Department of Resources, Energy & Tourism (DRET)
ENERGY EFFICIENCY ADVISORY GROUP (EEAG)
Research Project 1

ENERGY EFFICIENCY GRADUATES ATTRIBUTES PROJECT

Final Report - November 2011
Acknowledgements & Project Team Declarations

This project was funded by the Department of Resources, Energy and Tourism (RET), through its national Energy Efficiency Advisory Group (EEAG). It addresses one of three small project briefs developed by the EEAG to investigate various emergent issues around energy efficiency education, namely what energy efficiency means for the engineering profession (Project 1, led by QUT), how well energy efficiency is covered in existing undergraduate engineering programs (Project 2, led by the University of Adelaide), and how the advisory group – and the department – will know when it has been successful in developing energy efficiency knowledge and skills within university graduates (Project 3, led by the Australian National University). The authors are grateful for the collaborative academic rigour demonstrated across these three projects, whereby peer review and contribution between the three project teams has strengthened the results of each report.

Capacity building in energy efficiency is a significant challenge for higher education and it is critical to have support from the community of practice, for embedded and long-lasting change to be possible. This research project is indebted to the support of a number of academic colleagues from around Australia who are leading the way in considering what it means to prepare engineering graduates for 21st Century employment. In particular the authors would like to thank the following people for their commitment and contribution to the workshop (in alphabetical order): Mr Bradley Anderson, Dr Tim Aubrey, University of Technology Sydney; The Australian Industry Group; Dr Paul Compston, Australian National University; Dr Peter Gibbings, University of Southern Queensland; Dr Tom Goldfinch, University of Wollongong; Associate Professor Roger Hadgraft, University of Melbourne; Professor Doug Hargreaves, Queensland University of Technology/ Engineers Australia (Past President); Mr Karlson ‘Charlie’ Hargroves, University of Adelaide; Emeritus Professor Robin King, Australian Council of Engineering Deans; Dr Peter Knights, University of Queensland; and Ms Michele Rosano, Curtin University.

With thanks to the EEAG committee members who also contributed to the development of the workshop provocation material through an initial brainstorm during the EEAG May 2011 meeting, and to Mr Luiz Ribeiro and Stuart Richardson at the Department of Resources, Energy and Tourism for their vision, mentoring and support throughout this project.

Project team members involved in the preparation of this report include Ms Ocean Wilson (Research Assistant), Associate Professor Roger Hadgraft (Peer Review), Mr Karlson ‘Charlie’ Hargroves (Peer Review) and Mr Bradley Anderson (Industry Perspective).

This collaborative project has been managed by Dr Cheryl Desha, lecturer in the Faculty of Built Environment and Engineering at the Queensland University of Technology, and a member of The Natural Edge Project (TNEP), an academic partnership for research and capacity building for sustainable development. Dr Desha is a member of the Energy Efficiency Advisory Group, and has contributed to the two other projects in an advisory role as part of this EEAG 3-project initiative. Over the last several years, she has led and been involved in a range of energy efficiency education initiatives with the TNEP research group. This has included contributing to the development of 30 lectures on energy efficiency opportunities (by major economic sector and technology) as part of the CSIRO Energy Transformed Program. With funding support by the National Framework for Energy Efficiency Training and Accreditation Committee Dr Desha co-led the 2007 TNEP investigation into the state of engineering education for energy efficiency, and subsequently the 2009 investigation into barriers and benefits for lecturers teaching EE in engineering programs. She also contributed to the 2010 National Framework for Energy Efficiency (NFE) funded national survey of industry and academia regarding graduate expectations.
Executive Summary

The Energy Efficiency (EE) Graduate Attributes Project focuses on engineering as a priority profession that has a significant role to play in addressing energy demand and supply issues in Australia. Specifically, this project aims to support embedding EE knowledge and skills throughout the engineering undergraduate curriculum, to help build capacity within the Australian workforce across major sectors of the economy, from mining, manufacturing and industrial applications to design, construction, maintenance and retrofitting built environments.

The resultant report is intended to assist in future consultation with key groups such as Engineers Australia (EA), the Australian Council of Engineering Deans (ACED) and the eight EA colleges, to support systemic curriculum renewal and promote the design and development of high quality EE engineering education resources. The project is based on a whole-of-program outcomes-based approach to curriculum renewal, creating a transparent framework for integrating EE. This comprises collaborative consideration by academics and professional engineers who have experience in teaching and practising EE, to identify what students should learn to be equipped with relevant competencies by the time they graduate.

The investigation for this project comprised a literature review and an invited workshop for engineering educators with EE education experience, as summarised below.

Literature Review

During the literature review, a number of existing projects and resources were identified that could inform the workshop and future curriculum renewal projects. A number of significant challenges were also apparent for the higher education sector, slowing the embedding of EE within undergraduate engineering education. Key findings are as follows:

- The federal government has already committed funds for building capacity for EE over the last five years in particular, focusing on vocational education and in-house industry training drawing on resources developed through the Energy Efficiency Opportunities (EEO) and other such programs.

- Industry is beginning to seek employees with EE competencies, particularly in the area of EE opportunities and EE assessments, in line with the federal government’s requirements under the EEO program. This skills requirement will increase with the recent passing of legislation to place a price on carbon.

- Within the higher education sector (i.e. amongst the 32 universities producing around 6,000 engineering graduates each year), education for EE has been highly variable and ad hoc, with some engineering disciplines containing no EE content. Very few institutions provide a whole system approach to teaching EE within the curriculum.

- From the curriculum renewal literature there appears to be an opportunity for a rapid transition to embedding EE within undergraduate curriculum across the spectrum of engineering disciplines, using a systematic and whole of curriculum approach.

- Such an approach includes providing educators with clarity about the intended EE related ‘attributes’ that graduates need to be equipped with, in addition to the types of knowledge and skills that subsequently need to be developed within the degree program, and example learning pathways for doing so. It also includes providing educators with access to user-friendly, rigorous resources that can be easily embedded within subjects.
Engineering Educator Workshop

Following a literature review, this project used an initial brainstorm by the national Energy Efficiency Advisory Group (EEAG) and a 1-day workshop with invited EE educators from engineering disciplines covering six of the eight EA colleges, namely Chemical, Civil, Electrical, Environmental, Mechanical and 'ITEE' Information, Telecommunications and Electronics Engineering (i.e. omitting the Biomedical and Structural Colleges). The discipline area of mining and metallurgy was added to the list of disciplines for consideration, given the importance of this sector within the Australian economy and the potential for EE to impact environmental and economic performance. A non-technical area was also included, to ensure that EE related skills such as communication, inquiry and reporting would not be omitted from discussion.

The interactions with educators were focused on developing four deliverables, which are highlighted in the following sections:

1. A set of example EE graduate attributes (i.e. common competencies) common to all engineering graduates. This is intended to highlight the ‘concrete’ nature of EE, and the breadth of topic areas that EE encompasses for all disciplines.

2. For each of the 6 disciplines being considered, example EE elements and indicators (i.e. specific competencies). This is intended to highlight the discipline-specific EE contributions that a wide variety of core/mainstream engineering disciplines can provide.

3. Using an example graduate attribute “The ability to participate in energy efficiency assessments”, example EE learning outcomes that demonstrate learning pathways for the graduate competencies for each of the previously considered disciplines. This is intended to highlight the need to consider scaffolding learning to ensure that the curriculum develops the desired EE graduate attributes.

4. Examples of existing high quality EE resources that could be used to achieve the learning outcomes identified. This is intended to highlight the variety of content already available that can be used to develop EE competencies. It was anticipated that this would be undertaken for each learning outcome however as the number of learning outcomes generated by the workshop participants is extensive a sample is given that would be relevant to a number of learning outcomes.

Output 1: EE Common Graduate Attribute (GA) Development

49 examples of EE graduate attribute statements were identified by the invited workshop participants, which were then clustered into like-minded statements. The clusters are presented below (in no particular order of priority), with the number of statements per cluster providing an indication of the level of attention given by participants to the EE areas (i.e. the current context for EE). Within each cluster, an example graduate attribute is also provided, drawing from the language from the workshop.

On reflection by project participants, it was agreed that these brainstormed considerations could be grouped within the existing EA competency graduate attributes (see Table 2.1 within the report). These are shown in square-brackets and form a topic-specific example of elements and indicators that engineering schools could target to meet Engineers Australia accreditation requirements. This could provide an added incentive for universities to incorporate more EE content in their courses.
- **Cluster 1: Triple Bottom Line/ Emissions Accounting**  
  [15 Examples in Workshop; EA Competency links 1.1, 1.3, 3.4]

  These related to modelling energy flows, embodied energy and EE opportunities in infrastructure, lifecycle costing of infrastructure, assessing EE options including auditing and understanding direct and indirect costs, understanding costs and benefits including current and future costs (e.g. greenhouse gas emissions), and appreciating the complexity of systems in energy supply and demand.

  **Example GA:** An understanding of complex systems in energy supply and demand, including environmental, economic and legal considerations.

- **Cluster 2: Project Work**  
  [8 Examples in Workshop; EA Competency links 2.1, 2.3, 3.6]

  These included being able to make engineering judgements and decisions relating to EE considerations/ trade-offs, systematically incorporating EE into systems, considering the potential for EE gains across a product or system life cycle (from supply chain to end of life), understanding issues such as security, diversity, and sustainability factors and how these influence projects, understanding how to integrate EE into multi-criteria project evaluation, the ability to conceptualise broad, open-ended, ill-defined problems in terms of EE, and applying knowledge of energy and mass flows to pose alternative solutions.

  **Example GA:** An understanding of complex systems in energy supply and demand, including energy flows, legal and economic considerations.

- **Cluster 3: Social and Ethical Considerations**  
  [7 Examples in Workshop; EA Competency links 1.5, 1.6, 3.1]

  These included understanding the principles of sustainable development, understanding how technology can influence (positively or negatively) EE, social responsibility and sustainability, understanding human impacts regarding EE measures, societal enablers and impediments to implementing EE technologies, understanding societal (broad legal requirements/economics, etc) implications of EE, and knowledge of the relationship between energy use and greenhouse gas emissions.

  **Example GA:** An appreciation of the range of 21st Century climate, pollution and finite resource challenges and the key role of EE in addressing these pressures.

- **Cluster 4: Future Directions**  
  [6 Examples in Workshop; EA Competency link 1.4]

  These included the ability to integrate clean/renewable energy technologies, understanding the context regarding energy technology selection and renewable energy systems/options, being aware of directions of research into alternative energy solutions, appreciating the difference between old and new technology, and the ability to model temporal effects of clean energy innovation/ adoption.

  **Example GA:** An appreciation of the key role of EE in future technology and alternative energy solutions.
- **Cluster 5: Fluent Application – Applied**  
  [6 Examples in Workshop; EA Competency links 2.1, 2.2, 2.4]  
  These included the ability to integrate clean/renewable energy technologies, understand the context regarding energy technology selection, renewable energy systems/options (versus traditional energy systems/sources), knowing directions of research into alternative solutions (technologies and systems), old and new energy infrastructure technology, and ability to model temporal effects of clean energy innovation/ adoption  
  **Example GA:** An ability to consider EE as a core design parameter when developing any activity, product or service

- **Cluster 6: Communication and Policy**  
  [5 Examples in Workshop; EA Competency link 3.2]  
  These included the ability to communicate energy supply and demand, effectively communicate (within and outside the engineering discipline) and advocate about issues of EE and the case for identified EE opportunities, to communicate immediate and longer term implications of energy supply options, having an understanding about economic/legal policy context of energy change, understanding organisational barriers to taking up EE opportunities, and the ability to evaluate policy driven implementation of EE technologies at community, corporate and government levels.  
  **Example GA:** An ability to communicate EE opportunities and challenges within and beyond engineering disciplines

- **Cluster 7: Science – background knowledge**  
  [4 Examples in Workshop; EA Competency link 1.1]  
  These related to understanding energy flows, links between climate and energy, interactions between energy and natural systems, and understanding the underpinning physical, scientific and mathematical fundamentals of EE.  
  **Example GA:** An understanding of energy flow and natural and built systems interactions.

- **Cluster 8: Framing Systems – Engineering Thinking**  
  [1 Example in Workshop; EA Competency link 1.1, 1.2, 1.3]  
  This included understanding of how EE permeates many or all aspects of engineering, and the ability to assess energy (and mass) flows throughout a process or a facility. This understanding of system behaviour is generally a precursor to identifying opportunities, and then subsequently evaluating those opportunities.  
  **Example GA:** The ability to conceptualise energy and mass flows within a system.

- **Cluster 9: Innovation, Integration and Proactive Behaviour**  
  [1 Example in Workshop; EA Competency link 3.3]  
  This included the ability to integrate between and beyond engineering disciplines to effect change (leadership in engineering, entrepreneurial).  
  **Example GA:** An appreciation of the need to integrate between and beyond engineering disciplines to effect change in practice.
Output 2: EE Discipline-Based Element & Indicator Considerations

During the 1-day workshop, participants also identified discipline considerations that might be evident in EE education. Further to the federal government’s focus on identifying EE opportunities through energy assessments, participants focused on a graduate attribute related to this topic, i.e. “Ability to Participate in/Contribute to Energy Efficiency Assessments”. Within this context, given the strength of participating academic knowledge and skills in commercial, industrial and residential buildings, and given that buildings are recognised priority targets for reducing greenhouse gas emissions and improving EE, the area of ‘built environment’ was used as the context for the learning pathway exercise.

In the workshop, Chemical, Civil, Electrical, Environmental, Mechanical and Electrical/Electronics engineering educators were asked to focus on the context of mixed-use development to elicit as many ideas as possible. Participants representing the discipline of mechanical and mining and metallurgy were asked to consider a typical mineral extraction and processing scenario, while the learning and teaching participants were asked to focus on non-technical EE assessment related knowledge and skills which could be in any assessment scenario.

The following example discipline-specific EE elements/indicators were distilled from the workshop:

<table>
<thead>
<tr>
<th>Areas for Consideration</th>
<th>Example EE Element/ Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(for the common graduate attribute “Ability to Participate in/Contribute to Energy Efficiency Assessments”)</td>
</tr>
</tbody>
</table>
| Chemical                       | – An ability to conceptualise & compare EE opportunities within manufacturing processes  
|                                | – An ability to communicate EE challenges & opportunities in a given process |
| Civil                          | – An ability to deliver property development that is sympathetic to the environment & topography  
|                                | – An ability to deliver EE in commercial buildings & transportation systems |
| Electrical                     | – An advanced technical knowledge in the specialist area of energy generation & distribution (co-generation, emerging, renewable, etc)  
|                                | – An ability to conceptualise & compare, evaluate & optimise alternative approaches to electrical engineering problems, in consideration of EE & other sustainability issues |
| Environmental                  | – An ability to plan & manage an EE investigation  
|                                | – An ability to contribute to impact assessment in regard to EE assessment |
| Information Technology & Electronic (ITEE) | – Effective communication & advocacy of complex electrical engineering aspects of EE issues to the community (as a technical expert)  
|                                | – Knowledge/ cognisance of emerging EE fields, equipment efficiency, trade-offs, lifecycle modelling & sustainability |
| Mechanical                     | – Knowledge of clean energy technologies that build on fundamental knowledge, for example including solar thermal & geothermal  
|                                | – Proficiency in calculating energy consumption in materials processing, including production, use, & disposal phases |
| Mining & Metallurgy            | – Proficiency in identifying EE opportunities to mining methods including for example rock breakage & transportation.  
|                                | – Ability to ‘design for closure’, to reduce legacy costs & energy requirements (Life of Mine Design & Planning) |
| Non-Technical                  | – An appreciation of an engineer’s responsibility as a global citizen to improve EE in their workplace and industry  
|                                | – An ability to communicate complex EE principles to non-expert audiences |
Output 3: Example EE Learning Pathways

Taking these EE elements and indicators, for each of the areas a number of knowledge and skill areas were identified, which could be ‘learned’, ‘practiced’, and ‘demonstrated’ over the duration of the undergraduate curriculum. Example discipline maps were subsequently generated for this report, for a hypothetical 4-year engineering undergraduate program. This exercise was also undertaken for the specific example graduate attribute of “Ability to Participate in/Contribute to Energy Efficiency Assessments”.

Considering these example maps, it is apparent that there is a natural progression across most engineering disciplines, for development of EE related knowledge and skills. Furthermore, within the context of the assortment of disciplines offered in a given institution, these maps highlight the opportunity for various parts of the curriculum – in particular the first and second years – to include common modules of EE content. These could for example occur within a common course/unit/subject, or could appear as reference resources for each of the disciplines, with attention in one of the units.

Output 4: Example EE Resources

For the purpose of providing example curriculum, the learning outcomes were then used to show how existing resources could be used to develop a number of the highlighted areas of knowledge and skills. In summary, high quality EE educational resources are not widely available, and are highly varied in aspects such as the description of which graduate attributes or elements/indicators are being developed, learning points, and assessment. While there are some existing resources that could be used in course design, high quality resources for teaching EE in engineering are not readily available.

Building Capacity for Energy Efficiency in Australia - Next Steps

This project has identified the need for engineering education in EE in Australia, and has identified a wide range of EE related graduate attributes for engineering and key sub-disciplines. Areas for action that result from this investigation include:

1) There is significant breadth and depth to the types of knowledge and skill areas that are associated with EE, with a clear role for coverage within undergraduate curriculum and in addressing EA accreditation requirements. This provides a strong case for further exploring opportunities to assist academics with identifying critical EE attributes for their degree programs, and mapping appropriate learning pathways to achieve these.

2) Understanding that RET is particularly interested in the application of EE assessment skills, expanding this analysis into other industry sectors such as manufacturing and validating project outcomes with industry practitioners is an important next step to ensure graduate attributes and learning pathways are aligned with industry needs. This could be explored further in conjunction with EA technical colleges in the next phase of the EE project initiatives.

3) The clustering exercise and subsequent analysis was received by participants and reviewers as a useful way to work with information that was helpful and meaningful to participants. It may be a useful tool to take forward in this EE education initiative.

4) Currently EE engineering educational resources are limited, which provides a strong case for developing such resources.
Glossary

Attribute: See ‘Graduate Attribute’

Competency: See ‘Graduate Attribute’

Course: A unit of work undertaken, which is part of the overall ‘Program’ of study (i.e. 1/8 of a nominal full study year). It may be referred to as having anything from 3 to 12 ‘Credit Points’ of value. This is also commonly referred to by universities as a ‘Unit’ or ‘Subject’. At times it may also be referred to as a ‘Module’ although this use is avoided in this report.

Credit Points: The metric used to indicate the amount of work required to complete a ‘Course’ of study. Depending on the university metrics, a ‘Program’ will have an allocated number of Credit Points to distribute among the year levels of a ‘Program’.

Curriculum: All of the learning that is developed and implemented for a given engineering ‘Program’, by a university. This includes a syllabus (i.e. what is taught) and pedagogy (i.e. how it is taught).

Curriculum-Ready: A resource that can be immediately and easily incorporated into a ‘Course’ with minimal modification.

EA: Engineers Australia

EE: Energy efficiency

EEAG: Energy Efficiency Advisory Group

Element: An aspect of a ‘Graduate Attribute’ that needs to be developed for the attribute to be achieved. For example one ‘Graduate Attribute’ may have several ‘Elements’. Also known as an ‘Indicator’. An ‘Element’ may be used directly to create a ‘Learning Outcome’ for a Course, or may be developed through more than one ‘Learning Outcome’.

Indicator: See ‘Element’

Graduate Attribute: A desirable quality (or ‘Competency’) that a graduate engineer will possess by the time they complete their ‘Program’. This may be a common attribute which is shared with one or more other disciplines of engineering (or other disciplines).

Greenhouse Gas: Any of the atmospheric gases that contribute to the greenhouse effect by absorbing infrared radiation.

Knowledge and Skills: Components of the ‘Graduate Attribute’ that need to be developed over the duration of the ‘Program’, in order for the ‘Graduate Attribute’ to be achieved.

Impact: The contribution of an option on the extent of energy efficiency content within the engineering program curriculum.

Laboratory: A scheduled class, usually held in a laboratory room, involving activities such as construction, testing and analysis of equipment, machinery or materials.

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 developed through 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 ‘Knowledge and Skills’.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Likelihood</td>
<td>The chance that a lecturer in their own university context, would implement the option being considered</td>
</tr>
<tr>
<td>Materials</td>
<td>Sources of information that can be drawn upon when creating a specific, discrete ‘Resource’. ‘Materials’ have not been developed for targeted used in an educational setting. They may include for example policy documents, industry standards and regulations. In summary, ‘Materials’ are used to create ‘Resources’, which can be embedded in a given engineering ‘Program’ (i.e. in the ‘Curriculum’).</td>
</tr>
<tr>
<td>Module</td>
<td>A unit of work undertaken, which is part of an overall Course of study, and which may be taught over a period of one or more weeks within the course. In some institutions, this term may be used to describe a ‘Course’ (see above), where smaller units of work may be referred to as ‘sub-topics’.</td>
</tr>
<tr>
<td>Pedagogy</td>
<td>The way in which the course is taught, otherwise referred to as the strategy or style of instruction.</td>
</tr>
<tr>
<td>Program</td>
<td>The award that a student works towards, and which is made up of a certain number of approved courses. This is sometimes referred to by universities as a ‘Course’.</td>
</tr>
<tr>
<td>Resource</td>
<td>A discreet package of information that can be integrated or ‘spliced’ into existing courses, into knowledge and skill development and assessment. This could include for example a lecture, an assignment, an assessment item, some lecture notes, slides, discussion points etc. Sometimes referred to as a ‘Module’, ‘Unit’ or ‘Package’. Note that ‘resource’ may also refer to sources of information that can be drawn upon when creating a specific, discrete ‘Resource’ described in the above paragraph. In this report, this use is avoided, and the term ‘Materials’ is used instead (see ‘Materials’).</td>
</tr>
<tr>
<td>The Project</td>
<td>The EE Graduate Attributes Project</td>
</tr>
<tr>
<td>School/Department/Faculty</td>
<td>The level of coordination within a university context, where engineering programs are coordinated, and to which lecturers belong.</td>
</tr>
<tr>
<td>Sub-Topic</td>
<td>A minor topic within a course, which is associated with learning outcomes and assessment items for that course.</td>
</tr>
<tr>
<td>Syllabus</td>
<td>The document that includes statements of the aims and objectives of course and its content.</td>
</tr>
<tr>
<td>TNEP</td>
<td>The Natural Edge Project, <a href="http://www.naturaledgeproject.net">www.naturaledgeproject.net</a></td>
</tr>
<tr>
<td>Workshop</td>
<td>A scheduled class, usually held in a tutorial room with desks in group formation, and involving the consideration of worked examples and problem-solving guided by a teaching team member, over 1-2 hours duration.</td>
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</tbody>
</table>
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1. Research Method

Further to a number of federal and state initiatives in EE education, the EE Graduate Attributes Project (the Project) aims to support the embedding of such knowledge throughout the engineering curriculum, by developing a discussion paper that demonstrates how EE graduate competencies and learning outcomes can direct the targeted development of EE education resources for engineering lecturers in Australian Universities. Project outcomes will assist in future consultation with key groups, such as Engineers Australia’s (EA) colleges, that will seek to refine the outputs from this project so they can inform subsequent design and development of high quality EE engineering education resources.

The objectives of this study are to:

- Demonstrate how EE graduate competencies and learning outcomes can direct the targeted development of EE education resources for engineering lecturers in Australian Universities. Specifically, this project will identify EE graduate competencies and learning outcomes that can then be used to develop targeted resources for teaching engineering within higher education institutions.
- Assist key groups (such as EA colleges) to “inform subsequent design and development of high quality EE engineering education resources”. In other words, it aims to facilitate the synthesis of excellent resources for the teaching and learning of EE within engineering programs/courses.

1.1 Research Approach

Given the timing and brief provided by DRET, this project proposal adopts a literature review and workshop approach to investigating the national regulatory and professional context for embedding EE, and subsequently developing a suite of example competencies, learning outcomes and resources that can be used to support future larger projects across the key engineering disciplines. The following bullet points summarise the proposed method, and research tasks for this project:

1. Literature review – national context: A brief overview of the national context within which graduate EE competencies are being defined, including: the National Education for Sustainability Strategy; the National Framework for Energy Efficiency; the new National Academic Standards for engineering; and the recently revised Engineers Australia competency standards

2. Examples of EE competencies & learning outcomes and explanatory text: Examples of EE engineering graduate competencies, and appropriate learning outcomes, using a 1-day workshop of 10 participants on Friday 3 June 2011. The competencies include examples of: i) at least six overarching engineering competencies, and ii) at least two specific engineering competencies relevant to each of the following six EA college disciplines: Chemical, Mechanical, Electrical, Environmental, Civil, Information, & Telecommunications and Electronics Engineering (ITEE). Biomedical and Structural college disciplines can be added if desired.

3. Examples of learning outcomes, including example learning pathways, for the competencies for each EA college discipline identified above, demonstrating how each of these competencies could be developed over the duration of study.
4. **Examples of applied, high quality education resources** that would help achieve the learning outcomes identified (so as to provide a better idea of the learning outcomes desired, and approaches to achieving them). Based on the competencies, learning outcomes and learning pathways identified at the workshop, create links to a couple of example education resources.

Considering the role of all engineering disciplines in considering EE, the project attempted to span a number of core disciplines. This is summarised below, showing correlation with the Engineers Australia colleges:

**Table 1.1 Disciplines of focus**

<table>
<thead>
<tr>
<th>Engineering Discipline</th>
<th>Engineers Australia College</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical</td>
<td>Chemical</td>
</tr>
<tr>
<td>Civil</td>
<td>Civil</td>
</tr>
<tr>
<td>Environmental</td>
<td>Environmental</td>
</tr>
<tr>
<td>Electrical &amp; Electronic</td>
<td>Electrical Information, Telecommunications and Electronics</td>
</tr>
<tr>
<td>Mechanical</td>
<td>Mechanical</td>
</tr>
<tr>
<td>Mining and Metallurgy</td>
<td>-</td>
</tr>
<tr>
<td>Other Non-Technical</td>
<td>(Across all colleges)</td>
</tr>
</tbody>
</table>

Understanding that this project was a preparatory exercise to canvas the type of EE knowledge and skills to be embedded within engineering undergraduate curriculum, a number of disciplines reflected in the eight Engineers Australia colleges were not included in the study. These comprised the Biomedical and Structural Engineering colleges and the information and telecommunications part of Electronics engineering.

**1.2 Workshop Tasks**

The workshop format was a hybrid of the current ALTC ‘define your discipline’ project being run by Professor Roger Hadgraft, where graduate expectations are first brainstormed then fashioned into clusters of learning outcomes, and a methodology developed by The Natural Edge Project for clustering and evolving ideas around themes. Subsequently the tasks undertaken during this workshop included:

- Identifying EE Engineering Graduate Competencies;
- Individual brainstorming, followed by paired discussions;
- Group clustering of themes;
- Discussion of themes and prioritization of a thin slice to be carried through to next session;
- Identifying EE Learning Outcomes and Mapping;
- Facilitated individual exploration of learning outcomes to develop the selected thin slice (i.e. prioritized from previous session) & mapping implications; and
- Presentation and discussion of considerations and recommendations.

Key outputs from the workshop included notes from the brainstorming session, visual cluster maps of EE competencies in themes, notes from discussion, and participant notes (in template) for write-up, including a recording of discussion for a written summary and inclusion in this report.
2. Literature Review

2.1 Global Context – Education for Energy Efficiency

Society is increasingly calling for professionals across government, industry, business and civil society to be able to problem-solve issues related to climate change and sustainable development as part of their work. In particular there is an emerging realisation of the fundamental need to swiftly reduce the growing demand for energy across society, and to then meet the demand with low emissions options.1 A key ingredient to addressing such issues is equipping professionals with emerging knowledge and skills to address energy challenges in all aspects of their work.

The Council of Australian Governments has recognised this need, signing the National Partnership Agreement on Energy Efficiency in July 2009, which included a commitment to assist business and industry obtain the knowledge, skills and capacity to pursue cost-effective EE opportunities.2 Engineering will play a critical part among the 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.’3

Energy efficiency as a concept has gained significant attention over the last few decades, as governments and industries around the world have grappled with issues such as rapidly expanding needs for energy, the cost of supplying infrastructure for more extreme spikes in peak demand, the finite nature of fossil based energy reserves, and transition timeframes for expanding renewable energy supplies. Over the last decade in particular, there has been a significant growth in understanding of the complexity of these issues, their inter-relationships and the information and organisational challenges faced by companies to implement effective energy management strategies. Programs such as the Energy Efficiency Opportunities (EEO) program have sought to build capacity within companies to conduct EE assessments and identify cost effective opportunities to improve their energy performance. There has also been a realisation amongst various government departments and education providers that associated knowledge and skill sets to achieve EE goals are not being sufficiently developed in vocational or higher education.

Further to a number of federal and state initiatives in EE education, the EE Graduate Attributes Project (this project) aims to support the embedding of such knowledge throughout the engineering curriculum, by developing a report that demonstrates how EE graduate competencies and learning outcomes can direct the targeted development of EE education resources for engineering lecturers in Australian universities. Project outcomes will assist in future consultation with key groups, such as Engineers Australia’s (EA) colleges, that will seek to refine the outputs from this project so they can inform subsequent design and development of high quality EE engineering education resources.

In 2007 the National Framework for Energy Efficiency (NFEE) funded the first survey of EE education across all Australian universities teaching engineering education, which asked, ‘What is the state of education for energy efficiency in Australian engineering education?’.4 Responses from 27 of the 32 universities teaching engineering education, in every state and territory in Australia, suggested that EE education is currently highly variable and ad hoc across universities and engineering disciplines. The report concluded that there is an urgent need to embed EE knowledge and skills into engineering curriculum, beyond once-off courses, special interest topics
in later years, or highly specialised masters programs. Literature from around the world also clearly suggests that engineering education has been relatively slow to incorporate significant knowledge and skill areas, including the rapidly emerging area of sustainable development.

In responding to this identified gap in EE knowledge and skills, a significant barrier is the time lag in the higher education sector, in integrating new content within existing curriculum.\(^5\) While flagship courses and specialised ‘streams’ on EE have begun to emerge for a small percentage of engineering students, there is a ‘business-as-usual’ timeframe of up to two decades to fully and appropriately embed new concepts across the engineering curriculum to reach the majority of the 6,000 graduates\(^6\) entering the workforce each year in Australia from 3 year (technologist), 4 year (engineering) and 5 year (engineering double degree) programs, in addition to those engaged in formal (i.e. certificate, diploma or masters programs) and informal (short course or other professional development) learning. Hence, there is a need to swiftly increase the extent of EE knowledge and skills in engineering education at both undergraduate and postgraduate levels nationally.

This research project has been funded by the Department of Resources, Energy and Tourism (DRET) to provide guidance to assist engineering educators considering curriculum renewal in the area of EE education, through considering what EE knowledge and skills graduates should have when they complete their studies, and mapping this development through their curriculum. The findings of this research are intended for use by engineering departments, accreditation agencies, professional bodies and government, to identify opportunities for moving forward (based on rigorous research), and then to strategically plan the transition. The project provides a significant opportunity to explore options to support lecturers, program co-ordinators and senior staff to strategically approach, in an informed way, the challenge of increasing the levels of education for EE. This process, focused on EE, will also provide valuable parallels for a range of sustainable engineering related topics. The authors look forward to receiving feedback from engineering educators as they read and use this report to bring about curriculum renewal in EE education.

2.2 National Context – Engineers Australia

Over the last two decades in particular, Engineers Australia has produced a number of internationally regarded documents that promote the need for sustainability and key topics such as EE to be taken seriously. These include for example the Code of Ethics document which states on page 1,

“As engineering practitioners, we use our knowledge and skills for the benefit of the community to create engineering solutions for a sustainable future. In doing so, we strive to serve the community ahead of other personal or sectional interests.”

This is supported by the institution’s Sustainability Charter, which states,\(^7\)

“Engineers Australia believes that achieving sustainable development requires a fundamental change in the way that resources are used and in the way that social decisions are made. Accordingly, change will require time and a transitional process towards an aspirational outcome. This means that the process for achieving sustainable development becomes as important as the outcomes themselves. Regular reporting of progress towards sustainability outcomes is vital and should be conducted openly and transparently.”
These statements are translated into tangible statements for action in the Stage 1 Competency Standard that underpins program accreditation in Australia. As shown in the following table of the Engineers Australia Stage 1 Competency standards, there is a clear set of sustainability-related vocabulary that can be addressed by universities in their program development:

### Table 2.1 Engineers Australia Stage 1 Competency Standard

<table>
<thead>
<tr>
<th>1. KNOWLEDGE AND SKILL BASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Comprehensive, theory based understanding of the underpinning natural and physical sciences and the engineering fundamentals applicable to the engineering discipline.</td>
</tr>
<tr>
<td>1.2 Conceptual understanding of the, mathematics, numerical analysis, statistics, and computer and information sciences which underpin the engineering discipline.</td>
</tr>
<tr>
<td>1.3 In-depth understanding of specialist bodies of knowledge within the engineering discipline.</td>
</tr>
<tr>
<td>1.4 Discernment of knowledge development and research directions within the engineering discipline.</td>
</tr>
<tr>
<td>1.5 Knowledge of contextual factors impacting the engineering discipline.</td>
</tr>
<tr>
<td>1.6 Understanding of the scope, principles, norms, accountabilities and bounds of contemporary engineering practice in the specific discipline.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2. ENGINEERING APPLICATION ABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Application of established engineering methods to complex engineering problem solving</td>
</tr>
<tr>
<td>2.2 Fluent application of engineering techniques, tools and resources.</td>
</tr>
<tr>
<td>2.3 Application of systematic engineering synthesis and design processes.</td>
</tr>
<tr>
<td>2.4 Application of systematic approaches to the conduct and management of engineering projects.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3. PROFESSIONAL AND PERSONAL ATTRIBUTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Ethical conduct and professional accountability</td>
</tr>
<tr>
<td>3.2 Effective oral and written communication in professional and lay domains.</td>
</tr>
<tr>
<td>3.3 Creative, innovative and pro-active demeanor.</td>
</tr>
<tr>
<td>3.4 Professional use and management of information.</td>
</tr>
<tr>
<td>3.5 Orderly management of self and professional conduct.</td>
</tr>
<tr>
<td>3.6 Effective team member and team leader.</td>
</tr>
</tbody>
</table>

In the 2010 revision of the competency standards, a second level of descriptors have been added to provide additional explanation about the intention of the competency standards statements, termed ‘elements’ and ‘indicators’. These include the following references to sustainability:

- 1.5a) Identifies and understands the interactions between engineering systems and people in the social, cultural, environmental, commercial, legal and political contexts in which they operate, including both the positive role of engineering in sustainable development and the potentially adverse impacts of engineering activity in the engineering discipline

- 1.6d) Appreciates the social, environmental and economic principles of sustainable engineering practice.

- 2.3c) Executes and leads a whole systems design cycle approach including tasks such as:... systematically addressing sustainability criteria

- 2.4f) Demonstrates commitment to sustainable engineering practices and the achievement of sustainable outcomes in all facets of engineering project work.
Clarifying and strengthening the linkage between EA competency standards, sustainability, and concepts such as systems based thinking, provides an additional opportunity to promote the teaching of energy efficiency in engineering faculties, as well as helping faculties in meeting EA's accreditation framework requirements.

2.3 Education and Training Context

A number of national and state initiatives are increasingly focused on EE education and are also driving capacity building initiatives around EE knowledge and skills. This includes for example, a variety of existing, federally funded initiatives across the higher education and VET sector landscape, highlighted in the following paragraphs.

Despite the preliminary nature of activities to date, the existing and emerging initiatives point to emerging clarity around what EE means, and the context and scope of EE education that is more than just using less fossil fuel per unit activity. As renewable energy options and related topics influence EE outcomes, they are also being incorporated within the scope of EE education. However, as highlighted in the 2007 NFEE survey on EE education in engineering (also summarized in Project 2), a number of key EE topic areas do not appear to be receiving adequate coverage, particularly in the area of systemic consideration of energy flows and identification of actual EE opportunities based on detailed data analysis.

The following national initiatives have been undertaken to date, in the area of EE capacity building. The first two of which are mentioned in the 2010 Report of the Prime Minister's Task Group on Energy Efficiency, and all of which sit within Living Sustainably: the Australian Government’s National Action Plan for Education for Sustainability (2009):

- **Green Skills Agreement:** On 7 December 2009, the Council of Australian Governments (COAG) endorsed a new Green Skills Agreement to enable individuals and businesses to contribute to a sustainable, low-carbon economy in their workplaces and communities. The Agreement commits the Australian and state and territory governments to working with training organisations and business to ensure skills for sustainability are an integral part of all vocational education and training (VET) and are relevant to the needs of industry. There is some reference to higher education in the Green Skills Agreement (pp 3-4). Furthermore, while the Implementation Plan is primarily VET focused, there are multiple references to HE.

- **National Strategy on Energy Efficiency:** This Council of Australian Government (COAG) strategy contains two skills and training measures. The first is to develop the ‘National EE Skills Initiative’ (2010-11) as a strategy for future skills requirements of a low carbon economy. The second is to strengthen national capability in energy auditing and assessment, including developing a long-term training strategy for EE assessment skills, assessing the scope to rationalize EE Audit and assessment processes, and reviewing the energy audit standards.

- **National VET Sector Sustainability Action Plan:** The National VET Sector Sustainability Action Plan (NVSSAP) 2009-2012 was endorsed by the Ministerial Council for Vocational and Technical Education (MCVTE) in June 2009. It is intended to provide a national framework for the VET sector to support the development of a productive workforce as industry, government, individuals and the wider community move to a sustainable economy.

- **Long Term Training Strategy for Energy Efficiency Assessment Skills:** In 2009–10, the National Framework for Energy Efficiency (NFEE), a joint initiative of Australian, State and
Territory Governments, commissioned a research report investigating EE assessment skills to inform activities that would address the capacity and capability of industry in this area. The research was primarily based around the assessment requirements of the EE Opportunities (EEO) program, a NFEE and Australian Government initiative. The research identified a suite of functional skills covering the practical skills that allow companies to conduct rigorous effective EE assessments and the skills gaps which currently exist in the engineering and management professions.

These initiatives complement the Government’s 2009 Clean Sustainable Skills Package, a $94 million investment in green jobs and training opportunities, the 2009 Skills for the Carbon Challenge initiative which aims to provide national leadership in building the capacity of the tertiary education sector to supply skills needed for industry to prosper in a sustainable, low carbon economy, and the 2011 Clean Energy and Other Skills Package which will invest up to $32 million over four years to enable tradespeople and professionals to develop skills needed to deliver clean energy services, products and advice.

At a state level specifically with regard to EE education, in 2010 the Queensland Energy Efficiency Industry Leaders Group released an Industry Action Plan, within a Queensland Government led initiative, the Sustainable Energy Skills Formation Strategy. Four key areas of action were identified, including Government Policy; Industry Profile; Licensing and Accreditation; and Education and Training. To support this document, the QEEILG has developed an Implementation Plan outlining the specific measures the Group intends to put in place to ensure a planned, consistent and sustainable development of the industry’s workforce.

Alongside these state and national initiatives, there have been a number of institutional projects around EE education for the workplace, ranging from course lectures through to individual units, Certificate IV through and VGC level qualifications, as follows:

- Queensland Department of Education and Training: MSACMT670A Develop and manage sustainable energy practices. This unit has recently been completed by Dr Peter Hope for the VGC in Master Trade Applications – Sustainability Projects (SkillsTech, QLD DETA).

- The Natural Edge Project - Energy Transformed: Sustainable Energy Solutions for Climate Change Mitigation. This 600 page (30 lectures) online education program is a freely available and online education and training resource that documents how Australia can achieve at least 60 percent cuts to greenhouse gas emissions by 2050. Completed in 2009, the resource was developed with funding from the CSIRO Energy Transformed Flagship research program.

- Certificate IV in Home Sustainability Assessment: This resource is designed for specialist managers with responsibility for environmental sustainability, or general managers with a specific brief to manage environmental performance, including owners/managers of small businesses, consultants or advisors helping organisations to manage performance, or those involved in a role that concerns sustainability activities within an organisation.

- Certificate IV in Sustainable Energy and Resource Efficiency Technologies - Swinburne. This course covers the practice application of sustainable energy and resource efficiency technologies. The course is structured to deliver knowledge and skills for graduates to be able to install or supervise the installation of apparatus, provide advice to clients, provide retail and wholesale services to the relevant industry, and advise on policy and planning roles.
VGC in Sustainability, and VGC in Education and Training for Sustainability - The National Centre for Sustainability (NCS, Swinburne University). This VGC ETfS accreditation and resource development has been funded through Swinburne University and the Department of Education and Training NSW and is currently being piloted in Qld and NSW. A NSW DET VET EE cohort for the VGC ETfS is also being developed for teaching in NSW beginning March 2011.

Graduate Certificate in Energy Efficiency for Facility Managers – Swinburne University: NCS has led an industry based team to develop an accredited EE course and an industry accreditation scheme for facility managers, including the Facility Management Association of Australia, an industry specialist association and a private specialist RTO. Funding provided by the National Framework for Energy Efficiency, accredited by Victorian Registration and Qualifications Authority, with Sustainability Victoria retaining copyright ownership.

Teaching Unit on Energy Efficiency and Renewable Energy - The Australian Research Institute on Education for Sustainability (ARIES, Macquarie University): for inserting at the diploma or graduate diploma level in higher education or vocational education and training. This resource is funded by the Department of Education, Employment and Workplace Relations (DEEWR), as part of the Skills for the Carbon Challenge initiative.

A number of courses are also currently under development. For example:

Certificate IV in Energy Efficiency Assessment and Design - Energy Management Institute (EMI): This certificate is intended primarily for training electricians in assessment and design.

Graduate Certificate in Building Energy Analysis (non-residential) for Professionals – Swinburne University: This project is being lead by the Clean Energy Council in partnership with Swinburne’s National Centre for Sustainability and RMIT Centre for Design. Funding provided by the NFEE and Sustainability Victoria (SV), with SV retaining copyright ownership.

In summary, it is clear that there is an under-representation of higher education initiatives in Australia at present, which previous reports for the National Framework for Energy Efficiency have concluded is due to a number of barriers facing lecturers in developing and integrating resources within their lectures (see also literature review for Project 2). In 2010, following completion of the second NFEE report into barriers and benefits of embedding EE into engineering education, and following a report on the long term training strategy for EE capacity building in Australia, DRET created the national Energy Efficiency Advisory Group (EEAG) to strategically consider how such barriers can be addressed within the higher education system. At a state level, the NSW Office of Environment and Heritage also created an EE Training Program initiative, whereby the University of NSW and the University of Wollongong are trialing the rapid integration of EE within undergraduate and postgraduate engineering curriculum, and various NSW universities are piloting the integration of EE into accounting courses.

2.4 Curriculum Context

Engineering education has come a long way over the last two centuries, rising to the challenge of a series of periods of rapid change and upheaval such as the industrial revolution in 18th Century Britain and the two world wars of the 20th Century. Industrial society and in particular economic demands of the first half of the 20th Century required the invention of modern research and teaching universities and technical colleges. By the end of the Second World War, engineering
had become a core profession and a core part of the higher education curriculum, equipping professionals to deliver goods and services in the face of ever-increasing demand across an expanding spectrum of needs. The curriculum has evolved to follow the development of society and industry in order to continue to meet its needs, comprising a complex and highly specialised curriculum. A diagram indicating the progress of these impetuses, or ‘waves of innovation’, and the curriculum transitions that followed, is shown in Figure 1.

The fifth wave of innovation, which occurred towards the end of last Century, provided a new technological platform and numerous tools for enhancing communications, computation, design, drafting, and data analysis and storage, allowing operations to be significantly improved, and transaction costs to be significantly reduced. However the legacy of this wave is that it has come with an environmental impact that is now becoming evident and beginning to impact on economies and industries. Subsequently society now faces a host of emerging challenges and opportunities such as reducing greenhouse gas emissions, addressing climate change adaptation needs, dealing with resource scarcity and creating sustainable solutions that decouple economic growth from negative environmental pressure.

Figure 1: A schematic of curriculum renewal transitions, following significant waves of innovation
Source: adapted from Figure 1.1 in Hargroves and Smith (Natural Advantage of Nations, p17)

In the sixth wave, society is responding to these emerging challenges, with innovations that both build on the previous waves and also significantly reduce environmental pressures, including substantial new knowledge and skill sets across all engineering disciplines in new areas such as resource productivity, EE, whole system design, and biomimicry - design inspired by nature. Within this context, the system of engineering education faces a significant challenge to provide graduates that can assist industries to reduce such impacts and remain competitive and productive. Indeed, compelling evidence suggests that the emerging imperative for the next decade will be to rapidly embed education for sustainability (EfS) within all education programs, including engineering as a priority.

However, research findings from around the world indicate that, to date, the integration of significant new knowledge and skill sets within higher education is limited and at best ad hoc.
and the traditional time to undertake a full-scale curriculum transition (in the order of two decades) exceeds the available window for equipping professionals with critical new graduate attributes; a significant time lag dilemma’ facing educators. Furthermore, within the literature (for example see Heywood, there are few examples of systemic curriculum renewal that meet the recommended timeframe of one decade, or discussion of how curriculum renewal could be undertaken over such contracted timeframes.

Following extensive development and trialling of a number of elements of curriculum renewal the authors sought to develop a schematic that could demonstrate how these elements could be harnessed to provide a strategic approach to curriculum renewal. This enquiry included analysis of a number of earlier models by leaders in the field over the last half century, including Tyler, Taba, Wheeler, Kerr, Walker, Stenhouse, and Egan. The resultant circular schematic shown in Figure 3 provides the sense of non-linear dynamism while also demonstrating the need for a deliberative approach informed by a number of factors at each stage of the process. It is intended that the model provide an accessible and useful tool for engineering academics to review and update their units, courses and programs.

![Figure 2: The Deliberative and Dynamic Model for Rapid Curriculum Renewal](image)

Beginning with the curriculum renewal strategy text in the centre of the diagram, the model highlights the importance of having a central point of reference when undertaking systematic curriculum renewal, particularly when multiple educators are involved. The arrows immediately around this text are a reminder that the strategy needs to inform each and every stage of curriculum renewal. In the five larger circles around the central strategy, the five key steps in curriculum renewal are linked in an iterative process that requires a substantial amount of planning and investigation before the individual units are revised. The arrows interacting with the outer circle are a reminder that this stepped process requires continual monitoring and evaluation, internal and external collaboration, and awareness raising and capacity building among staff. Furthermore, the steps are informed by, and also inform, the three activities in the outer circle.
3. EE Common Graduate Attribute Development

Participants were asked to brainstorm common engineering graduate attributes that relate to EE (see bullet points below, which are ‘as written’ by participants). These were then clustered into themes by participants (see title in “” for each cluster of attributes), in no particular order. Following the clustering exercise, participants were asked to refer to the Engineers Australia Competency Standards and comment on how the clusters relate to the competency statements. As these standards provide guidance for curriculum content in Australian engineering courses, it is useful to show how the clusters align with them. The suggested links are shown in italics, at the bottom of each group.

Cluster 1: “Financial” (Triple Bottom Line/ Emissions Accounting)

Example text for graduate attribute statements related to energy efficiency:

- Know how to model energy flows within an engineering system over its lifetime
- Embodied energy in civil infrastructure
- Lifecycle costing of infrastructure, particularly energy/material costs/trade-offs
- Assesses energy efficiency options from a cost-benefit perspective, considering direct and indirect costs
- Cost/benefit analysis: ability, energy audits, broad cross-discipline understanding, ability to socialise the concepts and articulate to wide audience
- An understanding of complex systems in energy supply and demand
- Understand energy flows and estimates of energy efficiency
- Understand/estimate energy efficiency of processes/products
- Know how to estimate embodied energy in a material or artefact
- Understand/estimate life cycle (management, impact) of energy systems (services/ products)
- Understand/estimate embodied energy and energy balances
- An appreciation of economic/market considerations in energy supply and demand
- Know how energy costings/ budgets are undertaken in major industries
- Understand/estimate energy flows and energy audits
- Understand how to account for emissions for planned or existing mining and mineral processing systems

Links to Engineers Australia Stage 1 Competency Standard:
- Competency 1.1: Fluent Application
- Competency 1.3: In Depth Understanding
- Competency 3.4: Use of Information

Example EE graduate attribute for this cluster:

An understanding of complex systems in energy supply and demand, including environmental, economic and legal considerations.
Cluster 2: “Project Work”

Example text for graduate attribute statements related to energy efficiency:
- Be able to make engineering judgements and decisions relating to energy efficiency considerations/trade-offs
- Be able to systematically incorporate energy efficiency into systems
- Implement principles of energy efficiency in the engineering design process, including life cycle analysis
- Considers potential for energy efficiency gains across a product or system life cycle, from supply chain to end of life
- Understanding of energy efficiency, security, diversity, and sustainability factors and how these influence projects
- Understand how to integrate energy efficiency into multi-criteria project evaluation
- Ability to conceptualise broad, open-ended, ill-defined problems in terms of energy efficiency.
- Apply knowledge of energy flows to pose alternative solutions -> optimisation and design

Links to Engineers Australia Stage 1 Competency Standard:
- Competency 2.1: Complex problems
- Competency 2.3: Systemic Engineering
- Competency 3.6: Team Behaviour

Example EE graduate attribute for this cluster:
An understanding of complex systems in energy supply and demand, including energy flows, legal and economic considerations.

Cluster 3: “Social & Ethical Considerations”

Example text for graduate attribute statements related to energy efficiency:
- Understanding of how technology can influence (positively or negatively) energy efficiency
- Appreciating social responsibility
- Understand human impacts regarding energy efficiency measures
- Understand societal enablers and impediments to implementing energy efficiency technologies
- Understand the principles of sustainable development
- Understand the societal (broad legal requirements/economics, etc) implications of efficiency
- Knowledge of the relationship between energy use and greenhouse gas emissions

Links to Engineers Australia Stage 1 Competency Standard:
- Competency 1.5: Contextual factors
- Competency 1.6: Contemporary engineering practice
- Competency 3.1: Ethics

Example EE graduate attribute for this cluster:
An appreciation of the range of 21st Century climate, pollution and finite resource challenges and the key role of energy efficiency in addressing these pressures.
Cluster 4: “Future Directions”

Example text for graduate attribute statements related to energy efficiency:
- Ability to integrate clean/renewable energy technologies
- Understand context re: energy technology selection
- Understand renewable energy systems/options (vs traditional energy systems/sources)
- Know directions of research into alternative energy solutions (technologies and systems)
- Knowledge of energy infrastructure – old and new technology
- Model temporal effects of clean energy innovation/adoption

Links to Engineers Australia Stage 1 Competency Standard:
- Competency 1.4: Research

Example EE graduate attribute for this cluster:

An appreciation of the key role of EE in future technology and alternative energy solutions.

Cluster 5: “Fluent Application – Applied”

Example text for graduate attribute statements related to energy efficiency:
- Systems thinking – modelling of complex interactions (energy flow)
- Energy efficient buildings (liaise with architects)
- Energy efficient construction practices
- Water/energy trade-offs
- An ability to identify energy efficiency opportunities in their discipline
- Energy content of transport systems and infrastructure

Links to Engineers Australia Stage 1 Competency Standard:
- Competency 2.1: Complex Problems
- Competency 2.2: Industrial ecology – energy efficient waste processing (lifecycle)
- Competency 2.4: Engineering Project Management

Example graduate attribute for this cluster:

An ability to consider energy efficiency as a core design parameter when developing any activity, product or service.

Cluster 6: “Communication & Policy”

Example text for graduate attribute statements related to energy efficiency:
- Ability to communicate energy supply and demand
- To be able to effectively communicate (within and outside the engineers discipline) and advocate about issues of EE and the case for identified EE opportunities
- Ability to communicate immediate and longer term implications of energy supply options
- Understand economic/legal policy context of energy change
- Evaluates policy driven implementation of EE technologies at community, corporate and government levels
Links to Engineers Australia Stage 1 Competency Standard:
- Competency 3.2: Communication

**Example graduate attribute for this cluster:**
An ability to communicate EE opportunities and challenges within and beyond engineering disciplines

**Cluster 7: “Science (Background Knowledge)”**

Example text for graduate attribute statements related to energy efficiency:
- An understanding of energy flows (everything comes from the sun)
- Understanding of links between climate and energy (including water)
- Knowledge of interactions between energy and natural systems
- Understand the underpinning physical and scientific fundamentals of energy efficiency

A related area is also the ability to analyse data using statistical techniques such as regression analysis to establish relationships between parameters which could have an impact on energy use. Similarly estimation techniques are important to establish energy use or savings to various degrees of accuracy.

*Links to Engineers Australia Stage 1 Competency Standard:*
- Competency 1.1: Fluent Application

**Example EE graduate attribute for this cluster:**
An understanding of energy flow and interactions with natural and built systems.

**Cluster 8: “Framing Systems, Engineering Thinking”**

Example text for graduate attribute statement related to energy efficiency:
- Understanding of how energy efficiency permeates many or all aspects of engineering

*Links to Engineers Australia Stage 1 Competency Standard:*
- Competency 1.1: Engineering fundamentals
- Competency 1.2: Conceptual understanding
- Competency 1.3: In-depth understanding

**Example EE graduate attribute for this cluster:**
The ability to conceptualise energy and mass flows within a system.

**Cluster 9: “Innovation, Integration, Proactive Dimension”**

Example text for graduate attribute statements related to energy efficiency:
- Integrate engineering disciplines to effect change (leadership in engineering, entrepreneurial)

*Links to Engineers Australia Stage 1 Competency Standard:*
Competency 3.3: Pro-active demenor

**Example EE graduate attribute for this cluster:**
An appreciation of the need to integrate between and beyond engineering disciplines to effect change in practice.
4. EE Discipline Considerations

Participants were allocated an engineering discipline each, and asked to consider EE knowledge and skill requirements that relate to the highly topical example graduate attribute of “Ability to Participate in/Contribute to Energy Efficiency Assessments”. Specifically the participants were asked to focus on the context of mixed-use development (except for the discipline of mining and metallurgy, as noted in the text).

The lists on the following pages are in alphabetical order of discipline, 'as written' by participants. Some guidance in interpreting the lists is provided below:

- The lists are preliminary, to support future more in-depth consultation with the Engineers Australia colleges and industry practitioners.
- There are quite a few elements and skills that could underpin EE that are more generic, in addition to some specific items. In some instances the connection may be obvious to any reader, while others are better understood if there is knowledge of the discipline.
- Some of the elements and skills listed under one sub-discipline would also be valuable in one or more others. As the exercise was undertaken in discipline groups without interrogating the other lists, it is interesting to see some similarity between lists; the core themes are quite similar.
- Some of the data analysis skills required to model, evaluate, estimate energy use and energy savings do not appear in the lists. This could be because they are thought by the participants to be already well covered in programs, or the workshop participants may not have been aware that there are gaps in this area. The lack of awareness aligns with the findings of previous research projects (for example the NFEE 2007 Survey) and suggests a disconnect between what educators teach around EE and what industry actually needs (see Long Term Training Strategy for Energy Efficiency Assessment Skills and findings from Project Two).
- There are a variety of technologies and innovations that are listed under knowledge/skills areas across different disciplines. For example, coal seam gas and reverse osmosis are specific technological processes in comparison to knowledge/skill areas such as 'knowledge of physics, thermodynamics, and heat transfer'. This spread of technology-oriented versus first-principles oriented education reflects the diversity of contexts for university education in Australia, highlighting the opportunity for quite different contexts for EE education in future.

**Discipline: Chemical Engineering**

This could include for example: 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.

Example Element/Indicator:
- Ability to conceptualise and compare energy efficiency opportunities within manufacturing processes
- Ability to communicate energy efficiency challenges and opportunities in a given process
Component Knowledge and Skills (Learning Outcomes):

- Energy efficiency (optimisation) of processes and choice of processes
- Industrial ecology opportunities
- Choice of materials in manufacture of electrical devices and its impact on lifecycle costs (including energy content)
- Embodied energy of material manufacture
- Heat recovery processes (particularly low grade heat)
- Advising/persuading energy efficient choices
- Soil science – chemical aspects dealing with carbon [i.e. alternative fuels to reduce coal fired electricity use]
- Coal seam gas (alternative fuel) -> reverse osmosis (to remove salt from the water extracted as part of the process)
- Desalination
- Waste treatment (solid and liquid)

**Discipline:** Civil Engineering

*This could include for example 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.*

Example Element/Indicator:

- 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

Component Knowledge and Skills (Learning Outcomes):

- Electrical fundamentals (energy efficiency, control energy conversion)
- Applications (including specific areas); control, services, modelling
- Retrieval and research skills (what’s out there on the horizon)
- Systems engineering, complexity, lifecycle, emergent... for example, an understanding of water/energy trade-offs (eg: dams vs desalination vs…)
- Interdisciplinary teamwork/projects
- Components (buildings/urban planning)
- Systems basic (multidisciplinary view)
- Lifecycle energy costs
- Orientation implications for energy use
- Embodied energy of materials (and selection)
- Star rating systems for buildings
- EE aspects of water/wastewater treatment
- Social aspects of professional negotiation
- Understanding roles, impacts of other professions

**Discipline: Electrical Engineering**

*This could include for example considering energy efficiency opportunities systemically in the transmission of energy, 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).*

Example Element/Indicator:
- 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)
- Knowledge/cognisance of emerging energy efficiency fields, equipment efficiency <-> trade-offs, lifecycle modelling and sustainability

**Component Knowledge and Skills (Learning Outcomes):**
- Underpinning of fundamentals - basic electrical engineering and energy interfaces.
- The ability to remove heat from networks, leading to energy efficient transmission and reduced power consumption
- Underlying knowledge of areas including:
  - Standardisation of power supplies to minimise material use of redundant devices
  - Integrating electrical energy modelling with heat flow
  - Mechanical intersections with electrical circuit considerations
  - Lifetime considerations for computing and telecoms plant

**Discipline: Environmental Engineering**

*This could include for example: identifying energy losses in industrial processes and implementing measures to reduce or eliminate these losses; consulting with government or private clients to improve energy efficiency measures within new projects; conducting all environmental impact assessments with consideration given to the energy used (resource management and conservation); assisting to develop new sustainable energy technologies, (such as the environmental impact assessment for a new wind farm).*

Example Element/Indicator:
- An ability to plan and manage an energy efficiency investigation
- An ability to contribute to impact assessment in regard to energy efficiency assessment
- An appreciation of how energy efficiency contributes to environmental planning and management
Component Knowledge and Skills (Learning Outcomes):
- An understanding of energy efficiency related legislation and compliance requirements
- Knowledge of the importance of energy efficiency in key parts of the design process
- Knowledge of energy efficiency opportunities in the built environment
- Knowledge of the variety of measurement tools and models available to quantify energy efficiency opportunities
- Knowledge of the limitations and opportunities of ecosystems in accommodating a range of existing or emergent energy efficiency solutions
- Skill in coordinating interdisciplinary teams of engineers
- Ability to communicate environmental, societal and economic impacts of energy efficiency innovation
- Skills in choosing materials with regard to embedded energy

**Discipline: Information Telecommunications & Electronics Engineering**

*This could include for example creating software tools to assist energy efficient design etc in other disciplines, within engineering and outside (buildings and architecture, TBL accounting), or achieving energy efficiency in wireless networks (optimisation of network design with photovoltaics power, in computers and integrated circuits). It could also include contributing lighting, heating and air-conditioning, lifts and pumps etc, computers/ servers/ telecommunications (photovoltaic sources).*

Example Element/ Indicator:
- Possess an advanced technical knowledge in the specialist area of energy generation and distribution (co-generation, emerging, renewable, etc)
- 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)*

Component Knowledge and Skills (Learning Outcomes):
- Underpinning of fundamentals - basic electronic engineering (energy conversion) and mechanical interfaces, lighting, motors, etc.
- The ability to remove heat from electronic products and systems, leading to energy efficient design and reduced power consumption at all levels from chips to cabinets
- Ability to undertake control and intelligent server and system design, with sensors and actuators, alternative lighting etc
- Skills in modelling, information retrieval, life cycle assessments
- An inter-disciplinary approach to achieving energy efficiency in building performance

**Discipline: Mechanical Engineering**

*This could include for example development of new manufacturing techniques optimising 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 introducing changes to, the*
lifecycle of a product that improve energy efficiency; suggesting improved business practices for transport of materials to increase energy efficiency.

Example Element/Indicator:
- Knowledge of clean energy technologies that build on fundamental knowledge, for example including solar thermal and geothermal
- Proficiency in calculating energy consumption in materials processing, including production, use, and disposal phases.
- Ability to identify energy efficiency opportunities in the area and design and optimisation materials/manufacturing systems

Component Knowledge and Skills (Learning Outcomes):
- Knowledge of physics, thermodynamics, and heat transfer
- Knowledge of opportunities for optimising energy usage, including reducing demand, energy recovery technologies, and clean energy technologies
- Skills in engineering modelling design and analysis
- Knowledge and skills of sensor control systems (Life cycle analysis, materials selection)
- Knowledge of recycling technologies/recyclability of materials for energy efficiency gains
- Ability to assess/energy audit of manufacturing processes (LCA), including embodied energy in materials

Discipline: Mining and Metallurgy Engineering

Through the life of a mine, (i.e. life-of-mine planning) for both underground and surface operations, energy efficiency considerations could include for example finding energy efficiency opportunities in the integrated functions of mining and beneficiation (i.e. rock breakage), determining the most appropriate ore and selective mining processes (given that they affect the quantity of material to be handled in a beneficiation plant and energy consumption), finding energy efficiency opportunities in different transportation alternatives, effectively managing 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).

Example Element/Indicator:
- Proficiency in identifying energy efficiency opportunities to mining methods including for example rock breakage and transportation.
- 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

Component Knowledge and Skills (Learning Outcomes):
- Ability to calculate energy consumption and greenhouse gas emissions
- Ability to solve energy balance equations and do energy consumption/optimisation modelling
- Discounted cash flow analysis (project finance fundamentals)
- Unit operation: 1. Drilling and blasting fundamentals, 2. Mine transport alternatives
Knowledge of energy efficiency opportunities in processes including mine design and sequencing, ventilation and mine services (dewatering), life-of-mine design and planning, unit operations and mine services

- Project evaluation tools (multi-criteria decision and finance fundamentals)
- Communication fundamentals
- Integration with multi-disciplinary teams

Additional Interdisciplinary and Non-technical Considerations

This could include for example: engagement with the public through press and various publishing media (internet, radio, etc) to emphasise need for energy efficiency and explain strategies to implement energy efficiency; facilitating the introduction of energy efficiency considerations in decision making processes of government and private enterprise; demystifying engineering processes for an audience outside of engineering (such as management or marketing staff, voters, politicians); liaising with architects and urban planners to produce energy efficient urban design solutions.

Example Element/Indicator:
- An understanding of human factors involved in improving energy efficiency and the communication, training, behaviour or organisational change practices necessary for successful implementation and operation
- Appreciation of an engineer’s responsibility as a global citizen to improve energy efficiency in their industry
- Ability to communicate complex energy efficiency principles to non-expert audiences
- Life-long learning in the dynamic technologies of energy efficiency

Component Knowledge and Skills (Learning Outcomes):

- Working collaboratively – project work in a multi-disciplinary environment - Role of Other Disciplines, eg: urban planners and architects includes social aspects; relating to clients and other professions e.g. a company’s financial and operating officers etc., and optimisation of land use layout to minimise energy use (eg: urban layout)
- Systems thinking – across all areas of energy efficiency
- Problem solving in a multi-criteria, multi-dimensional, multi-disciplinary environment (including lifecycle energy costs, including embodied energy and demolition/recycling)
- Understanding of the critical role engineering plays in designing our future and our ongoing sustainability management of our air, water and resources through energy efficiency (carbon footprint, more energy costing, recovery of low-grade heat…)
- Understanding of the importance of energy efficiency in underpinning the Engineers Australia “sustainability” thinking/management required with their competing standards
- Appreciation of the role of behavioural change and the social context for energy efficiency, including global citizenship
5. Example EE Learning Pathways

Participants used the list of discipline-specific element/indicators and knowledge and skills to map EE ‘learning pathways’ for a hypothetical 4-year engineering undergraduate program, developing the graduate attribute through a learning pathway that includes ‘learning’, ‘practicing’ and ‘demonstrating’ the identified knowledge and skills:

- ‘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;
- ‘Demonstrate’ refers to the students applying the knowledge and theory to problem solving in a contextually appropriate way.

The graduate attribute (GA) selected for investigation was focused on EE assessments, specifically: The Ability to Participate in/Contribute to Energy Efficiency Assessments.

5.1 Learning Pathway Examples by Discipline

The following tables summarise learning pathway examples for each of the engineering disciplines considered, where diagrammatic indicators (leader lines, triangles and rectangles) have been used to show how the knowledge or skill could be introduced and then strengthened over a 4-year degree:

- Leader lines suggest that vocabulary may be introduced, or mentioned;
- Triangles suggest a process of awareness raising by the student; and
- Rectangles suggest a process of mastering the knowledge or skill, building from practicing to being able to demonstrate proficiency.

These should be read as schematics and indicative only, as there will inherently be a mixture of practice and learning occurring during the program.

Table 5.1. Example learning pathway for Chemical 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>K1 Knowledge of the ways in which systems interact.</td>
<td>Learn</td>
</tr>
<tr>
<td>K2 Embodied energy of materials (&amp; selection)</td>
<td>Learn</td>
</tr>
<tr>
<td>K3 Water &amp; wastewater treatment</td>
<td>Learn</td>
</tr>
<tr>
<td>S1 Identify and qualify/quantify energy flows through manufacturing processes</td>
<td>Learn</td>
</tr>
<tr>
<td>S2 Identify and quantify economic impacts, short and long term, of the process</td>
<td>Learn</td>
</tr>
</tbody>
</table>
**Table 5.2. Example learning pathway for Civil 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>K1 Systems basic (multidisciplinary view)</td>
<td>Learn</td>
</tr>
<tr>
<td>K2 Lifecycle energy costs</td>
<td>Learn</td>
</tr>
<tr>
<td>K3 Orientation implications for energy use</td>
<td>Learn</td>
</tr>
<tr>
<td>K4 Embodied energy of materials (&amp; selection)</td>
<td>Learn</td>
</tr>
<tr>
<td>K5 Water &amp; wastewater treatment</td>
<td>Learn</td>
</tr>
<tr>
<td>K6 Social aspects of professional negotiation</td>
<td>Learn</td>
</tr>
<tr>
<td>K7 Understanding roles and contribution of other professions</td>
<td>Learn</td>
</tr>
<tr>
<td>K/S 1 Rating systems for buildings</td>
<td>Practice</td>
</tr>
</tbody>
</table>

**Table 5.3. Example learning pathway for Environmental 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>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>
</tbody>
</table>
Communicate environmental, social and economic impacts of EE innovations

Choose low embedded energy materials

Table 5.4. Example learning pathway for Electrical/ Electronic 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>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>

Table 5.5. Example learning pathway for 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>K1 Physics</td>
<td>Learn</td>
</tr>
<tr>
<td>K2 Thermodynamics</td>
<td>Learn</td>
</tr>
<tr>
<td>K3 Heat transfer, Fluids</td>
<td>Learn</td>
</tr>
<tr>
<td>K4 Energy Recovery Technologies</td>
<td>Learn</td>
</tr>
<tr>
<td>Clean Energy Technologies</td>
<td>Learn</td>
</tr>
<tr>
<td>K/S 1 Sensor technologies &amp; control systems</td>
<td>Learn</td>
</tr>
<tr>
<td>S1 Engineering Design &amp; Analysis</td>
<td>Learn</td>
</tr>
</tbody>
</table>
Table 5.6 Example learning pathway Mining & Metallurgy 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>K1 Life-of-mine Design and Planning</td>
<td></td>
</tr>
<tr>
<td>K2 Unit operations and mine services</td>
<td></td>
</tr>
<tr>
<td>K3 Project evaluation tools (multi-criteria decisions &amp; finance fundamentals)</td>
<td></td>
</tr>
<tr>
<td>K/S 1 Energy consumption modelling</td>
<td></td>
</tr>
<tr>
<td>K/S 2 Project evaluation tools (multi-criteria decisions &amp; finance fundamentals for in-house gas accounting)</td>
<td></td>
</tr>
<tr>
<td>S1 Integration with multi-disciplinary teams</td>
<td></td>
</tr>
<tr>
<td>S2 Analysis &amp; Optimisation tools</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.7. Example learning pathway for interdisciplinary and non-technical knowledge and skills

<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 Design rules</td>
<td></td>
</tr>
<tr>
<td>K2 Understanding motivations for behaviour change</td>
<td></td>
</tr>
<tr>
<td>K3 Pros/cons of building new versus refurbishment</td>
<td></td>
</tr>
<tr>
<td>K4 Maintenance schedules for optimisation of energy efficiency</td>
<td></td>
</tr>
</tbody>
</table>
Considering these example knowledge and skill maps, it is clear that the learning pathway for any given learning outcome will depend on a range of considerations including the experience and preferences of the engineering educators, opportunities for embedding EE knowledge and skills within the existing structure, and the teaching and learning strategies employed by the institution. It will also depend on the types of available information and how it could be used. Finally, it is clear that embedding EE within a discipline requires a whole of program approach to ensure that the distinct requirements for knowledge and skill development are appropriately addressed throughout the program.

5.2 Example Approaches for Embedding EE

Following the workshop for this project, participant comments were used to inform a literature review of materials and resources about EE, in addition to gaining information from the EEAG Project 2. In Appendix B, a variety of key materials and resources are highlighted that could be used in current engineering degree programs to support the inclusion of EE knowledge and skills, ranging from material from which specific course resources could be developed to resources that could be dropped straight into a course with minimal time and effort.

Based on a preliminary review of the materials and resources by the research team, and comments from workshop participants and report peer reviewers about various resources, an indicative ranking is provided alongside each item (one to three stars), for the extent to which they could be embedded within the curriculum to address the types of learning outcome statements in the previous section (i.e. ‘curriculum ready’), where:

- One star (*) indicates the item is valuable but would require significant effort by the lecturer to integrate within course work (i.e. material with potential for use as a reference document).
- Two stars (**) indicate the ability to extract examples or case studies directly from the item, for example for tutorials or problem solving (i.e. material with potential for creating a resource).
- Three stars (***) indicate that the item is readily usable by the lecturer, as a drop-in module, lecture, tutorial exercise or similar (i.e. a curriculum-ready resource).

Considering the list of graduate attribute statements earlier in this report, clearly there are some knowledge and skills that are addressed in readily available resources, while others may only
have relevant materials that need to be further developed, or nothing at all (EEAG Report 2 addresses this level of coverage).

Considering the opportunities with existing materials and resources, two examples – in mechanical and civil engineering – are provided below to highlight how the learning pathway tables (above) could be used to embed EE within the curriculum. This is discussed by year level, with the knowledge and skills shown in brackets. Where the resources are referred to, the indicative ranking indicating useability (i.e. stars) are also shown (see Appendix B for full details and references).

1. **Incorporating Resources - Mechanical Engineering (See Table 5.5)**

Table 5.5 shows an example of a learning pathway for a mechanical engineering program, to embed EE knowledge and skills related to the graduate attribute “*The Ability to Participate in/Contribute to Energy Efficiency Assessments*”.

In this example, the EE relevant knowledge to be learned include physics (K1) and thermodynamics (K2). Knowledge and skills to be developed further relate to heat transfer and fluids (K3), energy recovery and clean energy technologies (K4), sensor and control system technologies (K/S1), and engineering design and analysis (S1). EE related skills to be demonstrable at graduation include life cycle analysis and materials selection (S2), and the ability to undertake a systems/ group project (S3).

When considering this range of knowledge and skills development in light of the materials and resources listed in Appendix B, there are already some materials and resources available that could assist with developing this graduate attribute:

**Year 1: [K1, K2, K3, K4, K/S, S1, S2]**

In this example, the main focus for learning and teaching in first year, for mechanical engineering students is learning about life cycle analysis, materials selection and physics. There is also some learning (in second semester) around thermodynamics, heat transfer, fluids, Energy recovery technologies, sensor technologies, control systems, engineering design and analysis.

With this in mind, the following resources could be of assistance.

- **The Whole System Design Textbook (***):** is a ready-to-use resource that covers whole system approach. Included is an exercise on redesign of a pump system, relevant to introducing concepts and calculations involved in life cycle analysis and materials selection.

- **The Australian Research Institute for Environment and Sustainability (ARIES) Tertiary training resources (***):** provide a module in EE and renewable energy which is intended for use in teaching a tertiary curriculum and which could be used in first year as introductory material.

- **The Sustainability Victoria energy and greenhouse management toolkit (**/ ***):** provides modules that provide guidance on increasing EE in the workplace. It is targeted mainly at business, and could be helpful in introducing the broader context for EE in the mechanical engineering curriculum.

- **Chan-Lizardo and Lindsey’s ‘Big Pipes, Small Pumps: Interface, Inc. Factor Ten Engineering Case Study’ (***):** focuses on the design of pumping systems, towards reaching a Factor 10 efficiency level. It suggests strategies for designing an efficient system, which would be relevant for introducing life cycle analysis, particularly where it touches on the philosophy of design.
It is noted that there may be a need for academics to develop resources in order to embed EE education in the teaching of physics, given the absence of targeted resources. Case studies that demonstrate how the laws of physics could be utilised to achieve a more efficient outcome in a process. Also, there may be a need for academics to create resources for embedding knowledge and skills related to EE in materials selection.

**Year 2-3:** [K2, K3, K4, K/S, S1, S2, S3]

During second and third year, the focus is on learning about and, later, practicing in thermodynamics, heat transfer, fluids, energy recovery technologies, sensor technologies, control systems, engineering design and analysis become the focus of EE education for developing this graduate attribute. Considering the list in Appendix B, it is clear that these component knowledge and skills areas are not as well resourced in the EE education resources or materials. Some development of resources on the part of the lecturer would be necessary here, and the databases listed within some of the suggested resources and materials could be searched, as a launching pad for locating such items.

In the absence of targeted resources, order to develop skills in life cycle analysis and materials selection, a number of materials and resources could be used to facilitate students practicing what was learned in first year. Here, the following resources could be useful to reference and extend into workshop/ tutorial/ group work activities of exploration around a real-world problem:

- The *Whole System Design Textbook* (***) and Lovins et al's *Factor 10 Engineering Design Principles* (*), a paper that discusses opportunities in transforming design and engineering practice through whole-system thinking and integrative design.
- The *Australian Research Institute for Environment and Sustainability (ARIES) Tertiary training resources* (***)
- The *Sustainability Victoria energy and greenhouse management toolkit* (**/ ***); and
- Chan-Lizardo and Lindsey’s ‘Big Pipes, Small Pumps: Interface, Inc. Factor Ten Engineering Case Study’ (***)
- Lovins ‘Efficiency and Micropower case study of Cuba’ (***)

**Year 4:** [K3, K4, K/S, S1, S2, S3]

In this example, in final year (assuming a typical 4-year undergraduate program), a clear demonstration of skills acquired in life cycle analysis, materials selection, and utilisation of these skills in a systems/group project are required of the mechanical engineering student.

In order to embed such EE skills within the curriculum, relevant resources would be real-world contextualised case studies and problems that students could refer to during their systems/ group project. For example, a group project could be based upon Activity 2, Session 8 of “Accelerating the transition to a sustainable energy future” set of teaching resources from ARIES (***) as a starting point for providing an opportunity for students to demonstrate their skills. This activity encourages the student to investigate the places where energy is used in a product’s lifecycle, which then ties in with the need to demonstrate skill in life cycle analysis and materials selection.
2. **Incorporating Resources – Civil Engineering (See Table 5.2)**

From the example learning pathway map in Table 5.2, it is clear that in order to develop EE assessment capabilities in the area of EE assessments for civil engineering students, the program needs to be ‘peppered’ with a number of core EE knowledge and skills, from first through the final year of study.

These include systems (K1), life cycle energy costs (K2), orientation implications for energy use (K3), embodied energy of materials (K4), water and wastewater treatment (K5), social aspects of professional negotiation (K6), understanding roles and contribution of other professions (K7) and rating systems for buildings (K8). Civil Engineering encompasses a broad range of EE knowledge and skills, from systems thinking through to rating schemes, which creates a complex system to embed emerging context.

With this in mind, the there are a number of materials and resources, which lend themselves to being utilised in the delivery of such targeted teaching, as follows:

**Year 1:** [K1, K6, K7]

In first year, priority EE teaching and learning goals could comprise learning about systems and the multidisciplinary viewpoint, the social aspects of professional negotiation, and understanding roles and contribution of other professions. Materials and resources include:

- The *Whole System Design Textbook* (**), which provides overall context for the importance of a whole system approach to EE Assessments.
- The *Australian Research Institute for Environment and Sustainability (ARIES) Tertiary training resources* (**), having been designed to complement introductory learning across many specialisations.
- *RET resources* (*/***, Federal Table, Appendix B) - Targeted case studies and/or recorded guest lectures could be created from these materials that provoke students to think about EE, what it means, and opportunities within civil engineering.
- *Sustainability Victoria Green Building Case Studies* (**) which provide introductory case studies on EE opportunities and which complement the whole system approach described in the *Whole System Design* text.

**Year 2-3:** [i.e. K2, K4, K5, K6, K7, and K/S 1]

In second and third year, there is a need to increase the amount of EE being taught, peppering a variety of knowledge and skills within the curriculum. In some areas this requires more learning, while in other areas students will be asked to apply the relevant knowledge and skills, and may need access to good reference materials rather than just more lecture notes. Resources that lend themselves to being utilised in the delivery of such targeted teaching are available for some of the key learning outcomes, while completely absent for others.

For example, one or more of the *CSIRO Energy Transformed Flagship* (***) lectures may be appropriate to splice into the curriculum in second and third year of engineering, embedding key point summaries and further research/ assignment options as printed within the resource. The *RET EEO program case studies* (**) would provide a ready set of local (Australian) readings for students to use as they move from learning about the opportunities to incorporating this information into their project work. The *US Department of Energy – case studies* (***) resource
could also be used for feeding directly into the curriculum as appropriate, given the wide variety of topics covered where EE opportunities are identified.

A number of materials lend themselves to developing the knowledge and skills areas listed in Table 5.2, provided that the academic can incorporate them into the curriculum. These include the NFEE policy packages (*) which provide important national context, RET reports and technical publications (*) which also provide national context, frameworks and steps for considering EE opportunities,

With regard to emerging resources, the New South Wales Office of Environment and Heritage (OEH) is currently overseeing several training projects, including the EE Training Program, which is currently being developed to train engineers to beat rising energy and production costs, save power, improve sustainability and achieve a competitive advantage. OEH also recommends a Green Skills and EE Strategy training program, which is not readily available for undergraduates but does offer subsidised training to increase the sustainability skills of the NSW workforce in many areas, including building and construction, manufacturing, transport and utilities, energy and utilities, carbon accounting, asset maintenance. In the absence of resources, this could be a pathway for academics to develop their own proficiencies through short courses in applied professional development (for example in lieu of industry placement/ secondment).

**Year 4: [K1-K7, K/S1]**

In final year (assuming a typical 4-year undergraduate program), the example in Table 5.2 highlights the role of demonstrating the suite of knowledge and skills developed, to produce a graduate proficient in contributing to EE assessments.

At this point in the program, there are a few targeted resources that could be used to provoke students to think about how the component knowledge and skill areas can be brought together to produce valuable and insightful EE Assessments, across industry and the built environment sectors. Considering Appendix B, examples include:

- **The RETScreen Clean Energy Project Analysis Software (***), which is a freely available online and globally relevant Canadian decision support tool that evaluates the energy production and savings, costs, emission reductions, financial viability and risk for various types of Renewable-energy and Energy-efficient Technologies (RETs). Students could use the corresponding e-textbook and the tool to model a range of applications in a virtual environment, through for example tutorials or group assignments.**

- **Bendewald and Franta’s ‘Factor 10 Engineering Case Study’ (*), a paper which describes the design and construction of a substantial building, which could have applications to both built environment and industrial contexts.**

- **Olgyay’s ‘Whole-Building Retrofits’ paper (*), which discusses the benefits of whole of building retrofits. This would be a good prompt for assignments that detail the need for a whole system approach to EE assessments.**
6. Conclusions and Recommendations

This project has reiterated the need for engineering education in EE in Australia, and has identified a wide range of EE related capacity building needs for engineering. During the project, workshop participants identified a wide range of EE related teaching and learning areas that they considered to be important for directing development of EE education resources for engineering lecturers in Australian Universities. Specifically:

- Nine example common EE graduate attribute statements were developed, based on clusters of knowledge and skill sets that map closely to the EA Stage 1 Competency requirements. These statements demonstrate the relevance for EE to be embedded within all undergraduate engineering curriculum, and the opportunity for universities to meet accreditation requirements in doing so.

- A number of example discipline-based EE elements and indicators were developed, related to the common graduate attribute “Ability to Participate in/Contribute to Energy Efficiency Assessments”. These statements demonstrate the need for EE to be embedded in a way that includes common EE knowledge and skills in addition to discipline-tailored aspects. This will ensure that the education is relevant to student needs, with regard to expectations for their capacity upon graduation.

An example learning pathway map was generated for each discipline considered, under the graduate attribute “Ability to Participate in/Contribute to Energy Efficiency Assessments”, for a hypothetical engineering undergraduate degree. These maps highlight the need for a whole of program approach to developing the desired EE graduate attributes, including developing a number of knowledge and skill sets that are not immediately apparent at the level of the graduate attribute.

A mixture of reference materials and educational resources were identified (see Appendix B), but these resources are limited, which provides a strong case for developing such resources. The need and further work on particular areas for consideration is addressed in the Project 2 EEAG report.

In conclusion, the graduate attribute, element and indicator statements, and example learning pathways provide a baseline from which more detailed consultation can proceed at a discipline level (for example through the EA engineering colleges), to identify specific EE learning outcomes that can then be supported through the targeted development of EE education resources.

Understanding that RET is particularly interested in the application of EE assessment skills, expanding this analysis into other industry sectors such as manufacturing and seeking input on project outcomes from industry practitioners, is an important next step to ensure graduate attributes and learning pathways are aligned with industry needs. Furthermore, the clustering exercise and subsequent analysis was received by participants and reviewers as a useful way to work with information that was helpful and meaningful to participants. This would be a useful tool to take forward in the next stages of this EE education initiative.
APPENDIX A:
Project 1 EEAG Reference Group
Provocation Brainstorming Notes
(Used to inform Workshop)
Task Summary:
In May 2011, as part of the project presentation to the EEAG reference group, the 9 attendees (identifiers removed for publication) were asked to brainstorm aspects of energy efficiency that are important today and future changes. These provocations were then distributed to the Workshop Participants as background reading. The results of exercise were also used to inform preparation for the workshop.

Within the brainstorm, attendees first listed their initial ‘top of mind’ thoughts (see the first bullet pointed list below). Following this reflection, attendees read their lists to the rest of the group in turn. During each reading, where attendees liked the terms, they added these to their list (see the subsequent items in italics).

Attendee Brainstorm - Raw Data:

Participant 1:
- Embodied energy, structures and equipment (future: increasing awareness and capability required)
- Energy efficiency of processes, eg chemical engineering, water treatment, etc (future: increasing)
- Energy generation (renewables) and (non-renewables) – improved efficiency (future: increasing expanded [sources of energy])
- Transport/logistics (future: increasing)
- Communication (future: increasing particularly as Internet grows exponentially)
- Water (future: increasing as new sources require more energy input (eg recycling)
- Food production (future: increasing)

Items added by this participant as others read from their lists:
- Resource management and stewardship and corporate waste management
- Industrial ecology
- Re-engineering the power grid
- Energy balances (examples of energy [physics] and applications to disciplines
- Avoiding unintended consequences
- Cost/benefit of energy efficiency
- Energy recovery/scavenging
- Minimising risk
- Selling benefits within the company (communication/negotiation)
- Entrepreneurship/business opportunities/innovation (eco-innovation)
- Understanding energy efficiency and energy audits (flows) and systems
- Evaluating effectiveness of energy efficiency improvements
- TBL accounting.

Participant 2:
- Carbon-constrained energy source will become increasingly important (renewables)
- Market pressure towards less energy consumption will require re-engineering grid, with better feed-in renewable solutions
- Holistic-systems-thinking will be necessary for future infrastructure development (eg transport) and procurement
- High consumption processes will have to maximise energy efficiency or go out of business

Items added by this participant as others read from their lists:
- Embodied energy
- Water and food production
- Resource scarcity
- Waste management
- Industrial ecology
- Students need to understand fundamentals etc of energy balances within applications/balances
- Designing for energy efficiency
- Avoiding unintended consequences > cost
- What priorities are given for energy efficiency with company operation (vs. core business), in relation to engineers' work especially
- Engineers’ need to sell (to managers) using sensitivity analysis etc. – business case in volatile situations of energy market.
- Need for cross-discipline understanding of energy /energy efficiency/energy assessment (quite complex systems)
- Capacity to identify opportunities (creativity) and analyse/evaluate > to sell innovation to operational managers
- Entrepreneurship and developing business cases
- Triple-bottom line accounting.

Participant 3:
- Understand the various forms of energy (future: won’t change significantly over time)
- Within each discipline, how energy is “provided” AND how that energy is consumed, ie energy balances, eg mechanical energy balance of an internal combustion engine; electrical/mechanical hybrid/electric vehicle; wind/solar (future: won’t change significantly)

Items added by this participant as others read from their lists:
- Renewable energy
- Waste management
- Co-generation
- Governance/regulation
- Carbon usage
- Need to integrate into systems
- Cost
- Design aspects
- Energy recovery
- Innovation including business case
- Corporate stewardship
- Triple bottom line

Participant 4:
- Knowing basic forms of energy and generation, storage, transformation (future: same as today basically, but more important)
- Application of the above to specific disciplines: water, transport (future: same as today basically, but more important)
- Knowing systems modelling, analysis, design (linking previous point (application)) (future: same as today basically, but more important)

Items added by this participant as others read from their lists:
- Water
- Transport
- Resource management
- **Accounting vs energy efficiency**
- **Future uncertainty**
- **Entrepreneurship**
- **Present Context:** embodied energy, sources of energy, designing for energy efficiency, cost
- **Future:** energy recovery, energy scavenging

**Participant 5:**
- Resource pricing/resource efficiency (future: resource recycling/resource scarcity)
- Resource management (future: resource stewardship)
- Energy efficiency (future: co-generation/tri generation, embodied energy)
- Waste management (future: closed loop production (zero waste))
- Water use/water management (future: water recycling/water efficiency)
- Governance/regulatory guidelines (future: corporate stewardship)

Items added by this participant as others read from their lists:
- **Industrial ecology** (future: * Industrial ecology II)
- **Connect water/energy systems** (future: * re-engineering water/energy/waste systems)
- **Carbon constraints** (future: * resource constraints)
- **Skills based engineering learning** (future: * knowledge based engineering learning [sustainability principles and fundamentals for specific disciplines])
- **Entrepreneurship** (future: ** eco-innovation (engineering))

**Participant 6:**
- Embodied energy (future: increasing)
- Sources of energy (renewable) (future: increasing)
- Energy recovery (future: greater need for innovation)
- Energy scavenging (future: greater need for innovation)
- Designing for energy efficiency (systems skills) (future: increasing)
- Avoiding unintended consequences (future: increasing)
- Cost (future: -)

Items added by this participant as others read from their lists:
- **Corporate stewardship**

**Participant 7:**
- Fundamental understanding of what energy efficiency is and how it connects all disciplines, eg at “project”/”building” level, NB: many engineers will graduate without this cross-discipline appreciation (future: same requirement, but with a better appreciation of the underlying common physics and engineering principles)

Items added by this participant as others read from their lists:
- **Integration** (future: an interactive set of case studies required?)
- **Much of previous comments revolves around processes and projects that are high level or discipline specific** (future: * big picture issues interesting but not at a more senior level)
- **The case studies re: energy balance reference becomes discipline specific.**
- **Clean/renewable would be included in the “big picture” cross-discipline approach as would recovery...**
- **Need for engineers able to demonstrate long term cost benefits of energy efficiency.**
Participant 8:
- Understand Energy
- Understand energy efficiency
- Understand Energy assessment, flows and ‘systems’
- Have capacity to identify opportunities
- Have capacity to analyse and evaluate operations
- Have capacity to promote and ‘sell’ operations to relevant people eg operation managers, CFOs etc
- Entrepreneurship; getting business case across
- Have capacity to work effectively on projects to implement operations and evaluate outcomes

Items added by this participant as others read from their lists:

- Energy generation energy efficiency
- Increasing Energy costs re water etc
- Pricing issues
- Link to waste reduction
- Energy transmission infrastructure
- Need for some industries/businesses to improve energy efficiency or go out of business
- E balance in all disciplines, and linking all these together ie whole systems approach
- Growing career opportunities

Participant 9:
- What priority is energy efficiency being given in engineers job role today? > competing priorities (future: new technologies, processes, innovation)
- Maximising output (future: new technologies, processes, innovation)
- Minimising operational risk (future: new technologies, processes, innovation)
- Minimising downtime (future: new technologies, processes, innovation)
- Building energy efficiency into project design? (future: new technologies, processes, innovation)
- Considering whole of life considerations (future: new technologies, processes, innovation)
- Considering energy price fluctuations (future: new technologies, processes, innovation)

Items added by this participant as others read from their lists:

- Technical concepts > business case
APPENDIX B:

Project 1 - Example Materials and Resources
Example Materials and Resources

Following a preliminary review of the materials and resources by the research team, and based on comments from workshop participants and report peer reviewers about various resources, an indicative ranking is provided alongside each item (one to three stars), for the extent to which they could be embedded within the curriculum to address the types of learning outcome statements in the previous section (i.e. ‘curriculum ready’). In this nominal scheme:

- One star (*) indicates that the item is valuable but would require significant effort on the part of the lecturer to integrate within course work (i.e. material with potential for use as a reference document)
- Two stars (**) indicate the ability to extract examples or case studies directly from the item, for example for tutorials or problem solving (i.e. material with potential for creating a resource).
- Three stars (***)) indicate that the item is readily usable by the lecturer, as a drop-in module, lecture, tutorial exercise or similar (i.e. a curriculum-ready resource).

Example Federal Government Materials and Resources:

<table>
<thead>
<tr>
<th>Star</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>*</td>
<td>National Framework for Energy Efficiency (NFEE) integrated and inter-linked policy packages: Nine packages that extend, or further develop, a range of cost effective energy efficiency measures that are currently being implemented at a national or jurisdictional level.</td>
</tr>
<tr>
<td>*</td>
<td>Department of Resources, Energy and Tourism (RET) - Energy Efficiency Opportunity program reports and technical publications: Highlight EE opportunities, and provide data for existing and future EE scenarios. Technical background to the need for, and potential of EE measures for various industries, as well as example processes through which these can be identified and realised. This includes for example, an Assessment Handbook, Energy Savings Measurement Guide and Energy Mass Balances.</td>
</tr>
<tr>
<td>**</td>
<td>Department of Resources, Energy and Tourism (RET) - Energy Efficiency Opportunity program case studies: Could be used as a basis for the further development of targeted case studies, covering the process used for identifying, developing and implementing energy efficiency measures and including commentary on payback periods and other benefits achieved.</td>
</tr>
<tr>
<td>***</td>
<td>CSIRO Energy Transformed - Sustainable Energy Solutions for Climate Change Mitigation: 30 lectures (‘chapters’) on how Australia can achieve at least 60 percent cuts to greenhouse gas emissions by 2050. Structured into 3 modules with 10 lectures in each, comprising educational aims, key learning points, and overview of the topic.</td>
</tr>
<tr>
<td>***</td>
<td>Whole System Design Textbook - An Integrated Approach to Sustainable Engineering: Funded by the Australian Federal Department of the Environment, Water, Heritage and the Arts (DEWHA) under the Education for Sustainability Grants Program. The WSD text is accompanied by a teaching plan for working through the 10 Whole System Design lectures (available online), sample assessment that uses a problem-based learning approach, and worked examples to enable even engineering educators with limited experience in whole system design and energy efficiency to be able to teach a course on the topic.</td>
</tr>
<tr>
<td>***</td>
<td>Australian Research Institute for Environment and Sustainability (ARIES) Tertiary training resources: Commissioned by the Australian Government Department of Education, Employment and Workplace Relations (DEEWR) this set of teaching resources was developed in 2010. The materials have been structured to support teachers/lecturers in developing and delivering a complete course and/or incorporating content on energy efficiency and renewable energy into existing courses. Within this document, there are also links to further useful teaching resources from around the world.</td>
</tr>
</tbody>
</table>
Example State Government Materials and Resources:

| **/ *** | ** Sustainability Victoria energy and greenhouse management toolkit:**51 Provides tools, case studies and guidance to help businesses to understand, develop and implement energy efficiency measures to produce financial savings, improved productivity, and compliance with legislation and licence conditions. Includes training modules, which include practical, worked examples that lead the user through the process for the various stages of an energy efficiency project. Module 5 freely available online. |
| ** ** | ** Sustainability Victoria Green Building Case Studies:**52 Case studies not specifically focused on energy efficiency, but do provide context and potential framework for energy efficiency, or be useful in providing a broader, whole-of-system context to engineering students. |

Example International Materials and Resources:

| *** | ** Rocky Mountain Institute - background readings and case studies:**53 These resources (available via the RMI website) are useful for discussions around issues such as nuclear power generation, the Jevons Paradox, the economic imperative for energy efficiency, and in responding to many issues raised in the media and political discussions. |
| *** | ** US Department of Energy - case studies:**54,55 Cover a variety of industries as well as residential homes, commercial buildings, vehicles and government. These case studies provide a good overview of the process of identifying energy efficiency opportunities, the drivers for this investigation, measures implemented and the outcomes. Also includes information resources for many of the EE technologies used by various industries and showcased in the case studies, and news items on recent technological research and development into energy efficiency. |
| *** | ** RETScreen Clean Energy Project Analysis Software:** Developed by Natural Resources Canada, a decision support tool to evaluate the energy production and savings, costs, emission reductions, financial viability and risk for various types of Renewable-energy and Energy-efficient Technologies (RETs). Free-of-charge and can be used worldwide, including product, project, hydrology and climate databases, a detailed user manual, and a case study based college/university-level training course, including an engineering e-textbook. Can be used to investigate the viability of energy efficiency improvements in a wide range of applications, for both new construction and retrofits, and entire facilities can be modelled, or sub-systems and rooms can be studied individually. |

Additional Example Materials and Resources - Case studies and Papers (available online):

| *** | ** Chan-Lizardo, K., and Lindsey, D. (2011) ‘Big Pipes, Small Pumps: Interface, Inc. Factor Ten Engineering Case Study’** This case study explains common shortfalls in the conventional design process that lead to sub-optimal design and high energy usage. The case study details the process undertaken to transform an industrial pumping design to use 90 per cent less energy, with lower capital costs. |
| * | ** Olgyay, V (2010) ‘Whole-Building Retrofits: A Gateway to Climate Stabilization’** This paper discusses the benefits of whole building retrofits. It discusses process and
This paper describes the design and construction of Autodesk’s Headquarters building and details how the design team achieved a LEED Platinum rating while delivering the project under budget. This resource would be particularly valuable for students involved in construction and systems engineering disciplines. |
The Factor Ten Engineering initiative, developed by Rocky Mountain Institute, demonstrates that very large energy and resource savings can be very profitable across a wide range of applications. Factor Ten Engineering uses such innovations to transform design and engineering practice, via whole-system thinking and integrative design. This document outlines the design principles of Factor Ten Engineering and is applicable across all engineering disciples. |
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53 RMI (nd) Resources, Rocky Mountains Institute, USA.
