tr>
<tr>
<td>2. Systems awareness, whole systems thinking, holistic approaches (Framing systems)</td>
<td>●</td>
<td></td>
<td>●</td>
<td>●</td>
<td>1.1, 1.2, 1.5, 2.1, 2.2, 2.3, 3.1</td>
</tr>
<tr>
<td>3. Collaboration, cross-disciplinary approaches, ability to work in a group</td>
<td>●</td>
<td></td>
<td></td>
<td>●</td>
<td>3.5, 3.6</td>
</tr>
<tr>
<td>4. Understanding of the auditing process (including the importance of appropriately framing questions)</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>2.4, 3.1, 3.4, 3.5</td>
</tr>
<tr>
<td>5. Knowledge of measuring technologies and metrics, ability to identify inputs/outputs/losses</td>
<td>●</td>
<td></td>
<td>●</td>
<td>●</td>
<td>1.2, 2.1</td>
</tr>
<tr>
<td>6. Knowledge of energy principles, energy &amp; relative amounts of energy needed for certain processes</td>
<td>●</td>
<td></td>
<td></td>
<td>●</td>
<td>1.1</td>
</tr>
<tr>
<td>7. Knowledge of benchmarking /best practice/standards and requirements</td>
<td>●</td>
<td></td>
<td></td>
<td>●</td>
<td>1.5, 1.6</td>
</tr>
<tr>
<td>8. Workshop facilitation skills</td>
<td></td>
<td>●</td>
<td></td>
<td>●</td>
<td>3.3, 3.6</td>
</tr>
<tr>
<td>9. Research skills</td>
<td></td>
<td>●</td>
<td></td>
<td></td>
<td>2.1, 3.4</td>
</tr>
<tr>
<td>Component knowledge and skills and learning pathways - Academic clustered themes (Ordered by number of industry gaps addressed)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ability to participate in design phase</td>
<td></td>
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<tr>
<td>Understanding design components, Working with team members, Communication, Making energy assessments of a proposed design/solution, Influencing design decisions</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>1, 2, 3, 5, 6, 7, 9</td>
</tr>
<tr>
<td>Ability to conceptualise the “Big picture”</td>
<td></td>
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<tr>
<td>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</td>
<td>●</td>
<td>●</td>
<td></td>
<td>●</td>
<td>2, 3, 5, 6, 7</td>
</tr>
<tr>
<td>Ability to apply core engineering technical skills to EE problems</td>
<td></td>
<td></td>
<td></td>
<td>2, 5, 6, 7</td>
<td></td>
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<tr>
<td>Applying thermodynamics, Modelling processes, Evaluating energy consumption in signal reductions processes (ITEE), Identifying hidden losses</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ability to make and test assumptions</td>
<td></td>
<td></td>
<td></td>
<td>2, 4, 5, 9</td>
<td></td>
</tr>
<tr>
<td>Working with imperfect data sets, Modelling processes, Conceptualising systems and representing them diagrammatically</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Understanding of core energy principles and their connection to discipline-specific foundation knowledge</td>
<td></td>
<td></td>
<td></td>
<td>5, 6, 7</td>
<td></td>
</tr>
<tr>
<td>Ability to make energy measurements</td>
<td></td>
<td></td>
<td></td>
<td>5, 9</td>
<td></td>
</tr>
<tr>
<td>Measuring and monitoring skills, Estimation skills</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Understanding of industry ‘best practice’</td>
<td></td>
<td></td>
<td></td>
<td>4, 7</td>
<td></td>
</tr>
<tr>
<td>Awareness of regulatory requirements and industry programs, Researching similar scenarios and outcomes, Benchmarking and measuring</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ability to communicate verbally</td>
<td></td>
<td></td>
<td></td>
<td>1, 8</td>
<td></td>
</tr>
<tr>
<td>Managing interpersonal relationships, Utilising appropriate questioning technique, Effective listening</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ability to communicate non-verbally</td>
<td></td>
<td></td>
<td></td>
<td>1, 8</td>
<td></td>
</tr>
<tr>
<td>Summarising data and concise report writing, Accurate note-taking in the field, Proficient documentation skills</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

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 2: Workshop Findings - Ability to Evaluate Energy Efficiency Opportunities

<table>
<thead>
<tr>
<th>Graduate Attribute: Ability to Evaluate Energy Efficiency Opportunities</th>
<th>Technical</th>
<th>Enabling</th>
<th>Discipline-specific</th>
<th>Cross-disciplinary</th>
<th>Mapping Gaps &amp; Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergent Knowledge and Skill Areas (Industry), and corresponding component knowledge and skills (Academia)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perceived Critical Gaps - Industry clustered themes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Ordered by extent of coverage by participants in discussions and written comments)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Systems thinking - Identify all inputs and outputs, measurement and verification, create a baseline</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>1.5</td>
</tr>
<tr>
<td>2. Diagnostic skills, Critical thinking</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>1.5, 2.2, 2.3</td>
</tr>
<tr>
<td>3. Understanding of core engineering principles, including basic physics, thermodynamics and heat transfer, fluid mechanics, electrical machines</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>1.1, 1.2</td>
</tr>
<tr>
<td>4. Knowledge of EE technology</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>1.1, 1.3, 1.4</td>
</tr>
<tr>
<td>5. Ability to compare what has worked well elsewhere and how it could be applied to a similar situation (adaptable application). ‡</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>2.1, 2.2, 2.4</td>
</tr>
<tr>
<td>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) △</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>1.1, 1.3, 1.4</td>
</tr>
<tr>
<td>7. Knowledge of best practice/ legislation/ codes/ benchmarking/ (including social and ethical considerations), need to also be able to keep up to date</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>1.5, 1.6, 3.1</td>
</tr>
<tr>
<td>8. Creative/ lateral thinking / Innovative thought processes, understand how and where to draw on external knowledge sources, capitalising on collaborative approaches/ team work</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>2.1, 2.3, 2.6</td>
</tr>
<tr>
<td>9. Reporting skills / documentations skills (potential opportunities, recording calculations)</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>3.2, 3.3, 3.4</td>
</tr>
<tr>
<td>10. Mentoring / working with subject matter expert (novice and expert team)</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>2.1, 2.3, 2.6</td>
</tr>
<tr>
<td>11. Building professional networks and business relationships *</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>3.1, 3.3, 3.5, 3.6</td>
</tr>
</tbody>
</table>
Component knowledge and skills and learning pathways - Academic clustered themes (Ordered by number of industry gaps addressed)

<table>
<thead>
<tr>
<th>Component knowledge and skills and learning pathways</th>
<th>Addressing Industry Gaps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awareness of EE practices, ability to benchmark</td>
<td>1, 2, 3, 4, 5, 7, 10, 11</td>
</tr>
<tr>
<td>Addressing Industry Gaps</td>
<td>1, 2, 5, 8, 10, 11</td>
</tr>
<tr>
<td>Ability to keep the ‘big picture’ in perspective</td>
<td>1, 2, 3, 4</td>
</tr>
<tr>
<td>Understanding of financial considerations</td>
<td>6, 8, 9</td>
</tr>
<tr>
<td>Ability to create robust assumptions</td>
<td>1, 2, 3</td>
</tr>
<tr>
<td>Ability to think laterally</td>
<td>1, 2, 8</td>
</tr>
</tbody>
</table>

‡ 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.

△ This theme emerged very strongly from the workshops. Limited ability to create business cases for improvements that accurately reflect factors such as capital expenditure and future payback periods was often cited as a major barrier to conducting ‘investment grade’ energy efficiency opportunity evaluations, although at least one participant commented that engineering students should not have to conduct in-depth financial analyses 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 3: Workshop Findings - Ability to **Implement** Energy Efficiency Opportunities

<table>
<thead>
<tr>
<th>Graduate Attribute: Ability to Implement Energy Efficiency Opportunities</th>
<th>Technical</th>
<th>Enabling</th>
<th>Discipline-specific</th>
<th>Cross-disciplinary</th>
<th>Mapping Gaps &amp; Competencies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Emergent Knowledge and Skill Areas (Industry), and corresponding component knowledge and skills (Academia)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Perceived Critical Gaps - Industry clustered themes</strong> (Ordered by extent of coverage by participants in discussions and written comments)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>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</td>
<td>●</td>
<td>●</td>
<td></td>
<td></td>
<td>1.5, 1.6, 2.3, 2.4, 3.2</td>
</tr>
<tr>
<td>2. Multi-disciplinary project management skills Understanding/ communicating scope, Engaging with stakeholders &amp; clients, Procurement management, Physical resources management, OHS responsibilities, Change management, Contract and contractor management, HAZOP type assessments</td>
<td></td>
<td>●</td>
<td>●</td>
<td></td>
<td>2.4, 3.4, 3.5, 3.6</td>
</tr>
<tr>
<td>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</td>
<td>●</td>
<td>●</td>
<td></td>
<td></td>
<td>3.2</td>
</tr>
<tr>
<td>4. Systems approach and future-mindedness</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
<td>1.5, 1.6</td>
</tr>
<tr>
<td>5. Knowledge of regulation and codes</td>
<td>●</td>
<td>●</td>
<td></td>
<td></td>
<td>1.1, 1.3, 1.4</td>
</tr>
<tr>
<td>6. Change management and change improvement skills, interpersonal skills and ability to influence behaviour (considering future directions)</td>
<td></td>
<td>●</td>
<td>●</td>
<td></td>
<td>1.4, 2.4, 3.1, 3.6</td>
</tr>
<tr>
<td>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</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td>3.4, 3.5</td>
</tr>
<tr>
<td><strong>Component knowledge and skills and learning pathways - Academic clustered themes</strong> (Ordered by number of industry gaps addressed)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Addressing Industry Gaps</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>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</td>
<td></td>
<td>●</td>
<td></td>
<td></td>
<td>1, 2, 3, 6, 7</td>
</tr>
<tr>
<td>Ability to consider opportunities in the context of the 'big picture' Whole of systems approach, Broad awareness of issues, Future mindedness</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td>1, 2, 4, 6, 7</td>
</tr>
<tr>
<td>Energy Efficiency &amp; Engineering Education</td>
<td>Briefing Note</td>
<td></td>
<td></td>
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<tr>
<td>------------------------------------------</td>
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</tr>
<tr>
<td><strong>thinking long-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</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ability to engage key stakeholders</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Making value propositions, Using relevant/engaging key terms, Communicating financial incentives/ business case, Influencing behaviour and decisions</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ability to communicate with key stakeholders</strong></td>
<td></td>
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</tr>
<tr>
<td>Communicating simple (but not simplistic) message, without jargon, Communicating without judgement, Managing interpersonal relationships</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Good understanding of relevant core technical skills</strong></td>
<td></td>
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<tr>
<td>Knowledge of control systems (HVAC) for example in mechanical engineering, Environmental science needs to include science</td>
<td></td>
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</tbody>
</table>

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.
Glossary

Accreditation
In Australia, external accreditation of university programs that lead to formative engineering qualifications is the responsibility of Engineers Australia (noting that the ‘provider’ is formally the educational authority for program accreditation, as required by ‘TEQSA’. See ‘TEQSA’ below). The accreditation process focuses on the delivery of graduate outcomes as specified in the Engineers Australia Stage 1 Competency Standard for each program, using criteria that cover the teaching and learning environment, the structure and content of the program, and the quality assurance framework. Accredited programs must include ‘exposure to engineering practice’. Engineers Australia ‘Colleges’ are involved through nominating members to accreditation panels. Accreditation is required on the introduction of a new program, and is reviewed every five years.

AQF
Australian Quality Framework. This is Australia’s national policy for regulated qualifications including engineering, intended to provide national recognition and consistent understanding of what defines each qualification type. Under ‘TEQSA’ and in line with the AQF, providers may offer a higher education award which leads to a qualification which corresponds with an AQF level from 5 to 10. As of 2012, engineering programs in Australia are considering how to adapt existing curriculum to meet AQF requirements for ‘Level 8’ which requires an honours or equivalent experience.

Attribute
See ‘Graduate Attribute’

Capability
A specific skill set that forms part of the ‘competency standard’. (See ‘Competency Standard’ below). These may be described as ‘technical’, ‘specialist’, ‘process’, ‘non-technical’, ‘common’ or ‘generic’ capabilities depending on the engineering discipline.

College
Eight colleges are distinguished by Engineers Australia to broadly cover all areas of practice in engineering, and are supported by a number of ‘technical societies’. The colleges are Biomedical, Chemical, Civil, Electrical, Environmental, Information Telecommunications and Electronics (ITEE), Mechanical and Structural. For the purpose of this consultation project, the discipline of ‘Mining and Metallurgy’ was added to the areas of practice, given the significance of this sector in Australia and the specific education delivered to engineers in this field.

Competency Standard
The Engineers Australia ‘Stage 1 Competency Standard’ for each engineering occupation consists of three broad competencies: knowledge and skills base, engineering application ability, and professional and personal attributes. Each competency is broken down into several ‘Elements’(See ‘Element of Competency’ below), each elaborated with a number of ‘Indicators of Attainment’ (See ‘indicator of attainment’ below). Together, each ‘competency’ and their elements, 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 (based on EA competency standard definition).

Course
A unit of work undertaken as part of the overall Program of study (i.e. 1/8 of a nominal full study year). This is also commonly referred to by universities as a ‘Unit’ or ‘Subject’, and may comprise of several ‘modules’.

Curriculum (singular) or Curriculums (plural)
All the courses of study offered by an educational institution (curricula), or a group of related courses (curriculum). For example ‘the mechanical engineering curriculum’. Curricula renewal may involve the redevelopment of one or more courses in a program, the review of syllabus, the pedagogy, and student assessment.

Engineers Australia (EA)
Engineers Australia is the unified, national competency assessment authority for engineering practice in Australia. It is also Australia’s professional body for engineers, and the national forum for the advancement of engineering and the professional development of its members.

Element of
Elements of Competency are the sixteen components of the three Competencies in the Engineers Australia Stage 1 Competency Standard, that must be
Competency
demonstrated for the accreditation of an engineering program to be achieved, or
demonstrated by an individual seeking admission to membership of Engineers
Australia without an accredited qualification. The Elements of Competency may
be used by a university to create ‘Learning Outcomes’ (see ‘Learning Outcome’
below) for the engineering curriculum to align intended ‘graduate attributes’ (see
‘Graduate Attribute’ below) with the Competency Standard’.

Energy Efficiency
See ‘Energy Efficiency Improvements’ below.

Energy Efficiency
Improvements
Using less energy input for an equivalent level of economic activity or service
(European Commission definition).

Engineer /
Engineering
Occupation
A qualified professional specialising in one or more fields (disciplines) of
engineering. Engineers are frequently required to apply their skills across a
range of circumstances that require interdisciplinary co-operation, and to be
work-ready upon completion of their engineering qualification. Engineers
Australia has members in the occupational categories of Professional Engineer,
Engineering Technologist and Engineering Associate. ‘Stage 1’ and ‘Stage 2’
Competency Standards are published for each occupation.

Exposure to
Engineering Practice
All accredited engineering programs must include opportunities for students to
gain understanding of engineering practice. This may include a prescribed
period of practical experience in industry and or industry lectures, site visits,
industry-based projects, and other forms of work-integrated learning.

Formative
Engineering
Qualification
The accredited qualification for entry to practice in each ‘engineering
occupation’. Generic award titles for formative qualifications for each occupation
are: Professional Engineer: Bachelor of Engineering or Master of Engineering;
Engineering Technologist: Bachelor of Engineering Technology; and
Engineering Associate: Advanced Diploma or Associate Degree.

Graduate Attribute
A desirable quality that a graduate engineer will possess by the time they
complete their ‘Program’. This may be a specialist attribute specific to one
discipline of engineering, a common attribute shared with other disciplines of
engineering or a universal attribute shared across all students of any discipline.
Educational institutions design their curricula so that the attributes of successful
graduates will meet the Engineers Australia Stage 1 competency standards.

Indicator (of
Attainment)
Each of the sixteen ‘elements’ of Engineers Australia’s ‘Stage 1 Competency
Standard’, is elaborated with ‘indicators’ of attainment. These provide insight to
the breadth and depth of ability expected for each element of competency,
thereby guiding the competency demonstration and assessment process, as well
as curriculum design. The indicators of attainment 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 (EA
definition).

Knowledge and
Skills
Portions of a ‘Graduate Attribute’ that need to be developed over the duration of
the ‘Program’, in order for the ‘Graduate Attribute’ to be achieved. They can be
further broken down into ‘Component Knowledge and Skills’.

Learning Outcome
A statement of what ‘Knowledge and Skills’ a student should have developed
and to what extent, by the time they complete a ‘Course’. The statement usually
begins with a phrase such as, “By the end of this course, you will be able to …”

Learning Pathway
The way in which one or more ‘Knowledge and Skills’ are built through the
course of a ‘Program’ to achieve a ‘Graduate Attribute’. A learning pathway
comprises a sequence of ‘Courses’ in a ‘Program’, where each Course has a
‘Learning Outcome’ that targets the development of one or more component
‘Knowledge and Skills’. The development of ‘Component Knowledge and Skills’
is often instilled through the processes of ‘learn’, ‘practice’ and ‘demonstrate’,
where: ‘Learn’ refers to the initial exposure to knowledge and theory about the
knowledge or skill; ‘Practice’ refers to students repeatedly accessing the
knowledge and theory; and ‘Demonstrate’ refers to the students applying the
knowledge and theory to problem solving in a contextually appropriate way.
<table>
<thead>
<tr>
<th>Program</th>
<th>The award that a student works towards, and which is made up of a certain number of approved courses. Universities sometimes refer to a program as a 'Course'.</th>
</tr>
</thead>
<tbody>
<tr>
<td>School/ Department/ Faculty</td>
<td>The level of coordination within a university context, in which engineering programs are coordinated, and to which lecturers belong.</td>
</tr>
<tr>
<td>Stage 1 Competency Standard</td>
<td>The Stage 1 Competency Standard sets the outcome expectations for a formative educational qualification accredited or recognised by Engineers Australia, to enable entry to practice into each of the three 'engineering occupations'. Each Stage 1 Competency Standard comprises three 'Competencies', 16 ‘Elements’ and a number of elaborating ‘Indicators of Attainment’. Being ‘ready for entry to practice’ implies that in employment, individuals from accredited programs will typically work initially on tasks of limited scope and complexity, under the guidance of a more experienced person, while they develop practice competencies and experience.</td>
</tr>
<tr>
<td>Stage 2 Competency Standard</td>
<td>(See ‘Stage 1 Competency Standard’) The Stage 2 Competency Standards for each occupational category defines the requirements for independent practice. They are used as the basis of assessment for chartered membership of Engineers Australia and, for Professional Engineers, for registration on the National Professional Engineers Register (NPER). The Stage 2 Competency Standards embody both the enabling (Stage 1) and the practice competencies relevant to a field of engineering and an occupational category. Persons who are Stage 2 competent are practice-experienced and are capable of working autonomously under general direction in normal operating environments. Particularly complex, critical or innovative work might call for limited guidance while experience develops further. (based on EA definition). This standard is under review (2012).</td>
</tr>
<tr>
<td>Technical Society</td>
<td>Engineers Australia uses ‘technical societies’ to form a bridge between engineering and other practitioners, providing a forum for mutual technical development, networking, expanding and sharing knowledge with like-minded professionals (Engineers Australia definition).</td>
</tr>
<tr>
<td>TEQSA</td>
<td>Tertiary Education Quality and Standards Authority. Under the Tertiary Education Quality and Standards Agency Act 2011 (TEQSA Act), all legal entities that meet the definition of a higher education provider in the Act are required to seek registration by TEQSA as a registered higher education provider.</td>
</tr>
</tbody>
</table>
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 contextual factors impacting the engineering discipline.
   1.6. Understanding of the scope, principles, norms, accountabilities and bounds of contemporary 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
12.

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


References


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29 The Natural Edge Project (no date) 'Energy Transformed: Lecture 5.1', TNEP, Australia, www.naturaledgeproject.net/Sustainable_Energy_Solutions_Porfolio.aspx#EnergyTransformedLecture5_1, accessed 31 March 2012.


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